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Interval-Valued Hesitant Fuzzy DEMATEL-Based Blockchain Technology Adoption Barriers Evaluation Methodology in Agricultural Supply Chain Management

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Abstract: Blockchain technology is emerging and has high potential to improve and transform the agricultural supply chain. This study investigates the critical barriers to blockchain technology adoption in the Vietnamese agricultural supply chain using a novel interval-valued hesitant fuzzy Decision-Making Trial and Evaluation Laboratory (IVHF-DEMATEL) approach. The IVHF-DEMATEL technique is applied to identify cause-and-effect relationships and draw the influence-relations map of the barriers. In contrast to prior work, which converts fuzzy sets into crisp sets and then uses crisp set operations, this study is the first study to investigate the Vietnamese agricultural supply chain that uses fully hesitant fuzzy operations representing experts' assessment without information loss during the conversion. Our results show that 'lack of government regulation', 'lack of scalability and system speed', 'a large amount of resource and capital requirements', and 'lack of trust among agro-stakeholder or public perception' are the main barriers. Consistent with previous studies, 'lack of government regulation' is the most significant barrier. The results also indicate the hesitant degree of each barrier and better inform decision-makers about uncertain situations. Moreover, a priority order for tackling barriers is proposed to accelerate blockchain adoption in the Vietnamese agricultural supply chain.

Keywords: agricultural supply chain; blockchain; DEMATEL; interval-valued hesitant fuzzy

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1. Introduction

In the challenging and fast-changing technology world, new technologies emerge more frequently than ever before. They can revolutionize the economic structure from within, incessantly destroying the old one and creating a new one [1]. One promising technology is blockchain, which can maintain and improve a sustainable supply chain [2]. According to the World Health Organization, almost one-tenth of people in the world get ill after consuming contaminated food, and 420,000 people die every year. Agro-stakeholders have tried to tackle food safety issues by integrating technologies into the agricultural supply chain. One of the emerging and promising technologies is blockchain. Not only solving food safety issues, but blockchain technology can also provide an excellent tracing approach for data-driven facilities and intelligent farming, thus restoring trust between producers and consumers.

According to Bai and Sarkis [3], blockchain can bring the following benefits to supply chains: increasing transparency, reducing losses from human error and grey market trading, decreasing bureaucratic effort on paperwork, establishing an excellent network across and amongst supply chain stakeholders, and promoting more environmentally friendly behaviors. Moreover, smart contracts with blockchain can make transactions faster and cheaper [4].

An agricultural supply chain can have remarkable potential from implementing blockchain technology, such as restoring trust between producers and consumers, providing a reliable approach to trace transactions, solving food quality and safety issues, and providing data for data-driven facilities and intelligent farming [5]. Due to the potential merits of blockchain, the technology has been applied in many areas of the agricultural supply chain: agriculture insurance, smart farming, food supply chain, and transaction of farm products. In August 2017, several prominent foods and fast-moving consumer goods suppliers integrated the blockchain into their supply chains [5]. Many countries, such as the United States (US), China, Italy, and India, actively investigate the applications of blockchain technology [6].

Vietnam, one of the largest agricultural producers in South East Asia projected to be in the top 10–20 percent of developing countries in terms of the proportion of its agricultural commodity export volume in 2025–2030 [7], has the immense benefit on its agricultural supply chain. In fact, Vietnamese companies started to use blockchain technology to provide traceability and to help them export products. Dong Thap province, one of the most exporting provinces in Vietnam that has exported mangoes to high-standard-requirement countries such as Australia, Japan, South Korea, and Russia, faces difficulties entering the US market. With a blockchain-based traceability system, Vietnam's first eight tons of mangoes reached the U.S. market on 18 April 2020 [8].

Since blockchain technology is a new technology and in its early development stage, deploying it can face many difficulties. Enterprises face many barriers while adopting a blockchain-based system: environmental barriers, organizational barriers, and technological barriers [9]. Kouhizadeh et al. [9], Yadav et al. [10], and Biswas and Gupta [11] also indicated that there are a large number of barriers affecting blockchain adoption. Yadav et al. [10] investigated blockchain adoption barriers in agricultural supply chains in the case of India, using Decision-Making Trial and Evaluation Laboratory (DEMATEL) to classify the barriers into cause and effect. However, their method may lose information after converting fuzzy values into crisp values at the beginning of the process. This study adopts the interval-valued hesitant fuzzy DEMATEL (IVHF-DEMATEL) approach to mitigate the information loss and comprehensively represent the results.

In order to understand the difficulties of deploying blockchain technology, various barriers to blockchain adoption were identified from the databases Web of Science, Science Direct, SCOPUS, and Springer. Articles were searched based on keywords, including blockchain technology, agricultural supply chain, and blockchain adoption barriers. Additionally, we interviewed experts to assess the barriers. We have used the IVHF-DEMATEL approach to investigate the barriers to blockchain technology adoption in the Vietnamese agricultural supply chain and obtained preliminary results [12].

To our best understanding, few studies investigate blockchain applications in Vietnam. This study is the first study that uses IVHF-DEMTEL to assess the barriers in the Vietnamese agricultural supply chain and preserve experts' opinions without converting them into crisp values. Consequently, this study aims to answer the following questions:

(i) What are the primary barriers to adopting blockchain technology in the Vietnamese agricultural supply chain?
(ii) What are the causes and effects of the significant barriers according to IVHF-DEMATEL?
(iii) Which barriers should be prioritized to be tackled for enhancing blockchain technology adoption?

The remaining structure of the study is organized as follows. Section 2 conducts a literature review. The method used in this study is presented in Section 3. Section 4 analyzes a case study of Vietnam. Finally, Section 5 is a conclusion.

2. Literature Review

Blockchain technology is an emerging and highly debated research topic in many areas, such as healthcare, smart contracts, the energy market, and financial and government sectors [6]. Due to the specific properties such as transparency, immutability, traceability, and reliability, blockchain technology has tremendous potential in the agricultural supply chain. Niknejad et al. [13] used a bibliometric technique to detect research trends and themes of blockchain technology in the agri-food supply chain. Their results revealed that the research articles primarily relate to traceability, transaction, the Internet of Things, and safety. Blockchain technologies have also appeared in many areas, such as food security, food safety, food integrity, support of small farmers, waste reduction and environmental awareness, and supervision and management of the supply chain [14]. Kamble et al. [15] identified many drivers influencing blockchain technology adoption, such as traceability, auditability, and immutability. Saurabh and Dey [16] found that many features of blockchain technology involving disintermediation, traceability, price, trust, compliance, and coordination facilitated the adoption process in the grape-wine supply chain.

Blockchain technology is expected to mature quickly. However, Mirabelli and Solina [6] found that blockchain technology in the agricultural sector is promising but has some limitations in the real context and its early stages. Antonucci et al. [17] reviewed blockchain applications based on a computational and an applicative point of view in the agri-food sector. They also observed that blockchain technology has great potential but is immature and complex to be applied. To assess the maturity of blockchain in business more accurately, Ronaghi [18] proposed a formal model and found that the blockchain of an Iranian company is at defining level. Many complex problems occur in real blockchain applications; therefore, adopting blockchain technology has received increasing academic and practical attention.

