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Impact of Blockchain Implementation on Enhancing Customer Satisfaction in Organizational Supply Chains: Dairy Product Manufacturers Case Study

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Abstract

This study investigates the impact of blockchain implementation on the dairy supply chain and customer satisfaction. While prior research has mainly focused on other industries and limited aspects of supply chains, there is a notable gap in studies addressing dairy supply chains. This research aims to fill this gap by presenting a comprehensive model incorporating transparency, agility, traceability, and supplier interactions. The study highlights the potential of blockchain to improve customer satisfaction and trust through enhanced transparency and better supply chain management. The research method is applied and survey-based, using both library research and fieldwork for data collection. Data were gathered through three validated questionnaires and analyzed using SPSS and Smart PLS software. The findings suggest that blockchain technology can significantly improve transparency and agility in the dairy supply chain, leading to higher customer satisfaction. This study offers valuable insights for future research and practical applications in the dairy industry.

Keywords: Blockchain; Dairy Industry Supply Chain; Customer Satisfaction; Agility; Transparency.

1. Introduction

The food industry is among the key sectors, and given its direct and indirect effects on public health, maintaining high product quality in this field is crucial. Within the food industry,the dairy sector is of a particular importance within the food industry due to the high consumption of its products by the public. Current tracking systems for agricultural supply chains, leveraging the Internet of Things (IoT), follow centralized models that pose unresolved challenges, including concerns over data integrity, manipulation, and single points of failure. In practice, securing verified and confidential data within a supply chain is difficult, as it requires a high level of trust between collaborating entities and the creation and exchange of a specific amount of authenticated information (Özer, 2011). Experts in the field suggest that whenever intermediaries are needed to guarantee the quality and security of information in the supply chain, stakeholders are motivated to enhance transparency within the supply chains of different agricultural products (Lu & Xu, 2017). Thus, blockchain can function as a decentralized certification authority, validating transactions and delivering tamper-resistant, encrypted data to any point within the supply chain as needed (Lu & Xu, 2017).

The objective of this research, is to first extract the components of blockchain, supply chain, and customer satisfaction by studying library resources. Based on the extracted components, the initial research model is determined. Subsequently, a questionnaire is designed, according to the model and identified components, This is validated by experts,before being distributed among the statistical population.: This encompasses dairy supply chain members in

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Iran for the supply chain questionnaire, blockchain experts and specialists for the blockchain questionnaire, and dairy customers for the customer satisfaction questionnaire. The changes brought by blockchain implementation in the supply chain on customer satisfaction are then assessed by distributing these three questionnaires. Finally, the impact of integrating blockchain technology into the supply chain on customer satisfaction is quantified through the analysis of the collected data.

In the following sections of this paper, we first delve into the **Theoretical Foundations** (Section 2), exploring key concepts such as **Blockchain** (2.1) and its applications in the **Supply Chain** (2.2). Next, the **Literature Review** (Section 3) addresses the **Research Gap** (3.1), focusing on areas like the **Lack of Empirical Studies in the Dairy Industry** (3.1.1), the **Lack of Comprehensive and Multifaceted Models** (3.1.2), and the **Need for Practical Evaluations of Blockchain Impacts** (3.1.3), along with **Blockchain's Impact on Trust among Suppliers** (3.1.4) and the **Economic and Cost-Benefit Assessment** (3.1.5). The **Tools and Methods** (Section 4) detail the **Research Model** (4.1) and the **Data Analysis Method** (4.2). The **Findings** (Section 5) present the results, including the **Test for Normality of Data** (5.1) and the **Hypotheses under Investigation** (5.2). Finally, the **Conclusion** (Section 6) summarizes the key insights of the study and offers **recommendations for future research**, highlighting potential areas for further exploration such as cross-industry comparisons, long-term impacts of blockchain implementation, and broader empirical studies to enhance understanding of blockchain's role in supply chains.

