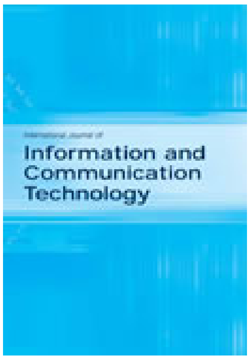

International Journal of Information and Communication Technology

ISSN online: 1741-8070 - ISSN print: 1466-6642
https://www.inderscience.com/ijict

Business model based on the synergistic drive of flexible supply chain and digital marketing

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Article History:

Received:	17 November 2023
Last revised:	02 February 2024
Accepted:	08 February 2024
Published online:	08 July 2024

Business model based on the synergistic drive of flexible supply chain and digital marketing

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Abstract: In this paper, cross-border e-commerce has emerged and steadily grown to become one of the main forms of international trade in China today. The green food whole industry chain, as an evolving model that arises and develops in response to changes in market demand and the structural adjustment of the agricultural industry, puts forward higher standards for the transmission and exchange of data across the industry chain. In order to accomplish information sharing throughout the industry chain, we built a big data platform model based on the theory of collaborative innovation. We also suggested two optimisation modes for the entire green food industry chain: the intelligent supply chain collaboration mode and the on and offline integration mode, which feature green food processors and retailers as the main bodies. Our analyses show that it helps businesses better adapt to market changes and the rapidly evolving internet economy when it comes to the process of business model innovation.

Keywords: green food; whole industry chain model; big data; collaborative innovation.

Reference to this paper should be made as follows: Mao, B. and Tian, H. (2024) 'Business model based on the synergistic drive of flexible supply chain and digital marketing', *Int. J. Information and Communication Technology*, Vol. 24, No. 8, pp.1–19.

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1 Introduction

The paradigm of foreign trade is shifting from ‘trade diversification’ to ‘global buy, global sell, global pay, and global transport’ in the context of economic globalisation and the progressive expansion of Internet coverage worldwide (Liu et al., 2023). Additionally, the primary participants in trade are no longer traditional trading enterprises but rather small and medium-sized businesses and individuals, and the mode of trade is shifting from traditional offline trade to cross-border e-commerce. Trade forms are changing from traditional offline to cross-border e-commerce; transaction characteristics are changing from ‘big in and out, low frequency’ to ‘small batch, high frequency’, and the trade supply chain is changing from being non-personalised and high volume to being personalised and fragmented in order to meet customer needs (Casciani et al., 2022).

In recent years, the cross-border e-commerce transaction scale maintains a high-speed growth of more than 20% per year, and the growth rate has far exceeded the traditional trade (traditional foreign trade growth rate of 7.8%), according to the latest statistics released by the Customs and Excise Department in 2021, the total amount of cross-border e-commerce imports and exports of China in the 2020 epidemic impact of the situation has increased by 31.1% (Nayal et al., 2022). In addition to displaying a burgeoning vitality, China’s cross-border e-commerce industry has also brought to light various issues that have arisen during the development:

1 cross-border e-commerce depends on third-party platforms, and information islands are created when there is a lack of information sharing between platforms

2 the cross-border e-commerce supply chain is lengthy and intricate; it is challenging to ensure the legitimacy of the product’s source and its quality; it is challenging to verify merchant credit information; and cross-border e-commerce financing is challenging

3 complicated cross-border e-commerce logistics, such as domestic transport, customs clearance, international transport, and overseas transport; this leads to challenges in managing logistics and unduly long logistics times; additionally, goods are not tracked promptly, and the customer experience is subpar

4 exorbitant cross-border payment costs and risks associated with security and exchange rate fluctuations, which negatively impact the interests of cross-border e-commerce

5 differing legal standards for customs and trade between cross-border e-commerce countries and data legal standards for the regulation of cross-border flows, creating a significant obstacle to cross-border trade compliance.