Zhao et al. [19] and Zheng et al. [20] discussed the challenges of blockchain technology. Hu et al. [21] tackled the trust crisis by proposing a consensus mechanism. Bai et al. [22] proposed a green supply chain framework to ensure the reliability of the data that can improve the transparency and trust of the system. Niu et al. [23] built a game-theoretic model to allocate pollution costs between supply chain parties. Eluubek kyzy et al. [24] used blockchain technology to design consortiums to maximize producers' profit. Biswas and Gupta [11] analyzed the barriers to implementing blockchain in the industry and service sectors. Yadav et al. [10] investigated the barriers to blockchain adoption in the Indian agricultural supply chain.

A well-known field in the literature addressing multiple criteria is multi-criteria decision-making (MCDM). One of the emerging approaches in this field is the ordinal priority approach (OPA), using a linear programming model to estimate the weight of experts, attributes, and alternatives [25]. Sadeghi et al. [26] used OPA to investigate the barriers to implementing distributed ledger technology/blockchain in the construction industry. The requirements and risks associated with blockchain in the construction industry are also investigated and analyzed in the multi-criteria decision-making context by using fuzzy OPA [27,28].

Moreover, DEMATEL is a commonly used technique in MCDM for finding causal relationships and interdependencies between variables. The technique has been applied to many fields [29]. Biswas and Gupta [11] used DEMATEL to analyze the barriers to implementing blockchain in the industry and service sectors. Yadav et al. [10] integrated DEMATEL and interpretive structural modelling (ISM) to identify the interrelationship between barriers to adopting blockchain in the Indian agricultural supply chain.

Fuzzy DEMATEL captures more accurate pictures than DEMATEL. Fuzzy DEMATEL often converts linguistic variables to fuzzy sets and then applies some score functions to convert fuzzy sets to crisp numbers. For example, the warm temperature is assumed to be in the range of 20–30 °C. After using some score functions, a crisp value of 25 °C can be obtained. To a certain degree, it may not make sense that warm temperature becomes 25 °C after transformation. To solve that problem, Asan et al. [30] proposed the IVHF-DEMATEL method that transforms linguistic variables into fuzzy sets and then applies fuzzy operations to avoid information loss. The result is a fuzzy representation that is more comprehensive and allows policymakers to know which barrier the experts are hesitant to instead of clear-cut ranking.

To our best understanding, few studies investigated blockchain technology in the Vietnamese agricultural supply chain. Vu and Trinh [8] analyzed blockchain technologies' strengths, weaknesses, opportunities, and threats in the supply chain. More than two-thirds of Vietnam's agriculture employees participate in agriculture, higher than in other ASEAN countries. They found blockchain technology has potential but also many barriers, such as small scale, costly infrastructure, platform, lack of knowledge, and scalability. However, the prior study has not investigated the Vietnamese agricultural supply chain's adoption challenges while using blockchain. Therefore, this study aims to investigate blockchain adoption barriers in the Vietnamese agricultural supply chain using IVHF-DEMATEL to give better insights.

3. Methodology

This study proposed a fully interval-valued hesitant fuzzy DEMATEL to investigate blockchain adoption barriers in the context of Vietnamese agricultural supply chain management. A committee of experts is formed to validate the existing barriers based on the literature review and experts' opinions. After several rounds to short-list the main barriers associated with blockchain adoption in the Vietnamese agricultural supply chain, these experts continue to assess interrelationships amongst barriers using the interval-valued hesitant fuzzy linguistic scales. In contrast to prior work using the defuzzification step, the fully interval-valued hesitant fuzzy operators are integrated with the DEMATEL approach to mitigate information loss. The research framework of this study is depicted in Figure 1.

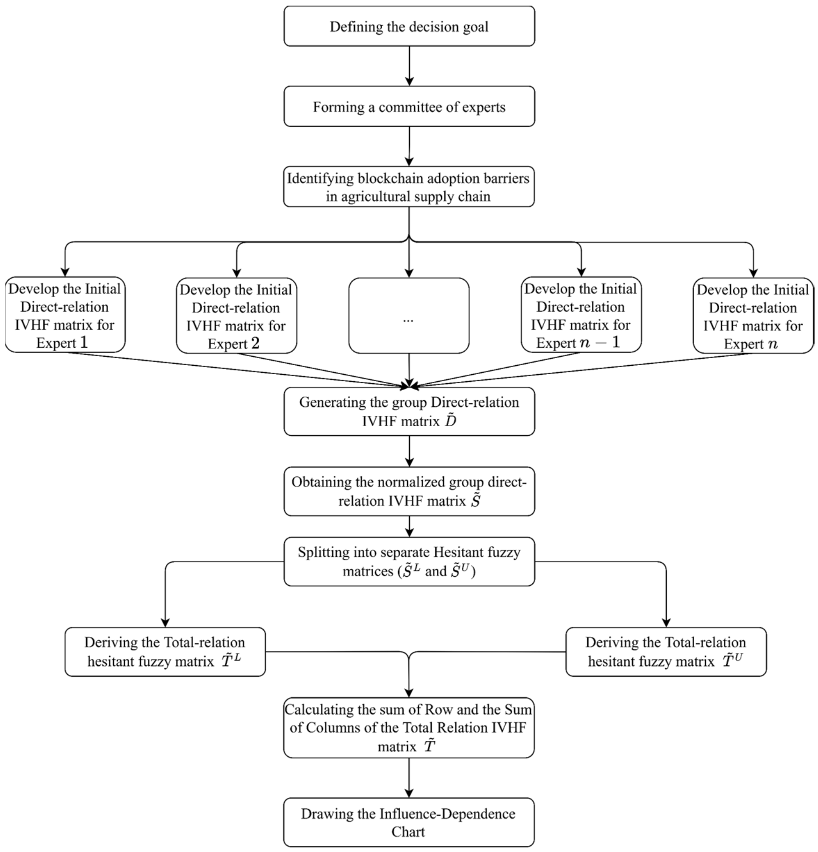

Figure 1. A proposed research framework.

3.1. Preliminaries

Determining definite membership or non-membership degrees is a difficult task in practice. Experts often rely on interval values when evaluating the degrees. The interval values can give experts flexibility and applicability. The interval values can collapse into single values if necessary. Torra [31] proposed that hesitant fuzzy sets are instrumental in dealing with experts' hesitation among several possibly fuzzy memberships to avoid information loss. These memberships can be interval values instead of only crisp values $[0,1]$. Some basic operators and definitions are provided as follows:

Definition 1. *Let X be a reference set and $D[0,1]$ be the set of all closed subintervals $[0,1]$. An interval-valued hesitant fuzzy set (IVHFS) on X is shown in Equation (1):*

$$\widetilde{A} = \{\langle x_i, \widetilde{h}_{\widetilde{A}}(x_i)\rangle | x_i \in X, i = 1,2,\ldots,n\} \tag{1}$$

where $\widetilde{h}_{\widetilde{A}}(x_i) : X \to D[0,1]$ denotes all possible interval-valued membership degrees of the element $x_i \in X$ to the set $\widetilde{A}$. $\widetilde{h}_{\widetilde{A}}(x_i)$ is called an interval-valued hesitant fuzzy element (IVHFE) shown in Equation (2):

$$\widetilde{h}_{\widetilde{A}}(x_i) = \{\widetilde{\gamma} | \widetilde{\gamma} \in \widetilde{h}_{\widetilde{A}}(x_i)\} \tag{2}$$

where $\widetilde{\gamma} = [\widetilde{\gamma}^L, \widetilde{\gamma}^U]$ is an interval number, with $\widetilde{\gamma}^L = \inf\widetilde{y}$ and $\widetilde{\gamma}^H = \sup\widetilde{y}$ representing the lower and upper limits of $\widetilde{\gamma}$, respectively.