2. Theoretical Foundations

Most conventional logistics information systems in agricultural and food supply chains (agri-food) primarily focus on storing orders and deliveries. However, there is a clear demand for these systems to incorporate additional functionalities such as transparency, traceability, and auditability. These features have the potential to enhance food quality and safety, making them increasingly sought after by consumers (C. Verdouw, 2013).Food holds special importance worldwide. Over the past few decades, customer trust in the food industry has been severely eroded by a series of incidents and scandals related to food safety risks. These include the outbreak mad cow disease, the introduction of genetically modified foods (Aung, 2014), the contamination of powdered milk with toxic substances, and the adulteration of cooking oil (Xiao, 2012). As a result, the rising consumer concerns about food safety and quality have attracted significant attention from both academic and industrial research. In response to the growing incidence of food safety issues, various IoT technologies, including architectures and hardware based on wireless sensor networks and RFID, have been employed for supply chain traceability and monitoring. However, a major unresolved issue remains whether the information exchanged among food supply chain participants in tracking systems can be trusted. Generally, depending on a single authoritative organization to manage all sensitive and valuable information necessitates a high level of trust (McConaghy, 2016).

Blockchain technology, which can eliminate the need for a central authority, may be a pivotal solution to these issues (Zhang, 2023). Blockchain technology has the potential to revolutionize multiple industries by facilitating secure, transparent, and decentralized transactions (Zhang, 2023). It can be used in agriculture to improve supply chain transparency and trace the origin, quality, and safety of products (Alandjani, 2023, February). In the electricity sector, blockchain can enable decentralized management, support peer-to-peer energy transactions, and lower transaction costs, thereby facilitating the integration of renewable energy sources and enhancing grid efficiency (Alandjani, 2023, February). In transportation, blockchain can enhance supply chain visibility, reduce fraud, and prevent unauthorized access to goods (Namasudra, 2023). Blockchain technology has garnered trust and is being utilized in various industries such as finance, real estate, healthcare, and cybersecurity (Angraal, 2017).

2.1 Blockchain

Blockchain can be described as a database that securely and permanently records transactions between parties [(DHL, 2018), (Science, 2016)]. Each block in the blockchain comprises three components: a hash, a time-stamped batch of recent valid transactions, and the hash of the preceding block. The hash function transforms input data into a fixed-length, seemingly random value (Ishii, 2017). It also includes a timestamp that serves to prove the data existed at the time it was recorded on the chain (Nakamoto, 2009). Essentially, it certifies that the data was recorded without cause and realistically. The previous block's hash links it to the subsequent blocks, preventing any alteration or insertion of new blocks between existing ones. Consequently, the subsequent block serves to corroborate the preceding block, thereby reinforcing the integrity of the entire blockchain (Nakamoto, 2009).

2.2 Supply Chain

Supply chain management is a set of activities where efforts are made to integrate service providers, producers, warehouses, and retailers in order to ensure the optimal production of goods and their timely delivery to the appropriate locations. Furthermore, the performance of these activities while ensuring customer satisfaction also leads to minimal costs (Gatora, 1995). The supply chain (SC) is a network of organizations and individuals that are directly or indirectly involved in creating value for the customer (Chopra, 2007). In summary, the supply chain can be defined as a system comprising organizations, individuals, activities, information, and resources engaged in the flow of a product or service from the initial supplier to the end customer (Nations, 2015). The Fourth Industrial Revolution has introduced transformative changes to production and service processes, significantly affecting supply chain solutions (Humski, 2022).

3. Literature Review

Shanahan et al. (2009) emphasized that the effectiveness of a tracking system relies on its capacity to trace individual products and logistical units, allowing for ongoing monitoring from initial production through to the final disposal by the consumer (Shanahan, 2009).

In 2011, Brave conducted a study to demonstrate the impact of supply chain agility on customer satisfaction. This paper presented an interpretive structural model to improve the relationships between variables and discussed the variables and their managerial implications. The main variables of this research included: organizational integration and willingness to improve, outsourcing, collaborative relationships, reduction of supply chain lead time, information sharing and trust, system flexibility, sensitivity and responsiveness to customers, customer satisfaction, senior management commitment, cost, and service quality (Barve, 2011).