Furthermore, a lot of documentary information is involved in cross-border e-commerce transactions. This documentation must be shared between trade multilaterals and submitted to regulatory bodies. Presently, trade information is dispersed amongst independent systems, leading to a lack of transparency. While each nation has established its own EDI data exchange format standards (He et al., 2023), information is not transferred quickly, data format conversion is expensive, and creating a common letter is difficult.

The National Bureau of Statistics released data showing that in 2020 China's total import and export trade volume of 32.16 trillion US dollars, of which cross-border e-commerce imports and exports of 1.69 trillion US dollars, accounting for only 5.25% of the total cross-border import and export trade. Cross-border e-commerce has grown at a faster rate than traditional import and export trade, but for the same amount of money (Khan et al., 2023a). The resolution of cross-border e-commerce transactions, supply chain financing, and technical competence to support the requirements of the development of the encountered challenges is necessary if we are to accomplish a breakthrough in scale.

A number of parties must engage in the business process and come to a unanimous decision regarding the transaction in order for cross-border e-commerce to take place. These parties include domestic and foreign buyers, cross-border e-commerce enterprises, domestic and foreign logistics enterprises, third-party payment companies, and service platforms. While blockchain technology has been around since 2008, its primary areas of study are cryptocurrency, blockchain finance, and product traceability. This thesis examines the current state of cross-border e-commerce, uses blockchain technology to create a cross-border e-commerce alliance chain, and suggests a blockchain-based approach to solving cross-border e-commerce issues.

The paper's innovation lies in the way it systematically and comprehensively introduces the reader to the enormous competitive advantages created by the flexible supply chain and digital marketing, as well as the problems it faces. It also provides a detailed explanation of the crucial role that synergistic effect played in the process of building the business model, which in turn provided valuable experience for the design of other businesses' business models in the cross-border e-commerce industry and their smooth and orderly development. Finally, the paper offers helpful suggestions regarding the issues raised.

This thesis aims to analyse the challenges faced by cross-border e-commerce and attempt to address them through the use of blockchain, an emerging technology. Additionally, it seeks to encourage cross-border e-commerce growth and enable each cross-border e-commerce company to fully utilise the resources of the alliance chain by establishing a cross-border e-commerce alliance system based on the blockchain to cut costs and intermediary processes, as well as to address trust issues in cross-border e-commerce.

2 Related work

The number of domestic and international journals and papers on blockchain-based cross-border e-commerce that have been published in the last two years has gradually increased. The majority of these publications are in the research areas of cross-border e-commerce logistics, cross-border payment, solving the trust problem in cross-border e-commerce, and legal and regulatory recommendations.

International researchers (Khan et al., 2022b) examined the blockchain-based business model and related regulatory matters, coming to the conclusion that blockchain technology can continuously innovate company models that are subject to regulation. Khan et al. (2022c) examined the fundamental shifts in the traditional industry brought about by blockchain technology. Alkaraan et al. (2023) examined the logistics and distance implications of international e-commerce in the EU market, as well as how logistics influences cross-border e-commerce development. Mariia et al. (2020) examined cross-border logistics routes in the context of epidemic optimisation issues. Hoeben et al. (2023) examined the potential applications of blockchain technology in supply chains and their potential economic benefits.

Domestic (Khan et al., 2022a) addresses the issues with cross-border payments and offers DECP, LIBRA, and other cross-border settlement options as a solution. Chen (2020) examines how blockchain technology can be applied to cross-border supply chains in the context of customs compliance, evaluates the benefits of combining blockchain technology with already-completed domestic and international projects, and provides recommendations for information sharing and collaboration between governmental and private sectors. Varadarajan et al. (2022) propose to employ blockchain as the underlying technology to establish a business ecosystem to provide cargo supervision and trade tracking, using cross-border e-commerce in Central Europe as the research object. Negri et al. (2024) describe how blockchain can be used to address the issue of cross-border e-commerce and offers a blockchain-based solution. Na et al. (2022) present the idea of commodities traceability and undertakes extensive research on blockchain for the monitoring of the entire cross-border logistics warehousing and shipping operation.