Definition 2. *Some basic operations on IVHFEs:*

$$\widetilde{h}^c = \left\{[1-\widetilde{\gamma}^U, 1-\widetilde{\gamma}^L] \middle| \widetilde{\gamma} \in \widetilde{h}\right\} \tag{3}$$

$$\widetilde{h}_1 \cup \widetilde{h}_2 = \left\{[max\left(\widetilde{\gamma}_1^L, \widetilde{\gamma}_2^L\right), max\left(\widetilde{\gamma}_1^U, \widetilde{\gamma}_2^U\right)] \middle| \widetilde{\gamma}_1 \in \widetilde{h}_1, \widetilde{\gamma}_2 \in \widetilde{h}_2\right\} \tag{4}$$

$$\widetilde{h}_1 \cap \widetilde{h}_2 = \left\{[min\left(\widetilde{\gamma}_1^L, \widetilde{\gamma}_2^L\right), min\left(\widetilde{\gamma}_1^U, \widetilde{\gamma}_2^U\right)] \middle| \widetilde{\gamma}_1 \in \widetilde{h}_1, \widetilde{\gamma}_2 \in \widetilde{h}_2\right\} \tag{5}$$

$$\widetilde{h}^\lambda = \left\{[\left(\widetilde{\gamma}^L\right)^\lambda, \left(\widetilde{\gamma}^U\right)^\lambda] \middle| \widetilde{\gamma} \in \widetilde{h}\right\}, \text{ scalar } \lambda > 0 \tag{6}$$

$$\lambda\widetilde{h} = \left\{[1-\left(1-\widetilde{\gamma}^L\right)^\lambda, 1-\left(1-\widetilde{\gamma}^U\right)^\lambda] \middle| \widetilde{\gamma} \in \widetilde{h}\right\}, \text{ scalar } \lambda > 0 \tag{7}$$

$$\widetilde{h}_1 \oplus \widetilde{h}_2 = \left\{[\widetilde{\gamma}_1^L + \widetilde{\gamma}_2^L - \widetilde{\gamma}_1^L\widetilde{\gamma}_2^L, \widetilde{\gamma}_1^U + \widetilde{\gamma}_2^U - \widetilde{\gamma}_1^U\widetilde{\gamma}_2^U] \middle| \widetilde{\gamma}_1 \in \widetilde{h}_1, \widetilde{\gamma}_2 \in \widetilde{h}_2\right\} \tag{8}$$

$$\widetilde{h}_1 \otimes \widetilde{h}_2 = \left\{[\widetilde{\gamma}_1^L\widetilde{\gamma}_2^L, \widetilde{\gamma}_1^U\widetilde{\gamma}_2^U] \middle| \widetilde{\gamma}_1 \in \widetilde{h}_1, \widetilde{\gamma}_2 \in \widetilde{h}_2\right\} \tag{9}$$

Definition 3. *An interval-valued hesitant fuzzy weighted averaging (IVHFWA) operator is a mapping $IVHFWA : \widetilde{H}^n \to \widetilde{H}$, as shown in Equation (10):*

$$\begin{aligned} &IVHFWA(\widetilde{h}_1, \widetilde{h}_2, \ldots, \widetilde{h}_n) = \otimes_{j=1}^n (w_j\widetilde{h}_j) \\ &= \left\{\left[1-\prod_{j=1}^n\left(1-\widetilde{\gamma}_j^L\right)^{w_j}, 1-\prod_{j=1}^n\left(1-\widetilde{\gamma}_j^U\right)^{w_j}\right] | \widetilde{\gamma}_1 \in \widetilde{h}_1, \widetilde{\gamma}_2 \right. \\ &\left. \in \widetilde{h}_2, \ldots, \widetilde{\gamma}_n \in \widetilde{h}_n\right\} \widetilde{h}_{\widetilde{A}}(x_i) = \{\widetilde{\gamma} | \widetilde{\gamma} \in \widetilde{h}_{\widetilde{A}}(x_i)\} \end{aligned} \tag{10}$$

3.2. IVHF-DEMATEL Approach

Asan et al. [30] proposed IVHF-DEMATEL to tackle experts' hesitant assessments and represent uncertainty accurately. The computing process is presented as follows:

Step 1. Determine the decision goal and form a committee of experts. The decision goal for the problem under study is defined, and a group of experts whose opinions and judgments will be used to construct and analyze the problem.

Step 2. Identify the critical barriers. To obtain a thorough picture of the system, a literature review is conducted to identify the barriers. Analyzing and recognizing interrelationships may be impossible or nonsensical without this shared foundation.

Step 3. Establish the initial direct-relation IVHF matrix $\widetilde{H}^k$. Assume there are K decision-makers. The k^{th} expert assigns the relationship degree between pairwise barriers in linguistic construct, and then the assessments are transformed into closed sub-intervals of $[0,1]$. If no relationship exists, the degree is assigned as $[0,0]$. This study conducts an in-depth interview that allows experts to give their opinions and agree on the linguistic scale listed in Table 1.

Table 1. Linguistic scale.

Linguistic Construct	Abbreviation	Lower Value	Upper Value
No influence	NI	0.00	0.00
Very low influence	VL	0.05	0.15
Low influence	LI	0.25	0.35
Medium influence	MI	0.45	0.55
High influence	HI	0.65	0.75
Very high influence	VH	0.85	0.95
Complete influence	CI	1.00	1.00

The corresponding k^{th} initial direct-relation IVHF matrix ($\widetilde{H}^k$) between barriers is established by Equation (11).

$$\widetilde{H}^k = \begin{bmatrix} \widetilde{0} & \widetilde{h}^k_{12} & \cdots & \widetilde{h}^k_{1n} \\ \widetilde{h}^k_{21} & \widetilde{0} & \cdots & \widetilde{h}^k_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{h}^k_{n1} & \widetilde{h}^k_{n2} & \cdots & \widetilde{0} \end{bmatrix}, \ k = 1, 2, \cdots, K \tag{11}$$

The IVHF element $\widetilde{h}^k_{ij} = \{(\widetilde{\gamma}^k_{ij})^L, (\widetilde{\gamma}^k_{ij})^U\}$ is a single interval where $(\widetilde{\gamma}^k_{ij})^L$ and $(\widetilde{\gamma}^k_{ij})^U$ represent the lower and upper limits of the IVHF element $\widetilde{h}^k_{ij}$, respectively.

Step 4. Generate the group direct-relation IVHF matrix $\widetilde{D}$.

