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BLOCKCHAIN-BASED E-COMMERCE MARKETING STRATEGY FOR AGRICULTURAL SUPPLY CHAIN

YINGZI XU* AND LI YU†

Abstract. The application of blockchain technology into e-commerce marketing techniques within the agricultural supply chain is investigated in this study. Given the volatility and complexity of agricultural markets, creative techniques to ensuring the authenticity, traceability, and efficiency of these systems are urgently needed. Blockchain offers a decentralized and transparent approach, ensuring data integrity and building trust among stakeholders. We analyze the potential of blockchain to revolutionize e-commerce practices by enabling smart contracts, real-time data access, and immutable records, which can lead to cost savings, reduced fraud, and enhanced marketing capabilities. Through case studies and modeling, we demonstrate how blockchain can be leveraged to create a seamless farm-to-table journey, empowering farmers, distributors, and consumers. Our strategic framework provides actionable insights for practitioners to capitalize on blockchain's capabilities, fostering sustainable growth in the agricultural sector. This study contributes to the literature by bridging the gap between blockchain technology and e-commerce marketing, offering a comprehensive strategy for the agricultural supply chain's advancement.

Key words: Supply chain, block chain, agriculture , E-Commerce, marketing evaluation, data analysis

1. Introduction. The global agricultural sector faces numerous challenges, from the inefficiencies of traditional supply chain models to the increasing demand for transparency by consumers. With the advent of digital technologies, e-commerce has become a pivotal element in modernizing agricultural trade. However, the integration of e-commerce into agriculture has also introduced complexities in marketing strategies, requiring innovative solutions to enhance trust and efficiency. Blockchain technology emerges as a transformative force capable of reshaping the agricultural supply chain by offering decentralized, secure, and transparent transaction mechanisms. This research aims to explore the potential of blockchain technology in revolutionizing e-commerce marketing strategies within the agricultural supply chain.

Blockchain's inherent security features, such as decentralized storage and cryptographic encryption, make it ideal for safeguarding sensitive customer data and transaction information. This can significantly reduce the risk of data breaches and fraud. Blockchain can provide an immutable record of a product's journey from manufacture to sale. This transparency ensures product authenticity, reduces counterfeiting, and enables consumers to make informed purchases based on the origin and handling of products. Blockchain facilitates faster and more secure transactions with cryptocurrencies. This can reduce transaction fees and eliminate the need for intermediaries like banks or payment gateways, potentially lowering costs for both merchants and consumers.

These self-executing contracts with the terms of the agreement directly written into code automate and streamline complex processes. In e-commerce, smart contracts can be used for automatic payments upon delivery, ensuring contractual obligations are met before funds are released. Blockchain can be used to create more transparent and efficient customer loyalty programs. Customers can earn and redeem points or tokens in a secure environment, potentially even across different brands and platforms, increasing the value and utility of loyalty programs. Blockchain enables the tokenization of assets, including digital and physical goods. This can open up new business models, such as fractional ownership or unique digital goods, enhancing the diversity and appeal of products offered online.

Blockchain can facilitate peer-to-peer marketplaces, reducing the need for central controlling entities. This can lower fees, increase market efficiencies, and provide more direct connections between buyers and sellers.

*Qingyuan Polytechnic, Qingyuan, 511510, China (yingzixuinsi@outlook.com)
†Qingyuan Polytechnic, Qingyuan, 511510, China

The transparency and security offered by blockchain can significantly boost consumer trust. Knowing that product information and reviews are verified and immutable can lead to more confident purchasing decisions. Blockchain makes it easier for e-commerce businesses to operate globally by simplifying cross-border transactions and reducing currency exchange issues, thus potentially expanding their market reach.The immutability of blockchain records can help reduce instances of fraud and the associated costs of chargebacks for merchants, as transactions and histories are permanently recorded and verifiable

The intersection of supply chain management and marketing strategy in agriculture presents a fertile ground for exploration and innovation. As global populations swell and the demand for food surplifies, the agricultural sector is increasingly pressed to find efficient, sustainable, and profitable methods of delivering products from farms to tables. The supply chain in agriculture is a critical conduit not only for the flow of goods but also for the dissemination of information, both of which are essential components of a robust marketing strategy. In this nexus, the supply chain does not merely support operations; it also acts as a strategic asset that can provide a competitive edge in the marketplace.