The role of synergy as an important component of enterprise strategy is becoming more and more prominent, which helps enterprises to efficiently utilise resources and expand new development space. Zhang and Liu (2021) in the research of cross-border e-commerce and cross-border logistics synergistic mechanism and path of malefactors, respectively, based on the species, based on the environment, based on the supply chain, based on geospatial perspectives of synergism, and for synergistic realisation of the path of the corresponding solution ideas. Periyasami and Periyasamy (2022) conducted a literature review on enterprise business synergy capabilities in the context of digital economy and came up with insights such as establishing an enterprise business synergy platform, setting up a data collection and analysis centre, establishing a synergy ecosystem, cultivating business talents capable of applying digital technologies and improving enterprise digital awareness and business synergy awareness.

In the early discourse on business models, Khan et al. (2023b) refer to business models as the theory of business operations, while Kurpjuweit et al. (2021) refer to business models as operational innovations. While Wang et al. (2022) suggest Wei Zhu's six-factor business model, which is composed of six main aspects – positioning, business system, key resource capabilities, profitability model, free cash flow structure, and enterprise value – Li et al. (2023) elaborates on the business model canvas model.

Memari et al. (2021), in its discussion of the theoretical framework of business model, sorted out the meaning of business model, the structural dimensions of the essential design, and pointed out that the success or failure of the business model largely depends on the potential for profitability and the time required to obtain profitability. After analysing the main modes and problems of cross-border e-commerce, Zhang et al. (2023) propose innovative paths in terms of policies, service systems, products, and quality service processes. Garay-Rondero et al. (2020) put forward the suggestions of deepening the market to seek branding development, integrating resources to optimise supply chain management, and providing deepening services based on users for the problems and paths of cross-border e-commerce platform development.

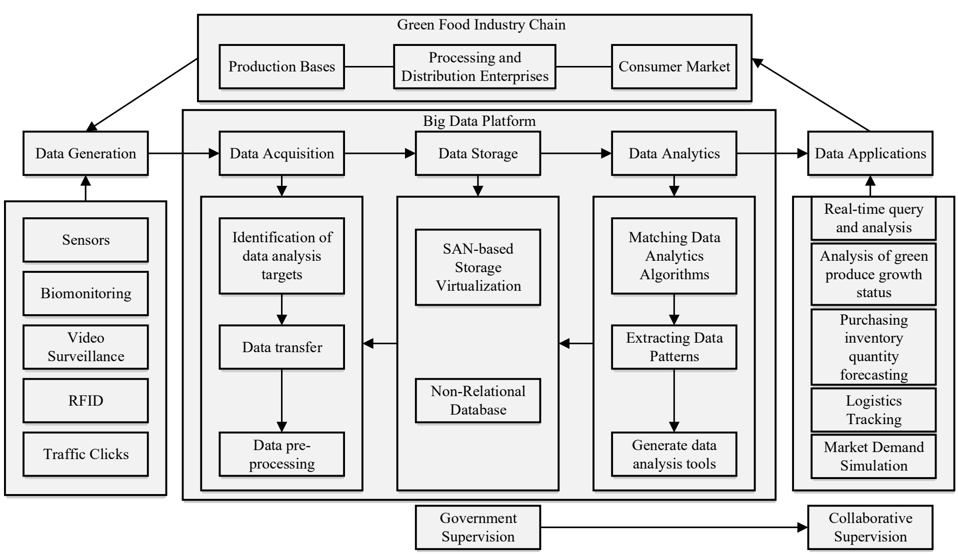
3 Data acquisition

Identification of data analysis goals, data transmission, and data pre-processing are all parts of the process of acquiring data, which is also known as information gathering. In order to achieve effective storage and data mining, a sizable amount of raw data created by the primary operations of each link in the chain of the green food sector is pre-processed through the data centre's high-speed transmission.