The relationship degrees are aggregated into a single IVFH matrix using Equation (12), an IVHFWA operator [32].

$$\widetilde{d}_{ij} = \oplus^p_{k=1}\left(\lambda_k \widetilde{h}^k_{ij}\right) = \left\{\left[1 - \prod_{k=1}^{K}\left(1 - (\widetilde{\gamma}^k_{ij})^L\right)^{\lambda_k}, 1 - \prod_{k=1}^{K}\left(1 - (\widetilde{\gamma}^k_{ij})^U\right)^{\lambda_k}\right]\right\} \tag{12}$$

where $\widetilde{d}_{ij}$ denotes the ij^{th} entry of the matrix $\widetilde{D}$.

$$\widetilde{D} = \begin{bmatrix} \widetilde{0} & \widetilde{d}_{12} & \cdots & \widetilde{d}_{1n} \\ \widetilde{d}_{21} & \widetilde{0} & \cdots & \widetilde{d}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{d}_{n1} & \widetilde{d}_{n2} & \cdots & \widetilde{0} \end{bmatrix}, \widetilde{d}_{ij} = \{[\widetilde{d}^L_{ij}, \widetilde{d}^U_{ij}]\}, i, j = 1, 2, \cdots, n \tag{13}$$

Step 5. Normalize the group direct-relation IVHF matrix $\widetilde{S}$.

The endpoints $\widetilde{d}_{ij} = \{[\widetilde{d}^L_{ij}, \widetilde{d}^U_{ij}]\}$ are divided by the maximum value of sums of all rows given by Equation (14). Because the lower limit of IVHF is always smaller than the upper limit, summing only the upper limits is sufficient.

$$d = \max_{1 \le i \le n}\left\{\sum_{j=1}^{n} \widetilde{d}^U_{ij}\right\}, \widetilde{s}_{ij} = \left\{\left[\widetilde{s}^L_{ij}, \widetilde{s}^L_{ij}\right]\right\} = \left\{\left[\frac{\widetilde{d}^L_{ij}}{d}, \frac{\widetilde{d}^U_{ij}}{d}\right]\right\} \tag{14}$$

where the normalized IVHF matrix ($\widetilde{S}$) is split into two separate matrices ($\widetilde{S}^L$ and $\widetilde{S}^U$), which are composed of the lower limit and upper limit of IVHF elements ($\widetilde{s}_{ij}$), respectively, as given by Equation (15).

$$\widetilde{S}^L = \begin{bmatrix} \widetilde{0} & \widetilde{s}^L_{12} & \cdots & \widetilde{s}^L_{1n} \\ \widetilde{s}^L_{21} & \widetilde{0} & \cdots & \widetilde{s}^L_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{s}^L_{n1} & \widetilde{s}^L_{n2} & \cdots & \widetilde{0} \end{bmatrix}, \widetilde{S}^U = \begin{bmatrix} \widetilde{0} & \widetilde{s}^U_{12} & \cdots & \widetilde{s}^U_{1n} \\ \widetilde{s}^U_{21} & \widetilde{0} & \cdots & \widetilde{s}^U_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{s}^U_{n1} & \widetilde{s}^U_{n2} & \cdots & \widetilde{0} \end{bmatrix} \tag{15}$$

Step 6. Derive the total-relation hesitant fuzzy matrix.

The total-relation hesitant fuzzy matrix ($\widetilde{T}$) equals the sum of all direct and indirect relationships between each pair of barriers of IVHF. It can be computed by using Equation (16), where m is sufficiently large.

$$\widetilde{T} = \widetilde{S} \oplus \widetilde{S}^2 \oplus \cdots \oplus \widetilde{S}^m \tag{16}$$

We can separate the lower and upper limits and then raise them to powers using the summation and multiplication operators as follows. Let $\widetilde{T}^L$ and $\widetilde{T}^U$ represent the lower and upper limits of the total-relation hesitant fuzzy matrix $\widetilde{T}$, respectively. $\widetilde{T}^L$ and $\widetilde{T}^U$ can be calculated by Equations (17) and (18):

$$\widetilde{T}^L = \widetilde{S}^L \oplus \left(\widetilde{S}^L\right)^2 \oplus \cdots \oplus \left(\widetilde{S}^L\right)^m \tag{17}$$

$$\widetilde{T}^U = \widetilde{S}^U \oplus \left(\widetilde{S}^U\right)^2 \oplus \cdots \oplus \left(\widetilde{S}^U\right)^m \tag{18}$$

Then, $\widetilde{T}^L$ and $\widetilde{T}^U$ can be combined to obtain the limit matrix $\widetilde{T}$ as shown below:

$$\widetilde{T} = \begin{bmatrix} \left\{\left[\widetilde{t}^L_{11}, \widetilde{t}^U_{11}\right]\right\} & \left\{\left[\widetilde{t}^L_{12}, \widetilde{t}^U_{12}\right]\right\} & \cdots & \left\{\left[\widetilde{t}^L_{1n}, \widetilde{t}^U_{1n}\right]\right\} \\ \left\{\left[\widetilde{t}^L_{21}, \widetilde{t}^U_{21}\right]\right\} & \left\{\left[\widetilde{t}^L_{22}, \widetilde{t}^U_{22}\right]\right\} & \cdots & \left\{\left[\widetilde{t}^L_{2n}, \widetilde{t}^U_{2n}\right]\right\} \\ \vdots & \vdots & \ddots & \vdots \\ \left\{\left[\widetilde{t}^L_{n1}, \widetilde{t}^U_{n1}\right]\right\} & \left\{\left[\widetilde{t}^L_{n2}, \widetilde{t}^U_{n2}\right]\right\} & \cdots & \left\{\left[\widetilde{t}^L_{nn}, \widetilde{t}^U_{nn}\right]\right\} \end{bmatrix} \tag{19}$$

Step 7. Sum the rows and columns of the total-relation matrix.

The hesitant fuzzy sum operator in Equation (8) is used to calculate the sum of each row and column, where $\widetilde{r}$ represents the total influence exerted by the i^{th} barrier on the other barriers, and $\widetilde{c}$ represents the total influence that the i^{th} barrier is affected by the other barriers, as shown in Equation (20).

$$\widetilde{r} = \begin{bmatrix} \left\{\left[\widetilde{r}^L_1, \widetilde{r}^U_1\right]\right\} \\ \left\{\left[\widetilde{r}^L_2, \widetilde{r}^U_2\right]\right\} \\ \vdots \\ \left\{\left[\widetilde{r}^L_n, \widetilde{r}^U_n\right]\right\} \end{bmatrix}, \widetilde{c} = \begin{bmatrix} \left\{\left[\widetilde{c}^L_1, \widetilde{c}^U_1\right]\right\} \\ \left\{\left[\widetilde{c}^L_2, \widetilde{c}^U_2\right]\right\} \\ \vdots \\ \left\{\left[\widetilde{c}^L_n, \widetilde{c}^U_n\right]\right\} \end{bmatrix} \tag{20}$$

Step 8. Construct the influence-dependence graph.

The influence-dependence (I-D) graph is a two-dimensional map where the horizontal axis denotes the sum of columns ($\widetilde{c}$) and the vertical axis denotes the sum of rows ($\widetilde{r}$). The four quadrants of this map represent four critical, influential, dependent, and excluded regions. This I-D map is linked to the causal diagram [33].