In 2014, Rahman conducted research to examine the impact of quality on customer satisfaction. He collected 282 structured questionnaires, and the data analysis indicated that service innovation, service reliability, service competitiveness, and service consistency have significant effects on customer satisfaction. In contrast, pricing, supply, meeting customer demand, value-added services, and brand value showed minimal effects on customer satisfaction. Additionally, the research showed that more attention should be paid to factors with minimal impact on customer satisfaction)Rahman, 2014(.

In 2017, Kouh et al. pointed out that the implementation of digital technologies in the supply chain can improve supply chain performance. Blockchain is an enabling technology with the most significant impacts, especially when combined with technologies like the Internet of Things, robotic diagnostic automation, or smart devices. This paper discussed how block chain affects the supply chain in terms of traceability, adaptability, flexibility, and stakeholder management. It examined examples in the pharmaceutical industry regarding product tracking, the automotive industry regarding purchasing platforms, and the food industry in terms of supplier recognition, and reviewed the weaknesses of the supply chain in terms of traceability, adaptability, flexibility, and stakeholder management, and proposed block chain-based solutions for each (L Kehoe, 2017).

In 2020, Xing et al. in their article explored the use of blockchain technology in the dairy sector. Their research focused on how blockchain can enhance the dairy supply chain system, highlighting potential benefits such as: 1) more effective communication between suppliers, 2) improved producer control and traceability within the supply chain, 3) increased producer efficiency, and 4) the demonstration of producer goodwill to various stakeholders and the dairy industry as a whole)Shuvam Shingh, 2020(. This review article relies on secondary data and information obtained from a range of published sources.

Blockchain technology has the potential to enhance the dairy supply chain system in multiple ways. First, it can facilitate more effective communication between suppliers, allowing for better coordination and collaboration (Kumar, 2023). Second, it enables producer oversight of the supply chain and its traceability, ensuring transparency and accountability (Bosona, 2023). Thirdly, it can enhance producer efficiency by streamlining operations and reducing inefficiencies (Yogarajan, 2023). Finally, using blockchain technology in the dairy industry can demonstrate the producer's goodwill to various stakeholders and industry as a whole, as it promotes transparency, traceability, and adherence to quality standards (Nadime, 2023, May).

In 2021, Francesco et al. (Marco Francesco, 2021), in their article analyzed 310 grocery stores in Germany, Italy, and the United Kingdom. This study examined the effects of verified technology information in animal milk on customer

expectations of taste and health, discovering similarities and differences among the three countries in the milk group. While significant differences in health were observed between the control and experimental groups, the results indicated that individuals exposed to verified blockchain information tended to make different evaluations of the perceived taste of animal milk, with no significant overall taste difference between the control group and the experimental group. These findings underscore the advantages of blockchain technology when used as a certification protocol for product and processing attributes.

1.3 Research Gap

Given the critical role of the dairy industry in food provision and its direct impact on public health, enhancing the efficiency and transparency of the supply chain for dairy products is essential. Blockchain technology represents an innovative solution that can significantly improve both transparency and efficiency within the supply chain. Despite the considerable number of studies on the application of blockchain in supply chains in recent years, there remain significant research gaps that need to be addressed. The following section outlines these research gaps in detail.

1.1.3 Lack of Empirical Studies in the Dairy Industry

Most existing research on blockchain and supply chains has concentrated on industries such as pharmaceuticals, automotive, and general food products. There is a notable lack of studies specifically investigating the application of blockchain within the dairy supply chain. Limited research has focused on the dairy sector and the impact of blockchain technology on it. Consequently, further investigation is required to thoroughly evaluate the benefits and challenges of implementing blockchain in the dairy industry**.**

2.1.3 Lack of Comprehensive and Multifaceted Models

Previous studies have mostly focused on a limited number of aspects of blockchain applications in the supply chain. For instance, some researches have only examined the impact of blockchain on transparency or product traceability, while other aspects such as agility, flexibility, and supplier interaction have received less attention. There is a need for a comprehensive and multifaceted model that considers all these aspects and analyzes the relationships between them.

3.1.3 Need for Practical Evaluations of Blockchain Impacts

Although the theoretical benefits of blockchain in the supply chain and case studies have been widely discussed, practical and empirical evaluations of its actual impact on supply chain efficiency and customer satisfaction are limited. Many studies have depended on secondary data and theoretical analysis, with few examining real-world empirical data. Consequently, there is a significant need for research utilizing actual data to assess the impact of blockchain implementation.