3.1 Identify data analysis target knowledge

Identifying the data analysis objectives is to clarify the objects and expected results of data analysis on the basis of understanding the real problems faced in the operation process of green food industry chain. Green food industry chain through the big data platform to realise the purpose of collaborative products, production, circulation and collaborative quality control, etc., the object of big data analysis is mainly the green agricultural products planting technology information generated by the green food industry chain planting link, soil information, whether the planting farmer masters the green agricultural products planting technology, weather information, pest and disease information, warehousing information, etc., and the processing technology information generated by the processing link, processing process information, processing flow information, procurement information, inventory information, logistics information, etc., and consumer preference information, willingness to pay information, green labelling awareness information, logistics and distribution information, retail store location information, etc., generated by the consumer market segment. The result of data analysis is mainly the prediction and control of the data on the quality control status, testing pass rate, storage capacity saturation, etc. of green agricultural products in production bases, inventory rate, product qualification rate, etc. of processing enterprises, and the logistics and distribution efficiency and flow realisation ability of the consumer market.

Figure 1 Big data platform model of green food whole industry chain



3.2 Data transmission

The subjects in each link of the green food industry chain generate massive raw data through sensors, video monitoring, enterprise information management systems, click traffic and other digital sources, which must be transmitted to the data storage infrastructure to wait for further processing. There are two stages to the data transmission process: transmission over the IP backbone network and transmission through the data centre. As shown in Figure 1, the IP backbone network offers high-capacity backbone lines for the transfer of big data from data sources to data centres, where storage placement adjustment and other processing are carried out.

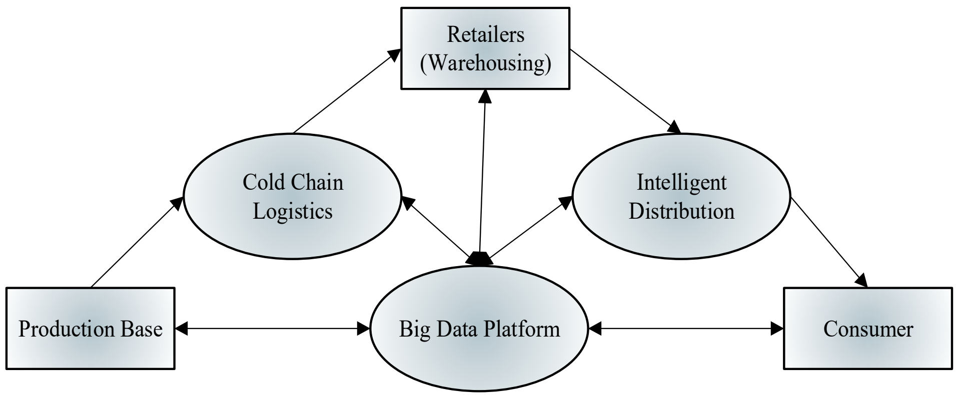
4 Application mode of value-added industrial chain

The main organisations of each link in the green food industry chain can identify opportunities to develop new products and understand customer needs in order to find new management methods and service approaches with the assistance of the big data platform by integrating a substantial amount of real-time and historical transaction information. Green food can be categorised into fresh agricultural products that flow directly from the production base to the consumer market without finishing and processed food that requires finishing according to the different processing processes. On the basis of the above model, an on-line and off-line integration mode with green food retailers as the main body is proposed for green fresh food, and an intelligent supply chain synergy mode with green food processing enterprises as the main body is proposed for green processed food, so as to utilise the green food whole industry chain big data platform to share the big data of the whole industry chain of green food in planting, processing and sales, and to create a big data platform as the core, to meet consumer demand-oriented, on-demand production of efficient synergistic green food whole industry chain model.