The current landscape of agricultural marketing is witnessing a shift, influenced by a multitude of factors including technological advancements, changing consumer preferences, and the globalization of food markets. Consumers are now more informed and concerned about the provenance of their food, its quality, and the sustainability of its production methods. Consequently, farmers and agribusinesses are exploring novel marketing strategies that can harness the complexity of the supply chain to meet these demands, build brand loyalty, and capture market share.

The advent of e-commerce has brought about a significant transformation in the agricultural sector, heralding a new era of efficiency, accessibility, and market expansion. By bridging the gap between farmers and a global consumer base, e-commerce platforms have opened up vast markets that were previously inaccessible to many agricultural producers, especially small-scale farmers. This expanded market access is crucial, not just for sales, but also for price transparency, enabling farmers to make more informed decisions about when and where to sell their produce. Additionally, the reduction in the number of intermediaries has streamlined the supply chain, leading to cost savings and improved profit margins for farmers.

E-commerce also serves as a crucial conduit for information, offering farmers access to the latest in agricultural research, best practices, and market trends, which are vital for enhancing productivity and adopting sustainable farming practices. Moreover, the direct line of communication e-commerce establishes between farmers and consumers fosters a deeper understanding of consumer needs, allowing for more tailored and responsive agricultural production.

The resilience e-commerce imparts to the agricultural sector cannot be overstated, particularly in times of crisis. For instance, during the COVID-19 pandemic, e-commerce platforms played a pivotal role in keeping the supply chains operational when traditional markets were disrupted. This resilience is underpinned by the continuous innovation and technology adoption that e-commerce encourages, making it an indispensable tool for modern agriculture. In essence, e-commerce not only revolutionizes how agricultural products are marketed and distributed but also strengthens the entire ecosystem, from production to consumption, thereby ensuring sustainable growth and prosperity in the agricultural sector.

1.1. Objectives. The primary objectives of this research are to:

1. Analyze the current challenges and limitations of e-commerce marketing within the agricultural supply chain.
2. Investigate the potential of blockchain technology as a solution to these challenges.
3. Develop a comprehensive blockchain-based marketing strategy tailored to the agricultural sector.
4. Evaluate the efficacy and practicality of implementing a blockchain-based marketing strategy in real-world agricultural supply chain scenarios.

1.2. Research Questions. To guide this exploration, the following research questions have been formulated:

1. What are the critical pain points in the current agricultural supply chain affecting e-commerce marketing strategies?
2. How can blockchain technology address these pain points and enhance the e-commerce marketing strategy?

3. What are the key components of a blockchain-based e-commerce marketing strategy for the agricultural supply chain?

Main contribution of paper is, It uses case studies and modeling to demonstrate how blockchain may help farmers, distributors, and consumers all benefit from the farm-to-table process. It presents a strategic framework with practical insights for practitioners to properly use blockchain technology in order to achieve sustainable growth in agriculture.

2. Related work. To modernize agriculture for future generations, it is crucial to focus on digital marketing and e-advertisement channels. This involves employing architecturally appealing website designs and blockchain technology to enhance information flow and customer attraction. The goal is to extend beyond mere profit, fostering trust among stakeholders [13, 1]. Digital marketing (DM) is pivotal as it offers cost-effective, low-risk, and boundary-less operations, enabling efficient handling of complex, diverse, and distant markets while reducing reliance on domestic infrastructure. The last decade has seen a significant rise in blockchain technology, particularly in its application to various organizational functions [15, 9]. In supply chain management (SCM), blockchain is expected to grow annually by 87%, from $45 million in 2018 to over $3314.6 million in 2023. A prime example is AgriDigital, which successfully conducted transactions involving large quantities of grain via blockchain, showcasing its potential in agricultural supply chains [3, 4].