4.1.3 Examination of Blockchain's Impact on Trust among Suppliers

One of the major challenges in the supply chain is establishing trust among suppliers. Previous research has shown that blockchain can enhance trust among suppliers through increased transparency and traceability. However, more detailed studies are needed to examine how and to what extent blockchain affects trust among suppliers in the dairy supply chain.

5.1.3 Economic and Cost-Benefit Assessment

Few studies have assessed the economic implications and cost-benefit analysis of implementing blockchain in the dairy supply chain. Although blockchain has significant potential to improve efficiency and reduce costs, the initial implementation and maintenance costs must also be considered. Research that accurately evaluates the costs and economic benefits of this technology can help decision makers implement blockchain with a more comprehensive view.

6.1.3 Conclusion

This research seeks to address the identified gaps by offering a thorough and scientific analysis of the impact of blockchain implementation on the dairy supply chain. Through empirical analysis and modeling, the study aims to provide new insights into the field. The findings could enhance the efficiency and transparency of the dairy supply chain, boost customer satisfaction, and serve as a valuable reference for future research in this area**.**

4. Tools and methods

In this study, various components of blockchain and supply chain, as well as customer satisfaction factors, were extracted through the examination of various sources. Subsequently, a suitable model for the research was extracted based on the extracted components. Three questionnaires were designed based on the model and components, and after validation by experts to confirm the validity of the questionnaires, three questionnaires were distributed to the statistical community. Finally, the collected data were analyzed using SPSS and SmartPLS software, and the proposed model was evaluated.

The research method is applied in terms of purpose, as the result of this research helps consumers of dairy products to make better decisions with more knowledge about the quality and price of dairy products resulting from greater transparency in the supply chain. This will increase producers' responsiveness to consumers, ultimately leading to increased customer satisfaction with dairy products. Additionally, the results of this research can increase trust among supply chain members, the main reason being transparency in data exchange between them.

In terms of methodology, this research is descriptive and the choice of research method depends on the nature of the research objectives. Depending on the nature of the research tool for collecting information, both library and field methods were used. Theoretical and theoretical research information was collected by studying of previous books and research and through sampling, and information related to the relationship between factors affecting customer satisfaction in the supply chain and blockchain was collected through field method using questionnaires.

4.1 Research Model

The research model, which was extracted and designed by studying and reviewing multiple sources and identifying components related to the subject - listed along with their sources in Table 1 - is shown in Figure 1.