4.1 Retailer integration mode

Indicating the direction for the entire operating process of the green food supply chain is the synergistic mode: market demand-oriented. The big data platform obtains the demand condition in time by capturing consumers' demand information and consumption habits, and arranges the production plan and organises the production reasonably according to the demand condition. Green fresh food does not need to be processed, and is directly delivered from the production base to retailers or consumers through cold chain logistics. Therefore, for the green fresh food industry chain, the consumer market takes on the primary duty of collecting consumer data, which is essential for the chain's optimisation and integration. By establishing a consumer membership system, downstream green food retailers retain customers and gather consumer data. At the same time, they connect the big data centre through the e-commerce platform and realise efficient distribution with the aid of intelligent logistics, realising the integration of online and offline (Figure 2).

Figure 2 Green food retailer-oriented online and offline integration model



The retailer establishes a close connection with green fresh food consumers through WeChat public number, WeChat small program, APP and other online methods to establish a membership system. The big data centre links to the backstage system to collect and process member data, and feedback the results to the retailer so that the retailer can provide members with more satisfactory services, while the membership system also helps to implant the concept of the green fresh food brand and enhance the loyalty of the members. On the one hand, the big data platform can analyse the data on members' consumption habits and consumption ability to manage members hierarchically, provide specific preferences and additional services for each level of consumers, and improve the efficiency and effectiveness of membership management; on the other hand, it can actively push valuable information to members in line with their hobbies and daily purchasing habits based on the results of the analysis of members' daily consumption to improve the flow of goods.

Green fresh food retailers link the big data centre through the e-commerce platform, connect the online and offline entrances, commodities, experience, payment, delivery, after-sales and other links to establish an integrated online and offline sales model, so as to allow consumers to choose freely, optimise their shopping experience, and improve their loyalty to green food. On the basis of maintaining the original functions of online and offline, online undertakes data collection and mining, customer service, etc., and transmits the data directly to the big data platform, and the data analysis results of online are used to guide the shelves and displays of offline commodities; offline undertakes the creation of scenarios, warehousing, etc., to improve the consumer's impression of the online goods and to give them a better overall shopping experience, the big data platform's analytical findings are combined with offline scenario experience. The offline scene experience is used to enhance consumers' perception of online products, thus bringing better consumption experience for customers. The logistics and distribution of green fresh food accumulates data information on outlets, trunk lines, terminals and personnel through the big data centre, scientifically formulates distribution plans, and provides logistics information services for consumers and retailers. Online and offline realise the integration of commodities, prices, payment methods, logistics, after-sales, membership and information.

4.2 Evolutionary game analysis under nonlinear demand function

4.2.1 Supplier evolution game analysis

According to Table 1, the expected benefits of the supplier's 'incentivisation' strategy are

$$E^{nC}\left(\pi_s^n\right) = y^n \pi_{s4}^{n*} + \left(1-y^n\right)\pi_{s3}^{n*} = \frac{\left[y^n + \left(1-y^n\right)e^{-\frac{\beta}{1-\beta}}\right]}{b^n(1-\beta)} a^n e^{-\left(2+b^n c\right)} \tag{1}$$

Table 1 Payment matrix of the game parties under nonlinear demand

Supplier	*Retailers*	
	Prefer altruism (y2)	*No preference for altruism (1 – y2)*
Incentive (x^n)	$\pi_{s4}^{n*} = \frac{a^n e^{-\left(2+b^n c\right)}}{b^n(1-\beta)}$	$\pi_{s3}^{n*} = \frac{a^n e^{-\left(b^n c + \frac{2-\beta}{1-\beta}\right)}}{b^n(1-\beta)}$
	$u_{r4}^{n*} = \frac{a^n e^{-\left(2+b^n c\right)}}{b^n}$	$u_{r3}^{n*} = \frac{a^n e^{-\left(b^n c + \frac{2-\beta}{1-\beta}\right)}}{b^n}$
No incentive ($1 - x^n$)	$\pi_{s2}^{n*} = \frac{a^n e^{-\left(2+b^n c-\beta\right)}}{b^n}$	$\pi_{s1}^{n*} = \frac{a^n e^{-\left(2+b^n c\right)}}{b^n}$
	$u_{r2}^{n*} = \frac{a^n e^{-\left(2+b^n c-\beta\right)}}{b^n}$	$u_{r1}^{n*} = \frac{a^n e^{-\left(2+b^n c\right)}}{b^n}$