The cut-off points of the horizontal and vertical axes, which separate four quadrants from the I-D map, are determined by calculating the average sum of columns according to Equation (21) and the average sum of rows according to Equation (22), respectively.

$$\left\{\left[\tilde{c}^{L}_{avg},\tilde{c}^{U}_{avg}\right]\right\}=\left\{\left[\frac{1}{n}\otimes\left(\oplus^{n}_{i=1}\tilde{c}^{L}_{i}\right),\frac{1}{n}\otimes\left(\oplus^{n}_{i=1}\tilde{c}^{U}_{i}\right)\right]\right\} \tag{21}$$

$$\left\{\left[\tilde{r}^{L}_{avg},\tilde{r}^{U}_{avg}\right]\right\}=\left\{\left[\frac{1}{n}\otimes\left(\oplus^{n}_{i=1}\tilde{r}^{L}_{i}\right),\frac{1}{n}\otimes\left(\oplus^{n}_{i=1}\tilde{r}^{U}_{i}\right)\right]\right\} \tag{22}$$

4. Case Study

Since Vietnam has a significant export of agricultural products, blockchain technology has high potential and benefits for the Vietnamese agricultural supply chain. As shown in the literature review, blockchain technology adoption barriers have not been investigated in the case of Vietnam. This study aims to assess the interrelationship between barriers and identify cause and effect. A committee is formed with ten experts working in agriculture, blockchain companies, or government. The weight of each expert's opinion is assumed to be equal. The profile of experts with different experience levels is shown in Table 2.

Table 2. Profile of experts in this study.

No.	Years of Experience	Working Experience
Expert 1	10	MBA
Expert 2	8	Scholar
Expert 3	12	MBA
Expert 4	10	Scholar
Expert 5	15	MBA
Expert 6	10	Scholar
Expert 7	10	MBA
Expert 8	12	Scholar
Expert 9	15	Policy maker
Expert 10	20	Policy maker

The databases Web of Science, Science Direct, SCOPUS, and Springer identified various barriers to blockchain adoption. Articles were searched based on keywords, including blockchain technology, agricultural supply chain, and blockchain adoption barriers. Moreover, we interviewed experts to identify critical barriers. Ten potential barriers shown in Table 3 have been considered in this research.

4.1. Results

The committee of ten experts was interviewed to give their IVHF assessments for pairwise comparison. An in-depth interview was adopted to obtain the experts' opinions by paper questionnaire. The dataset is provided in the study by Tran and Nguyen [34]. Equation (12) states that ten individual assessments are aggregated into a single interval. The obtained group direct-relation IVHF matrix is given in Table 4.

The normalized group direct-relation IVHF matrix shown in Table 5 is obtained by dividing each element of matrix D by the maximum value of the sum of rows using Equation (13). The matrix comprises the lower and upper limits of the hesitant fuzzy elements using Equation (14).

The lower and upper limits of the matrix S are raised to successive powers until obtaining zero matrices. The zero matrices are obtained for the matrix's lower and upper limits S by raising them to the 10th power. The resulting matrices are summed to yield the lower and upper limits of the matrix, respectively. The summation of these power matrices is performed by using Equations (17) and (18).

After obtaining the matrices T^L and T^U, they are combined to calculate the total-relation hesitant fuzzy matrix *T*, as shown in Table 6. Table 7 lists the sum of rows and columns of the total-relation matrix. The sum of rows indicates the sum of influence exerted from the i^{th} barrier to the other barriers, and the sum of columns indicates the sum of influence that the i^{th} barrier is affected by other barriers.

Table 3. Explanation of blockchain adoption barriers.

No.	Barriers	Explanation	Reference
B1	Lack of government regulation	Most countries have not regulated and legislated blockchain.	[11,19]
B2	A large amount of resource and capital requirement	The blockchain-based system consumes high energy and requires the right initial investment and sufficient infrastructure.	[11,19]
B3	Security and privacy concerns	Blockchain-based systems can be hacked and attacked by malicious actors. Agro-business organizations are also concerned about confidentiality due to exposing their information to competitors.	[11,19,20]
B4	Lack of standardization	There is no universal standard, so integrating and operating blockchain is challenging.	[11,19]
B5	Lack of consortia	Consortia can provide more resources, meet financial requirements, and take advantage of the economy of scale.	[35]
B6	Lack of trust among agro-stakeholder or public perception	Agro-stakeholders suspect the uses of the blockchain-based system; stakeholders such as farmers may not be aware of a blockchain-based system.	[10]
B7	Lack of scalability and system speed	It is challenging to scale up the blockchain-based system; the transaction speed is deficient.	[11,19,20,35]
B8	The complexity of blockchain-based system design	The efficient blockchain-based system design requires a high level of skill sets.	[10]
B9	Agro-stakeholder resistance to blockchain culture	The middleman in the agro-supply chain may resist blockchain due to affecting their benefits.	[10]
B10	Lack of consumer demand for certified products	Consumers may not prefer blockchain-based (certified) products due to high prices.	[36]

Table 4. Group direct-relation IVHF matrix $\widetilde{D}$.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	{[0.0,0.0]}	{[0.656,0.813]}	{[0.596,0.757]}	{[1.0,1.0]}	{[0.687,0.839]}	{[0.701,0.848]}	{[0.685,0.837]}	{[0.619,0.772]}	{[0.652,0.809]}	{[0.665,0.819]}
B2	{[0.178,0.258]}	{[0.0,0.0]}	{[0.334,0.428]}	{[0.222,0.315]}	{[0.618,0.785]}	{[1.0,1.0]}	{[0.158,0.252]}	{[0.391,0.489]}	{[0.315,0.443]}	{[1.0,1.0]}
B3	{[0.233,0.322]}	{[0.052,0.123]}	{[0.0,0.0]}	{[1.0,1.0]}	{[0.052,0.123]}	{[0.345,0.433]}	{[0.282,0.37]}	{[1.0,1.0]}	{[0.15,0.232]}	{[0.188,0.271]}
B4	{[0.156,0.217]}	{[0.142,0.232]}	{[0.118,0.193]}	{[0.0,0.0]}	{[0.142,0.232]}	{[0.057,0.134]}	{[0.177,0.262]}	{[0.278,0.365]}	{[0.263,0.351]}	{[0.282,0.37]}
B5	{[0.249,0.318]}	{[0.299,0.393]}	{[0.308,0.401]}	{[0.436,0.534]}	{[0.0,0.0]}	{[0.334,0.428]}	{[0.4,0.495]}	{[0.497,0.598]}	{[0.327,0.416]}	{[0.477,0.578]}
B6	{[0.164,0.217]}	{[0.547,0.651]}	{[0.46,0.561]}	{[0.372,0.468]}	{[0.539,0.642]}	{[0.0,0.0]}	{[0.422,0.519]}	{[0.499,0.603]}	{[0.505,0.608]}	{[0.486,0.589]}
B7	{[0.379,0.501]}	{[1.0,1.0]}	{[0.252,0.346]}	{[0.342,0.44]}	{[0.414,0.535]}	{[0.364,0.458]}	{[0.0,0.0]}	{[0.527,0.631]}	{[0.376,0.47]}	{[0.509,0.61]}
B8	{[0.486,0.589]}	{[0.388,0.484]}	{[0.41,0.509]}	{[0.332,0.421]}	{[0.719,0.86]}	{[0.392,0.486]}	{[0.545,0.646]}	{[0.0,0.0]}	{[0.611,0.725]}	{[0.567,0.669]}
B9	{[0.057,0.134]}	{[0.057,0.134]}	{[0.102,0.19]}	{[0.102,0.19]}	{[0.158,0.233]}	{[0.233,0.323]}	{[0.235,0.319]}	{[0.247,0.34]}	{[0.0,0.0]}	{[0.345,0.433]}
B10	{[0.533,0.653]}	{[0.414,0.535]}	{[0.38,0.475]}	{[0.414,0.535]}	{[0.426,0.545]}	{[0.194,0.326]}	{[0.396,0.514]}	{[0.329,0.453]}	{[0.313,0.433]}	{[0.0,0.0]}