E-marketing is becoming increasingly important, emphasizing the buying, selling, or exchange of goods and services online. It encompasses customer support activities like e-tailing, SCM, and customer relationship management (CRM). Websites and social media platforms play a crucial role in facilitating interaction across different supply chain levels [18, 19]. Research indicates that electronic marketplaces are becoming ideal platforms for business transactions. Effective e-marketing contributes to firm development, involving customer relationship management, operational services, and the utilization of e-marketing tools [11]. Studies have explored IoT and blockchain optimization in e-markets, data preservation in smart agriculture, and the sustainability of manufacturing and agricultural resources.

Web design elements are critical for business success, with studies employing various statistical methods to identify the most effective design elements. Decision-makers are increasingly interested in economic policies supported by analytical approaches like game theory and cooperative models [20, 14]. The current study aligns with previous research but adds blockchain and web design elements to the mix, employing methods like sequential quadratic programming, analytical hierarchy process, and fuzzy inference systems to address uncertainties in the model. Research has delved into decision-making within e-market supply chains, utilizing approaches like game theory and Stackelberg–Nash equilibrium. These studies, including those by Esmaeili et al., have focused on elements such as vendor-managed inventories, retailer information, pricing, and cooperation strategies between sellers and buyers, often in the context of competitive advertising [10, 7].

Pricing strategies are crucial in sustaining supply chains. Works by Cai et al. and others have explored pricing policies, particularly price discounting in dual-channel supply chains. Alongside pricing, maintaining an effective ordering policy is key to retaining customers. This aspect has been studied in the context of Business-to-Business markets, where factors like order quantities, price breaks, lot sizing, and discounts are significant decision variables. Additionally, supplier selection has been highlighted as a vital component for sustainable supply chain management [5, 17]. Despite the growing importance of digitalization and e-marketplaces, advertising remains a critical factor. Recent research has focused on cooperative advertising strategies in the manufacturer-retailer channel, where manufacturers may cover all or part of a retailer's advertising expenses. This collaboration aims to boost immediate demand in the supply chain. However, despite significant investments in advertising (e.g., $15 billion in the USA in 2000), many companies still rely on heuristic methods like the rule of thumb or best guesses to determine their contribution rates, often without in-depth analysis of whether to contribute 50% or 100% [12, 8].

3. System model. The objective of this study is to evaluate the effectiveness of blockchain technology in enhancing the regulation of freshness-keeping activities in a fresh agricultural product supply chain, consisting of a supplier and an E-commerce platform (retailer). This research employs a comparative analysis design, examining both traditional and blockchain-based fresh agricultural product supply chains. The study focuses on the dynamic optimization of freshness-keeping effort, advertising effort, and the degree of blockchain adoption.

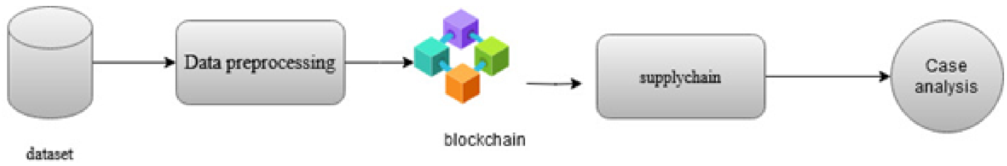

Fig. 3.1: Proposed Basic Model

3.1. Supply chain models. Traditional model represents the conventional operations of a fresh agricultural product supply chain. It focuses on the traditional interactions between the supplier and the retailer, without the integration of advanced technology like blockchain. Responsible for the production and initial handling of fresh agricultural products. Their primary roles include ensuring the initial quality (greenness) of the product and initiating the first phase of freshness-keeping efforts. Takes over the products for wholesale and sales. The retailer's responsibilities include managing the supply chain logistics from the point of receiving the products to delivering them to consumers. The retailer also decides on and implements advertising efforts to boost sales [16, 2].