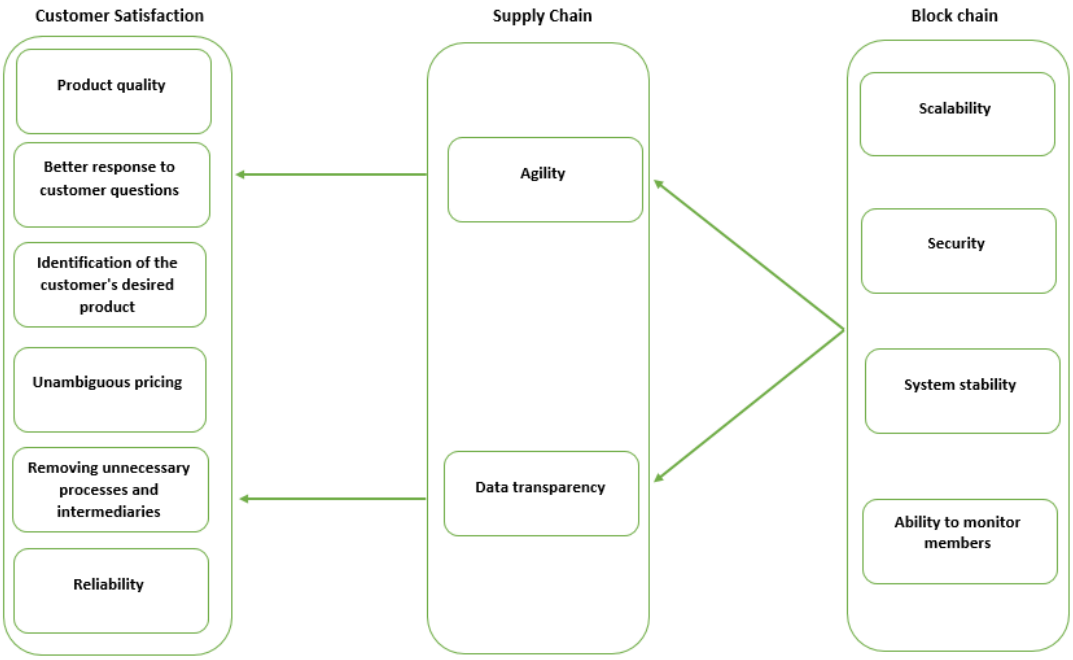

Figure 1. Final Research Model

Table 1. Components Used in the Model Along with Their Sources

Variable name	Source
Scalability	(JaeShup Oh, 2017)
security	(Hany. Hanna, 2020) , (JaeShup Oh, 2017)
System stability	(JaeShup Oh, 2017)
Ability to monitor members	(JaeShup Oh, 2017)
Agility	(Barve, 2011)
Data transparency	(L Kehoe, 2017)
Product quality	(Osayuwamen Omoruyi, 2016)
Better response to customer questions	(Sunil Chopra, 2000)
Identification of the product desired by the customer	(Sunil Chopra, 2000)
Unambiguous pricing	(Rahman, 2014)
Removing unnecessary processes and intermediaries	(Sunil Chopra, 2000)
Reliability	(Rahman, 2014)

This study employs a simple random sampling method. Given that the study uses Structural Equation Modeling (SEM), selecting the sample size is important. Since SEM is quite related to multivariate regression in some aspects, a minimum of 4 cases per measured variable in SEM is reasonable. Therefore, in this study, considering the number of observed variables, which are 29 for blockchain, 17 for the supply chain, and 41 for customer satisfaction, the minimum sample size for the blockchain questionnaire should be 116 = 4×29, for the supply chain 68 = 4×17, and for customer satisfaction 164 = 4×41. Also, using the Cochran formula for an unknown population size, the minimum sample size is 384. Consequently, in this study, a sample of 435 consumers, 435 producers and distributors of dairy products, and 435 experts knowledgeable about blockchain was used to estimate the model with minimal error.

Since the variance of the statistical population was unknown in this study, a preliminary study on a group of individuals from the population was necessary to pre-estimate the sample variance. Therefore, a group of 38 individuals from each population was randomly selected, and the questionnaires were distributed among them. After extracting data related to the responses of this group, considering the sample size of 435 and with an error of less than 5%, the questionnaire was distributed to the statistical population.

The sampling was conducted through convenience sampling from the statistical population. The sample size evaluated in this study was 1530 people, and this number of questionnaires was distributed. Finally, some samples were excluded due to insufficient data and not meeting the inclusion criteria, and in total, data from 435 respondents were analyzed for each questionnaire.

In this study, three closed-ended questionnaires were used to collect data for hypothesis analysis and model testing. A five-point Likert scale (ranging from strongly disagree to strongly agree) was used to measure and capture opinions. The conceptual model of the research, extracted based on the research objectives, was the basis for designing the questionnaire questions. The research model consists of three parts: customer satisfaction, supply chain, and

blockchain, for which indicators were identified by extracting from scientific sources and validation by experts and elites. The questions were designed based on these indicators to fully cover the research variables and their interrelationships. In other words, the questionnaire aims to collect data that will lead to the validation of the research.

4.2 Data Analysis Method

Data analysis was performed using SMART PLS and SPSS software at both descriptive and inferential statistical levels. At the descriptive statistics level, statistical measures such as frequency, mean, percentage, variance, and standard deviation were used. At the level of inferential statistics level, correlation coefficient, analysis of variance (ANOVA), multiple regression, structural equation modeling (SEM) using SMART PLS software, and the partial least squares (PLS) method were used.