Table 5. Normalized group direct-relation IVHF matrix $\widetilde{S}$.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	{[0.0,0.0]}	{[0.091,0.109]}	{[0.084,0.103]}	{[0.126,0.126]}	{[0.095,0.112]}	{[0.097,0.113]}	{[0.095,0.112]}	{[0.087,0.105]}	{[0.091,0.109]}	{[0.092,0.11]}
B2	{[0.027,0.038]}	{[0.0,0.0]}	{[0.049,0.062]}	{[0.033,0.046]}	{[0.086,0.106]}	{[0.126,0.126]}	{[0.023,0.037]}	{[0.057,0.07]}	{[0.046,0.064]}	{[0.126,0.126]}
B3	{[0.034,0.047]}	{[0.008,0.018]}	{[0.0,0.0]}	{[0.126,0.126]}	{[0.008,0.018]}	{[0.05,0.062]}	{[0.041,0.054]}	{[0.126,0.126]}	{[0.022,0.034]}	{[0.028,0.04]}
B4	{[0.023,0.032]}	{[0.021,0.034]}	{[0.018,0.029]}	{[0.0,0.0]}	{[0.021,0.034]}	{[0.009,0.02]}	{[0.026,0.039]}	{[0.041,0.053]}	{[0.039,0.051]}	{[0.041,0.054]}
B5	{[0.037,0.046]}	{[0.044,0.057]}	{[0.045,0.058]}	{[0.063,0.076]}	{[0.0,0.0]}	{[0.049,0.062]}	{[0.058,0.071]}	{[0.071,0.084]}	{[0.048,0.06]}	{[0.068,0.081]}
B6	{[0.024,0.032]}	{[0.077,0.091]}	{[0.066,0.079]}	{[0.054,0.067]}	{[0.076,0.089]}	{[0.0,0.0]}	{[0.061,0.074]}	{[0.071,0.085]}	{[0.072,0.085]}	{[0.07,0.083]}
B7	{[0.055,0.072]}	{[0.126,0.126]}	{[0.037,0.05]}	{[0.05,0.063]}	{[0.06,0.076]}	{[0.053,0.066]}	{[0.0,0.0]}	{[0.075,0.088]}	{[0.055,0.067]}	{[0.073,0.086]}
B8	{[0.07,0.083]}	{[0.056,0.069]}	{[0.059,0.072]}	{[0.048,0.061]}	{[0.099,0.114]}	{[0.057,0.069]}	{[0.077,0.09]}	{[0.0,0.0]}	{[0.086,0.099]}	{[0.08,0.093]}
B9	{[0.009,0.02]}	{[0.009,0.02]}	{[0.015,0.028]}	{[0.015,0.028]}	{[0.024,0.034]}	{[0.034,0.047]}	{[0.035,0.047]}	{[0.036,0.05]}	{[0.0,0.0]}	{[0.05,0.062]}
B10	{[0.076,0.091]}	{[0.06,0.076]}	{[0.055,0.068]}	{[0.06,0.076]}	{[0.061,0.077]}	{[0.029,0.048]}	{[0.057,0.073]}	{[0.048,0.065]}	{[0.046,0.062]}	{[0.0,0.0]}

Table 6. Total-relation IVHF matrix $\widetilde{T}$.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	{[0.061,0.114]}	{[0.158,0.227]}	{[0.143,0.212]}	{[0.196,0.251]}	{[0.167,0.241]}	{[0.162,0.231]}	{[0.158,0.228]}	{[0.169,0.245]}	{[0.16,0.233]}	{[0.178,0.252]}
B2	{[0.069,0.116]}	{[0.057,0.101]}	{[0.096,0.147]}	{[0.093,0.149]}	{[0.139,0.199]}	{[0.167,0.205]}	{[0.078,0.134]}	{[0.118,0.176]}	{[0.1,0.16]}	{[0.18,0.222]}
B3	{[0.067,0.107]}	{[0.052,0.097]}	{[0.038,0.073]}	{[0.162,0.194]}	{[0.056,0.105]}	{[0.086,0.131]}	{[0.081,0.127]}	{[0.164,0.198]}	{[0.068,0.116]}	{[0.079,0.129]}
B4	{[0.042,0.074]}	{[0.045,0.085]}	{[0.038,0.076]}	{[0.027,0.058]}	{[0.047,0.091]}	{[0.033,0.074]}	{[0.049,0.089]}	{[0.067,0.11]}	{[0.062,0.103]}	{[0.069,0.113]}
B5	{[0.072,0.115]}	{[0.088,0.139]}	{[0.083,0.133]}	{[0.11,0.161]}	{[0.052,0.099]}	{[0.091,0.142]}	{[0.099,0.15]}	{[0.12,0.174]}	{[0.093,0.146]}	{[0.121,0.175]}
B6	{[0.066,0.11]}	{[0.123,0.175]}	{[0.107,0.159]}	{[0.109,0.164]}	{[0.127,0.183]}	{[0.056,0.101]}	{[0.107,0.161]}	{[0.129,0.187]}	{[0.12,0.175]}	{[0.131,0.188]}
B7	{[0.095,0.147]}	{[0.17,0.21]}	{[0.086,0.141]}	{[0.109,0.166]}	{[0.12,0.181]}	{[0.111,0.164]}	{[0.056,0.104]}	{[0.135,0.194]}	{[0.109,0.167]}	{[0.141,0.198]}
B8	{[0.11,0.16]}	{[0.113,0.169]}	{[0.108,0.163]}	{[0.113,0.171]}	{[0.153,0.214]}	{[0.113,0.17]}	{[0.129,0.185]}	{[0.075,0.13]}	{[0.139,0.198]}	{[0.147,0.207]}
B9	{[0.028,0.064]}	{[0.034,0.074]}	{[0.036,0.076]}	{[0.041,0.084]}	{[0.049,0.091]}	{[0.055,0.095]}	{[0.056,0.096]}	{[0.062,0.107]}	{[0.025,0.057]}	{[0.076,0.119]}
B10	{[0.107,0.156]}	{[0.104,0.161]}	{[0.094,0.148]}	{[0.112,0.17]}	{[0.109,0.171]}	{[0.078,0.14]}	{[0.101,0.159]}	{[0.104,0.168]}	{[0.093,0.155]}	{[0.063,0.116]}

Table 7. Sum of rows and the sum of columns of interval-valued hesitant fuzzy sets.