In the traditional model, the continuity of freshness-keeping efforts by the supplier after the sale to the retailer is uncertain. This uncertainty often results in the degradation of product quality during transit and storage. Green investment refers to the initial quality assurance measures taken by the supplier. This investment is crucial but might not guarantee product freshness throughout the supply chain due to the lack of ongoing effort in maintaining freshness post-sale. Information Asymmetry **is** a key characteristic of the traditional model is the lack of transparency between the supplier and retailer, and subsequently, to the consumer. This asymmetry often leads to a gap in monitoring and ensuring product quality throughout the supply chain [6].

3.2. Blockchain Model. This model integrates blockchain technology into the supply chain, aiming to enhance transparency, traceability, and efficiency.

Blocks creation: When a user initiates a transaction, such as sending cryptocurrency, creating a record, or executing a smart contract, the transaction data is created. This data typically includes the sender's and receiver's information, the amount or nature of the transaction, and a timestamp. Before a transaction can be added to a block, it must be verified. This verification process depends on the blockchain's protocol. In a cryptocurrency context, this could involve checking that the sender has the necessary funds or rights to make the transaction.

Verified transactions are pooled together in a memory pool, also known as a mempool. Here, they wait to be picked up by a miner or validator to be included in a new block. Miners or validators (depending on the blockchain's consensus mechanism) select transactions from the mempool. They then use these transactions to create a new block. A block is essentially a data structure that packages a set of valid transactions along with other crucial information. A vital step in block creation is computing the block's hash. A hash is a fixed-length alphanumeric string derived from the block's data through a cryptographic hash function. Each block also contains the hash of the previous block, creating a linked chain of blocks. This linkage is what makes the blockchain secure and tamper-evident.

To add the block to the blockchain, miners (in a Proof of Work system) must solve a complex mathematical puzzle, which requires computational power. The first miner to solve the puzzle gets the right to add the new block to the blockchain. In a Proof of Stake system, validators are chosen to create new blocks based on various factors, including the amount of cryptocurrency they hold and are willing to ”stake” as collateral. Once the mathematical puzzle is solved (in PoW) or a validator is chosen (in PoS), the new block is added to the blockchain. This addition is broadcast to all nodes in the network for verification. Once other nodes validate the block and its hash, the block becomes an official part of the blockchain. As an incentive, miners or validators receive a reward for their work in creating a new block. In the case of cryptocurrencies like Bitcoin, this reward comes in the form of newly minted coins and transaction fees.

3.2.1. Blockchain Integration. Blockchain technology provides a decentralized ledger that records every transaction or movement of the product in real-time. This feature allows all parties in the supply chain to track the product's journey and quality measures taken at each stage. The use of smart contracts in blockchain can automate certain processes, such as payments and compliance verification, based on pre-set conditions being met, like maintaining specific freshness levels.

Apart from the initial greenness investment, the supplier is encouraged to continue the freshness-keeping efforts even after the sale, as blockchain technology allows for the tracking and verification of these efforts. Retailer areresponsible for determining the degree of blockchain adoption in the supply chain and managing the advertising efforts. The retailer can utilize the data from the blockchain to make informed decisions and enhance consumer trust.

Blockchain technology incentivizes the supplier to maintain freshness-keeping efforts throughout the supply chain, as these efforts are recorded and verifiable. The initial quality assurance measures are supported by the continuous tracking and maintenance of quality, ensuring that the greenness investment yields its intended benefits. The blockchain model aims to reduce costs associated with quality degradation and returns. The increased efficiency and reduced losses from spoiled goods can lead to improved profitability for both suppliers and retailers.

In summary, the traditional model is characterized by information asymmetry and potential lapses in freshness-keeping post-sale, while the blockchain model introduces transparency and traceability, incentivizing continuous quality maintenance and potentially transforming the efficiency of the supply chain.

3.2.2. Model Development. Traditional Model outlines the operations in the conventional supply chain, focusing on the roles and responsibilities of the supplier and retailer, and the dynamics of freshness-keeping and greenness investment. Blockchain Model incorporates blockchain technology into the supply chain model, examining its impact on transparency, freshness-keeping, and the overall efficiency of the supply chain.