5. Findings

The data obtained from the questionnaires were analyzed using Excel, SPSS, and Smart PLS software. Initially, preprocessing and data cleaning were performed, and the data were entered into the software in named columns. The relevant tests were then applied to the data.

1. Test for Normality of Data

Depending on the nature and type of data, parametric and non-parametric tests can be used to examine relationships between variables. If the data are normal, both parametric and non-parametric tests can be used, but if the data are not normal, only non-parametric tests can be used. The Kolmogorov-Smirnov test for normality showed that the distribution of the collected data for all components and dimensions followed a non-normal distribution. As a result, non-parametric methods such as the Spearman correlation and partial least squares (PLS) methods were used in the study.

2. Hypotheses under Investigation

2.1. Conducting Statistical Tests on the Data

To fit the conceptual model, both the Spearman correlation and Smart PLS software were used. The coefficients in the Pearson correlation and the path coefficients in Smart PLS range from -1 to +1, with values closer to +1 and -1 indicating greater influence. For greater confidence, the study's hypotheses were examined using multiple methods:

2.1.1. Hypothesis 1: Implementing blockchain increases transparency in the supply and distribution chain of dairy products.

Using Smart PLS software, the fitted model for this hypothesis is shown in Figure 2.

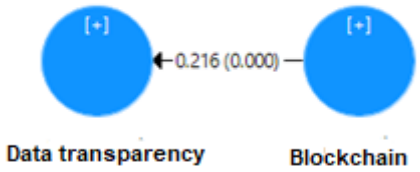

Figure 2. Implemented model in Smart PLS software for the first hypothesis

The regression coefficient, or path coefficient, between blockchain and data transparency is +0.216, suggesting a positive impact of blockchain implementation on data transparency within the supply chain. With a p-value of 0.000, which is less than 0.05, this indicates a statistically significant relationship between blockchain and data transparency. Thus, the first hypothesis is supported

2.1.2. Hypothesis 2: Implementing blockchain increases the agility of the supply and distribution chain of dairy products.

This hypothesis was examined using the Spearman correlation coefficient in SPSS software. The implemented model is shown in Figure 3.

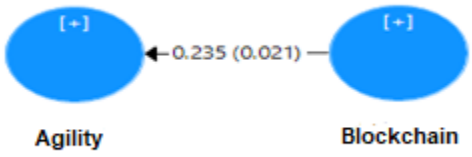

Figure 3. Implemented model according to the second hypothesis based on the Spearman correlation

The Spearman correlation coefficient for the impact of blockchain on supply chain agility is +0.277, with a significance value of 0.005, which is below the 0.05 threshold, indicating a significant relationship. The positive coefficient (+0.277) suggests that as blockchain capabilities increase, so does agility in the supply chain. Therefore, the second hypothesis is confirmed

2.1.3. Hypothesis 3: Transparency in the supply chain of dairy products improves customer satisfaction with these products.

This hypothesis was examined using the Spearman correlation coefficient in SPSS software. The implemented model is shown in Figure 4.

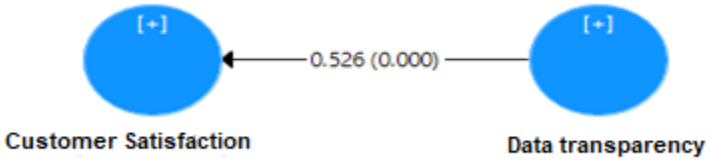

Figure 4. Implemented model according to the third hypothesis based on the Spearman correlation

The Spearman correlation coefficient for the impact of data transparency on customer satisfaction is +0.569, with a significance value of 0.000, which is below the 0.05 threshold, indicating a significant relationship. The positive coefficient (+0.569) demonstrates a positive correlation between data transparency in the supply chain and customer satisfaction. Consequently, as data transparency increases, so does customer satisfaction. Therefore, the third hypothesis is confirmed.

2.1.4. Hypothesis 4: Agility in the supply chain of dairy products improves customer satisfaction with these products.

Using Smart PLS software, the fitted model for this hypothesis is shown in Figure 5.