Barrier	$\widetilde{r}_i$	$\widetilde{c}_i$	Rank ($\widetilde{r}_i$)	Rank ($\widetilde{c}_i$)
B1	{[0.816,0.921]}	{[0.526,0.712]}	1	10
B2	{[0.69,0.829]}	{[0.633,0.792]}	4	7
B3	{[0.594,0.747]}	{[0.582,0.762]}	8	9
B4	{[0.389,0.6]}	{[0.683,0.821]}	9	3
B5	{[0.624,0.788]}	{[0.663,0.823]}	7	4
B6	{[0.681,0.827]}	{[0.636,0.795]}	5	6
B7	{[0.7,0.84]}	{[0.62,0.789]}	3	8
B8	{[0.722,0.858]}	{[0.705,0.845]}	2	2
B9	{[0.377,0.594]}	{[0.642,0.808]}	10	5
B10	{[0.638,0.813]}	{[0.72,0.851]}	6	1

As a result of IVHF-DEMATEL, the influence-dependence chart is illustrated in Figure 2. The analytical results introduce four classified groups based on the level of influence and dependence described below.

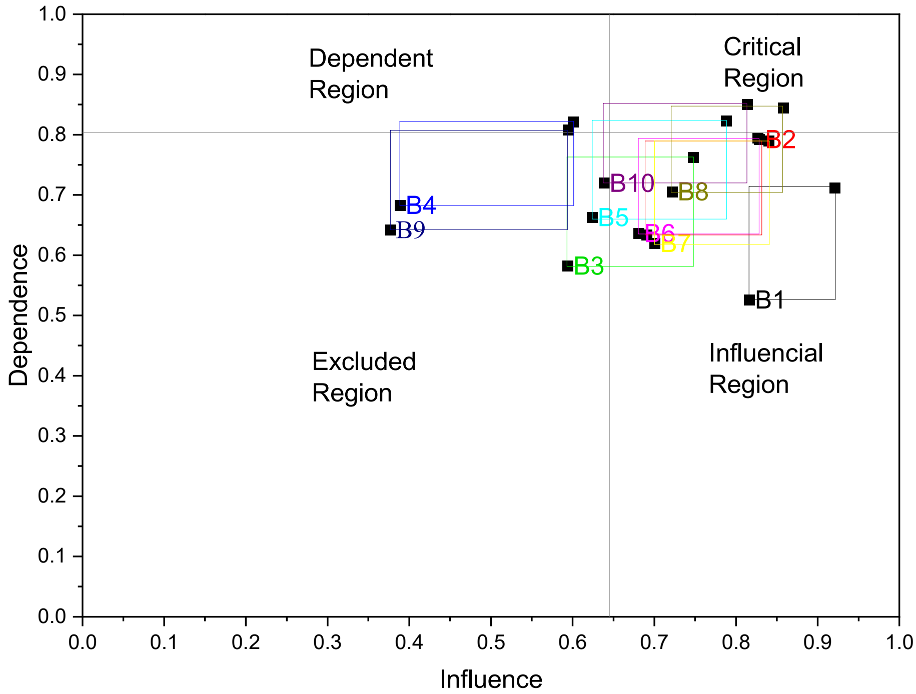

Figure 2. Influence-dependence chart of the proposed approach.

The influential region involves the barriers having strong influence but weak dependence; these barriers should be prioritized. The critical region involves strongly dependent and influential barriers that impact themselves and affect others; consequently, they are unstable. The excluded region has weak influential and dependent barriers; these barriers do not have a significant impact nor link to the system. The dependent region includes barriers with strong dependence but weak influence; these barriers are strongly affected by other barriers and do not change the system alone.

Even though the four regions help assess barriers, experts' hesitancy makes the aggregate results belong to more than one region. To effectively assess barriers, we use three indicators, as shown below.

The first indicator, the distance dimension, evaluates how far and overlapping barriers are. According to Figure 2, B4 and B9 overlap mostly, which means they have a similar effect. B2, B3, B5, B6, B7, B8, and B10 are close and overlap. It makes their effect challenging to be distinguished. Notably, B1 stands out from other barriers. B1 becomes one of the barriers having the clearest effect the experts agreed on.

The second indicator is relative size. A larger rectangle describes a higher level of hesitancy. B9 is associated with the most hesitancy, followed by B4, B3, B5, B7, B6, and B10. The other three barriers, B2, B1, and B8, have smaller rectangles due to the less hesitancy in experts' assessments.

The third indicator is position. B1, B2, B6, and B7 belong to the influential region; B9 and B4 mainly belong to the excluded region. B3 belongs to the excluded and influential regions, and B8 belongs to the critical and influential regions. B5 and B10 cover all four regions, which means B5 and B10 become critical, influential, dependent, or excluded based on how the situation happens.

Those barriers to blockchain technology adoption can be further classified based on the lowest and highest points of the rectangles. Table 8 shows the role of each barrier in optimistic and pessimistic scenarios, respectively. For priority, B1, B7, B2, and B6 belong strictly to the influential regions. It implies that B1, B7, B2, and B6 should be tackled first in descending order. B4 and B9 can be ignored. Comparing relative positions, B8 has better positions than B10, B5, and B3 regarding influence and dependence so that we can prioritize B8 over B10 over B5 over B3. Since B3, B5, and B10 are excluded factors in the pessimistic condition, a low improvement priority is set for them. The influence-dependence chart indicates that the full priority order for tackling barriers is B1, B7, B2, B6, B8, B10, B5, and B3.

Table 8. The characteristic role of barriers is based on different scenarios.

Barriers	Optimistic Scenario	Pessimistic Scenario
B1	Influential	Influential
B2	Influential	Influential
B3	Influential	Excluded
B4	Dependent	Excluded
B5	Critical	Excluded
B6	Influential	Influential
B7	Influential	Influential
B8	Critical	Influential
B9	Excluded	Excluded
B10	Critical	Excluded

For simplicity, fuzzy sets are defuzzified into crisp values using the mean of the lower and upper bounds of the fuzzy sets (Table 9). We can obtain the causal relationship diagram (Figure 3).

Table 9. Sum of rows and the sum of columns in crisp values.

Barrier	r_i	c_i	$r_i - c_i$	$r_i + c_i$	Classify
B1	0.869	0.619	0.250	1.487	Cause
B2	0.760	0.713	0.047	1.472	Cause
B3	0.671	0.672	−0.002	1.343	Effect
B4	0.495	0.752	−0.258	1.247	Effect
B5	0.706	0.743	−0.037	1.449	Effect
B6	0.754	0.716	0.038	1.469	Cause
B7	0.770	0.705	0.066	1.475	Cause
B8	0.790	0.775	0.015	1.565	Cause
B9	0.486	0.725	−0.240	1.211	Effect
B10	0.726	0.785	−0.059	1.511	Effect

Comparing the results before and after defuzzification, both results are similar: B1, B7, B2, B6, and B8 are causes in descending order; B10, B5, B3, B4, and B9 are effects. There are differences based on the way we defuzzify. We can strictly tell which barriers are cause or effect in relative order after defuzzification, but we cannot always tell the order of barriers before defuzzification. This tradeoff of defuzzification raises a new question: which method should be used to defuzzify interval-valued hesitant fuzzy sets into crisp values? More innovative defuzzification methods should be proposed.