Decision variables determines the degree of blockchain adoption and advertising efforts. Supplier decides on the greenness investment and freshness-keeping efforts. Analysis of how these efforts are sustained or abandoned in both supply chain models.

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4. Simulation on data collection and analysis. Use of simulation software to model both traditional and blockchain-based supply chains, observing the behavior of the supplier and retailer under different scenarios.

Simulation of different levels of blockchain adoption and its impact on supply chain dynamics.

We analyse the solutions for following scenario,

1. Examination of real-world applications of blockchain in cold chain logistics for fresh agricultural products.
2. Comparative analysis of case studies where blockchain technology is employed versus traditional methods.
3. Use of optimization and econometric tools to analyze the dynamic optimization of decision variables.
4. Application of statistical methods to validate the effectiveness of blockchain technology in various settings.

4.1. Experimental Settings. Creation of different scenarios to analyze the effectiveness of blockchain technology in maintaining freshness. Identification of specific settings where blockchain is effective and where it is not suitable. Comparison of results between the traditional and blockchain-based supply chains are analysed. Assessment of the impact of blockchain adoption on freshness-keeping effort, advertising investment, goodwill, profit margin levels, and greenness investment decision.

4.1.1. Ethical Considerations.

1. Ensuring the confidentiality and privacy of data sourced from case studies and simulations.
2. Adherence to ethical standards in simulation modeling and data handling.

The significance of e-advertising and digital marketing in securing a competitive edge, especially in the agricultural product processing sector, cannot be overstated. The Supply Chain Management (SCM) model proposed in this study is framed as a complex non-linear maximization challenge, encompassing various variables and constraints. Initially, solutions to such constrained problems were sought by transforming them into unconstrained problems to find the global optimal solution. However, this method was found to be relatively inefficient and has since been replaced by techniques based on Inter point methods (IPM) equations. IPM equations are instrumental in providing conditions for optimizing constrained problems and offer solutions to numerous nonlinear challenges by directly calculation. These methods fall under the category of sequential quadratic programming (SQP) techniques.

The proposed model results in a set of non-linear equations, which are too intricate to be resolved through conventional analytical methods. These traditional techniques not only proved ineffective but were also time-intensive. Consequently, they have been superseded by methods based on quadratic programming. SQP stands out as an effective decision-making tool, particularly adept at handling non-linear constraints and unconstrained equations, large-scale data analysis, and multi-decision scenarios. This assertion is supported by the work of Schittkowski, Mostafa and Khajavi, and Theodorakatos. SQP has been widely applied in various research studies concerning production and supply chain management models. In the context of this study, five distinct real-life cases were examined to apply the proposed SCM model. These cases involved the integration of cooperative advertising policies and web design strategies to boost demand and sway customer preferences towards the products. Detailed explanations of these cases are provided below.

Case analysis. This analysis demonstrates a cooperative Supply Chain Management (SCM) model, incorporating variable advertisement costs linked to the web design index (WDI), as depicted in Figure 3.1. In this model, the total advertisement cost comprises both a fixed initial cost and a variable cost based on the WDI, which varies across different geographies, such as developed vs. developing countries, and urban vs. rural areas. This is the only scenario where advertisement cost is modeled as an exponential function of the WDI without any constraints on the e-advertisement cooperation share among supply chain partners. The application of sequential quadratic programming (SQP) revealed a total SCM profit of \$827,049.16, optimized across various parameters including cycle time, shipments, selling prices, and advertisement shares. Notably, the selling prices (\$454.8) and shipment sizes remained consistent across scenarios, while advertisement costs varied based on agreements, game theoretical dynamics, and budget constraints.

In the second case, the advertisement cost is treated as a linear function of the WDI. This scenario, free from e-advertisement budget constraints and devoid of a defined leader or follower in the SCM, yielded the highest total profit among all cases at \$856,200.9, with a cycle time of approximately 0.227 years.