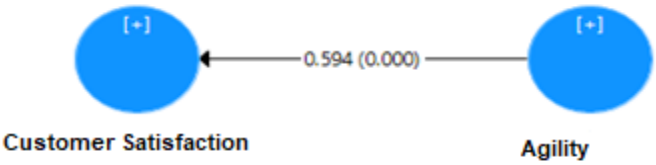

Figure 5. Fitted model for the fourth hypothesis in Smart PLS software

The path coefficient, or regression coefficient, between agility and customer satisfaction is +0.594, indicating a positive relationship between the two. With a p-value of 0.000, which is less than 0.05, this signifies a statistically significant relationship. Therefore, the fourth hypothesis is confirmed.

2.1.5. Hypothesis 5: Using blockchain in the supply chain of dairy products improves customer satisfaction with these products.

The final model based on the partial least squares method in Smart PLS software is shown in Figure 6.

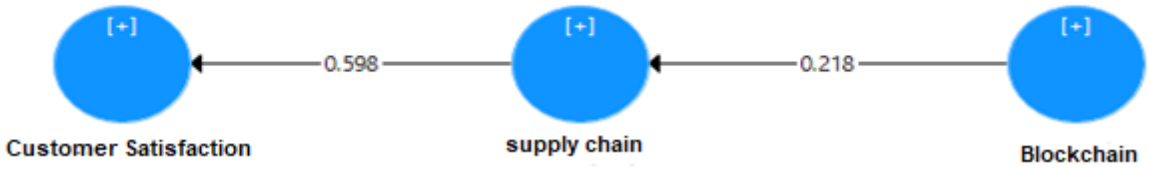

Figure 6. Fitted model in Smart PLS software

The path coefficient, or regression coefficient, between blockchain and the supply chain is +0.218, and between the supply chain and customer satisfaction is +0.598. This indicates a significant positive impact of blockchain on the supply chain, and in turn, a positive impact of the supply chain on customer satisfaction.

In the first step, hierarchical multiple regression, controlling for blockchain, explained 54.2% of the variance in customer satisfaction. With the inclusion of blockchain in the model, the explained variance in customer satisfaction increased to 58.9%.

Table 2. Results of the fifth hypothesis test

model	R Square	change R Square	Significance of the model
1-Supply chain	0.542	0.542	0.000
2-Supply chain+ Blockchain	0.589	0.047	0.012

According to the obtained results, blockchain has a significant impact on customer satisfaction, independently explaining 4.7% of the variance in customer satisfaction. Therefore, the fifth hypothesis is confirmed.

Table 3. Results of hypotheses

hypothesis	theories	Relationship Analysis
1	*Blockchain implementation creates transparency in the supply chain and distribution of dairy products.*	Positive and meaningful
2	The implementation of blockchain makes the supply chain and distribution of dairy products more agile.	Positive and meaningful
3	Transparency in the supply chain of dairy products improves customer satisfaction of these products.	Positive and meaningful
4	The agility of the supply chain of dairy products improves the customer satisfaction of these products.	Positive and meaningful
5	The implementation of blockchain in the supply chain of dairy products improves customer satisfaction of these products.	Positive and meaningful

To determine the impact of each component related to the dimensions of the supply chain and blockchain on customer satisfaction, the standardized beta coefficient (Beta) is used. The results for this coefficient are shown in Figure 7.