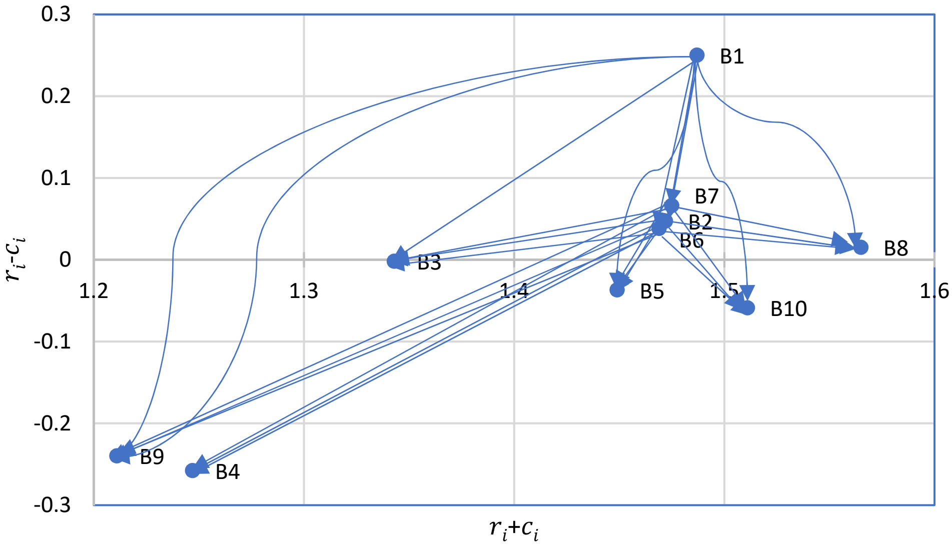

Figure 3. Causal relationship diagram.

4.2. Discussions

Compared with the results of Yadav et al. [10], our findings are consistent with their results which indicate that lack of government regulation and trust among agro-stakeholder or public perception are the causal factors influencing blockchain technology adoption. However, other findings are markedly different from those of Yadav et al. [10]. Notably, a large amount of resource and capital requirement and lack of scalability and system speed is classified as effects by Yadav et al. [10] but as causes by our findings. We observe that Vietnam and India have different contexts while applying blockchain.

Since blockchain is a decentralized system without a third party and the government is often classified as a centralized authority [37], potential issues can arise. One of the issues is unclear taxation if agro-stakeholders use blockchain technology to make transactions; another issue is data privacy laws [11]. A successful story in implementing blockchain technology in the Vietnamese agricultural supply chain cannot represent solutions to the lack of government regulations. Government regulations should be established and clear to help agro-stakeholders avoid potential issues.

Additionally, the second most important barrier in our finding is 'lack of scalability and system speed'. Many solutions have been developed to tackle this barrier. Jabbar et al. [37] classified solutions related to scalability into four categories: on-chain solutions, off-chain approach, consensus mechanism-based scalability, and distributed acyclic graph-based scalability. Even though plenty of solutions are proposed, the optimal solutions for the Vietnamese agricultural supply chain are still unknown. More investigations on the solutions to lack scalability and system speed in the Vietnamese agricultural supply chain are worthy of further study.

Two primary barriers to blockchain technology adoption are 'a large amount of resource and capital requirement' and 'lack of trust among agro-stakeholder or public perception.' Because the Vietnamese farming scale is small and smallholder farmers do not know enough about blockchain technology [8], deploying blockchain technology becomes difficult. Increasing farming scale, reducing technology requirements, and introducing the technology to agro-stakeholders can be potential solutions.

Consistent with Biswas and Gupta [11], our study also finds that 'lack of government regulation' and 'lack of scalability and system speed' are the causes. It shows that these barriers are still significant obstacles to blockchain technology adoption in the Vietnamese agricultural supply chain and the world. Vietnamese and Indian agricultural supply chains are facing the problem of 'lack of trust among agro-stakeholder or public perception'. Interestingly, the Vietnamese agricultural supply chain focuses more on scalability, system speed, resources, and capital requirements rather than the blockchain-based system's interoperability, standardization, and complexity that the Indian agricultural supply chain prioritizes. This finding shows that the Vietnamese agricultural supply chain utilizes different ways to foster the blockchain adoption process.

With the number of barriers N, the number of pairwise comparisons will be $N(N-1)/2$, and the effort from experts to assess the relationship between barriers will increase exponentially. The experts also need to give their assessment in interval values that require extra effort. Since IVHF-DEMATEL uses fully hesitant fuzzy operations, more computational power is required. Furthermore, Equations (17) and (18) can go to infinity and have not been simplified; the equations require huge computational power. It leads to the tradeoff between precision and computational power. Higher precision requires more computational power. In order to reduce the computational power, more efficient operators of interval-valued hesitant values should be proposed.

Compared to other methods, IVHF-DEMATEL can preserve the experts' opinions when we have enough effort from experts and computational power. IVHF-DEMATEL allows the decision makers to know the hesitant degree of each barrier. Other methods often defuzzify fuzzy sets into crisp values that distort information. IVHF-DEMATEL also allows the decision-makers to be aware of uncertain situations since barriers can overlap in the influence-dependence chart instead of a clear-cut ranking of barriers. IVHF-DEMATEL requires huge computational power, but it has higher precision.

5. Conclusions

Blockchain technology is an emerging and challenging technology in the agricultural supply chain, especially for Vietnam, with a significant export of agricultural products. This study investigates the barriers to adopting blockchain technology in the Vietnamese agricultural supply chain. Integrating the data from the literature review with experts' opinions, ten barriers are identified in the Vietnamese agricultural supply chain case. The analytical results indicate that lack of government regulation, lack of trust among agro-stakeholder, a large amount of resource andcapital requirement, and lack of scalability and system speed must be prioritized in descending order.

Our findings show that three barriers belong strictly to the influential region, even though experts were hesitant. 'Blockchain-based system design's complexity' belongs to the influential and critical regions; it should be tackled carefully. 'Lack of standardization' and 'agro-stakeholder resistance to blockchain culture' are classified as excluded since they belong mainly to the excluded region. The other barriers belong to two or four regions, meaning the experts are unsure and have different opinions.

Yadav et al. [10] reported the same finding in the Indian case: lack of government regulation is the most significant barrier to adopting blockchain technology. Therefore, to facilitate the adoption process, the first thing that must be done is establishing regulations related to blockchain technology. Our other findings are markedly different from their classification and priority. The Vietnamese and Indian agricultural supply chains have different ways to boost blockchain technology adoption effectively.

Due to the limited resources, not all barriers to adopting blockchain technology can be tackled immediately in the Vietnamese agricultural supply chain. This study identifies the most critical barriers and their priority to boost the adoption process. Future research can be conducted on allocating resources to tackle barriers given their priority. Blockchain technology can help the Vietnamese agricultural supply chain achieve transparency, solve food quality and safety issues, reduce costs, restore trust, and provide data for data-driven facilities and intelligent farming.

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