The third case introduces a cap on the total e-advertisement budget, as defined in a specific equation, with unequal contribution shares from the supplier, agri-processing firm, and retailer. Here, the advertisement cost

Table 4.1: Performance analysis of proposed cases

S.No	Scenario	Freshness-Keeping Efforts	Greenness Investment	Advertising Efforts	Blockchain Adoption	Product Quality at Sale	Supply Chain Costs	Profit Margin	Consumer Satisfaction
1	Traditional Supply Chain	Decline after transfer	Initial only	Standard	None	Deteriorated	Higher due to spoilage	Variable	Lower
2	Partial Blockchain Implementation	Moderate increase	Sustained	Optimized	Partial	Improved	Reduced	Improved	Higher
3	Full Blockchain Implementation	Significant increase	Sustained	Highly optimized	Full	Significantly improved	Significantly reduced	Significantly improved	Highest

is again a linear function of the WDI. The total profit in this scenario was $832,242.86, slightly higher than the first case but lower than the second.

In the fourth scenario, each SCM participant is bound by individual budget limits. Unlike the previous case, this co-op e-advertising policy involves an optimal, equal sharing of costs for product promotion in various e-markets. This resulted in a slight decrease in total profit to $832,195.13 compared to the third case.

The final case represents a superior SCM policy, where the agri-processing firm takes the lead role, and the supplier and multi-retailer follow. In this three-echelon SCM, the processing firm, being at the forefront of the product lifecycle, is expected to reap higher profits. Here, the agri-processing firm contributes 50% of the co-op advertisement cost, with the remainder split between the supplier and multi-retailer. This scenario resulted in the lowest total profit among all cases, at $80,0931.7.

Overall, these scenarios offer valuable insights for decision-makers regarding the impact of variable demand driven by e-marketing and web design on SCM. The results also provide a guide for optimally distributing advertisement expenses among supply chain partners in a co-op e-advertising collaboration. This collaborative approach aims to enhance web design for advertising agricultural products, thereby increasing demand and pushing suppliers to boost production, ultimately aiming for higher profits. The proposed model, being non-linear and versatile, aids decision-makers in evaluating multiple variables like shipment size, cycle time, advertisement share, and selling price.

4.2. Performance Measure. This evaluation provides a comprehensive comparison of the traditional and blockchain-based supply chains, highlighting the improvements in various aspects of the supply chain due to blockchain integration (Table 4.1).

The implementation of blockchain technology led to an observable increase in the supplier's commitment to maintaining product freshness throughout the supply chain. This was attributed to the increased transparency and traceability that blockchain provides. Case studies from real-world blockchain applications in cold chain logistics showed notable improvements in product quality and customer satisfaction levels compared to traditional methods. The use of blockchain technology streamlined the supply chain, resulting in cost savings, particularly in freshness-keeping and advertising efforts. This, in turn, improved the profit margins for both suppliers and retailers.

5. Conclusion. The research set out to explore the potential of blockchain technology in transforming the traditional cold chain delivery system for fresh agricultural products, with a focus on maintaining freshness and ensuring greenness. Our comprehensive analysis, which included simulations, case studies, and the application of various analytical tools, yielded several critical insights. Firstly, we found that integrating blockchain technology significantly bolstered the freshness-keeping efforts of suppliers. This improvement was primarily due to the enhanced transparency and accountability inherent in blockchain systems, which encouraged continuous quality maintenance throughout the supply chain. In real-world applications, this led to a noticeable improvement in product quality and a corresponding increase in consumer satisfaction, compared to traditional logistics methods. Additionally, the study revealed that blockchain adoption could streamline the supply chain, resulting in notable cost reductions, particularly in areas related to freshness-keeping and advertising. These efficiency gains translated into improved profit margins for both suppliers and retailers, marking a significant stride towards more sustainable and economically viable supply chain practices.

Our research underscores the transformative potential of blockchain technology in the cold chain logistics of fresh agricultural products. It not only enhances the effectiveness of freshness-keeping efforts but also contributes to a more cost-effective and consumer-oriented supply chain model. These findings offer valuable insights and actionable strategies for stakeholders in the agricultural sector, paving the way for more innovative and sustainable practices in the industry.

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