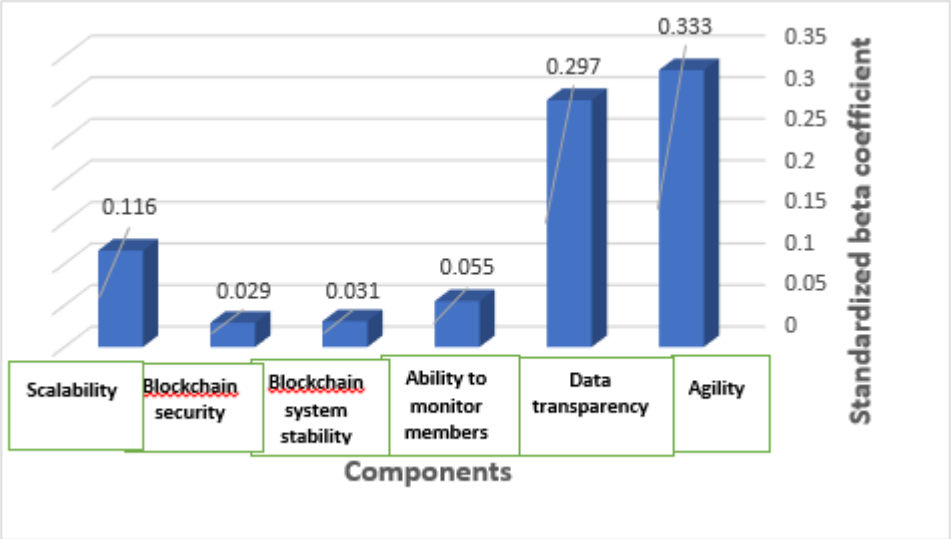

Figure 7. Chart showing the contribution of each component in predicting customer satisfaction

Agility with 0.33 and data transparency with 0.297 have the greatest impact on customer satisfaction compared to other components.

6. Conclusion

Since the 20th century, the reliance of businesses on supply chains has increased. Supply chains have become a critical business process that can enhance the competitiveness of businesses in the marketplace. Logistics plays a significant role in achieving effective value propositions for customers. However, most traditional information systems in agricultural and food supply chains (agri-food) mainly focus on tracking and storing orders and deliveries, lacking key features like traceability and transparency. Enhancing transparency can lead to improved food quality and safety.

Over time, organizations face changing environments and customers and stakeholders with new demands. To sustain their existence and durability, organizations must appropriately respond to these changes. The food industry, including the dairy sector, is no exception. A key area undergoing change in the food industry, particularly in the dairy industry, is the supply chain. There is a need for new and efficient approaches to managing it.

One of the emerging technologies is blockchain, a distributed ledger that provides access to data and information for all participants within this ledger. It enhances user control and distributes data control and flow from a central core throughout the entire chain. Blockchain can be applied in various industries for different purposes, one of which is the dairy sector. Blockchain can be implemented in the dairy supply chain to enhance information flow and boost consumer oversight and confidence in products. Therefore, this study aims to examine the impact of blockchain implementation and usage in the supply chain on customer satisfaction within the dairy industry.

The results of the study's hypotheses indicate that blockchain has a significant positive impact on both transparency and agility within the supply chain. Dairy organizations can adopt blockchain technology to enhance their logistics and supply chain, with a particular focus on improving transparency and agility. Additionally, given the positive and significant impact of transparency and agility on customer satisfaction—an essential factor for organizations, especially in competitive industries like the food sector, and particularly in the dairy industry—organizations can prioritize implementing and enhancing transparency and agility in the supply chain to boost customer satisfaction. Finally, to enhance customer satisfaction with dairy products, organizations in the dairy industry can implement blockchain in their supply chain and benefit from its advantages.

Supply chains, particularly in the dairy industry, often operate under fluctuating market demands, regulatory changes, and unpredictable disruptions (e.g., pandemics, supply shortages). Blockchain's effectiveness in such **uncertain environments** remains an underexplored area. Future studies should investigate how blockchain can adapt to or mitigate risks in **volatile supply chain conditions**, such as sudden shifts in consumer preferences, economic instability, or logistical challenges. Additionally, exploring **real-time data management** in these conditions could provide insights into how blockchain technology helps organizations remain agile and responsive while maintaining customer satisfaction. Addressing uncertainty would contribute to a more **holistic understanding** of blockchain's long-term potential and resilience in dynamic supply chains.

For future research on the impact of blockchain implementation on enhancing customer satisfaction in organizational supply chains, especially within the dairy industry, several key areas offer valuable opportunities. Researchers could explore cross-industry comparisons to determine whether blockchain's effects on customer satisfaction vary between different sectors beyond dairy. Additionally, examining the long-term impacts of blockchain integration, particularly on sustainability and traceability, could provide a more comprehensive understanding of its benefits. Future studies should also focus on empirical investigations involving larger datasets and diverse geographic regions to increase generalizability. Lastly, exploring how blockchain can facilitate collaborative relationships among suppliers, manufacturers, and consumers through enhanced transparency and trust would provide further insights into its potential.

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