The expected benefit to the supplier from adopting the 'no incentive' strategy is

$$E^{nNC}\left(\pi_s^n\right) = y^n \pi_{s2}^{n*} + \left(1-y^n\right)\pi_{s1}^{n*} = \frac{1-y^n+y^n e^{\beta}}{b^n} a^n e^{-\left(2+b^n c\right)} \tag{2}$$

The average benefit to the supplier is

$$\bar{E}^n\left(\pi_s^n\right) = x^n E^{nC}\left(\pi_s^n\right) + \left(1-x^n\right)E^{nNC}\left(\pi_s^n\right) \tag{3}$$

From $S^n\left(x^n\right) = \frac{dx^n}{dt} = x^n\left[E^{nC}\left(\pi_s^n\right) - \bar{E}^n\left(\pi_s^n\right)\right]$, we get the equation of the supplier's replication dynamics

$$S^n\left(x^n\right) = x^n\left(1-x^n\right)a^n e^{-\left(2+b^n c\right)}\left[\frac{y^n\left(2-\beta-e^{\beta}\right)-1}{b^n(1-\beta)} + \frac{\left(1-y^n\right)e^{-\frac{\beta}{1-\beta}} + \left(1+y^n e^{\beta}\right)\beta}{b^n(1-\beta)}\right] \tag{4}$$

Let $S^n(x^n) = 0$, get the possible stable state

$$x_1^{n*} = 0,\ x_2^{n*} = 1,\ y^{n*} = \frac{1-\beta-e^{-\frac{\beta}{1-\beta}}}{2-\beta-e^{-\frac{\beta}{1-\beta}}-(1-\beta)e^{\beta}}.$$

Let $M = \dfrac{1-\beta-e^{-\frac{\beta}{1-\beta}}}{2-\beta-e^{-\frac{\beta}{1-\beta}}-(1-\beta)e^{\beta}}$, the evolutionary analysis of the supplier's replication dynamic equation, we can get Proposition 1.

Proposition 1: With a nonlinear demand function: at $y^{n*} < M$, the supplier evolves a stable strategy as a 'disincentive' strategy; at $y^{n*} > M$, the supplier evolves a stable strategy as an 'incentive' strategy; and at $y^{n*} = M$, the proportions of 'incentivised' and 'disincentivised' suppliers in the supply chain remain unchanged.

Proof: From equation (4), we have

$$S^{n'}(x^n) = (1-2x^n)a^n e^{-(2+b^n c)} \times \left[\frac{y^n(2-\beta-e^{\beta})-1}{b^n(1-\beta)} + \frac{(1-y^n)e^{-\frac{\beta}{1-\beta}}(1+y^n e^{\beta})\beta}{b^n(1-\beta)}\right].$$

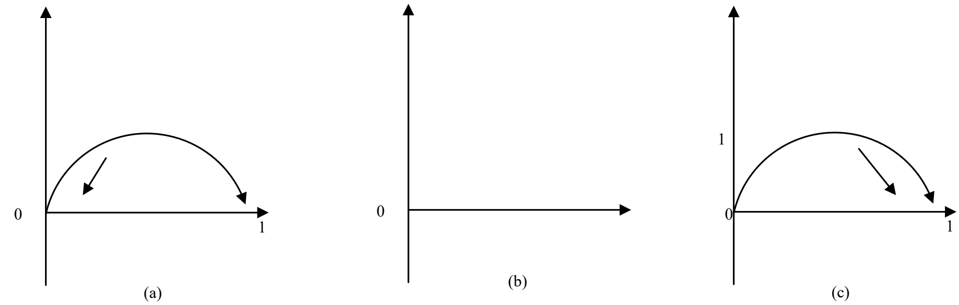
Let $S^n(x^n) = 0$, get $x_1^{n*} = 0, x_2^{n*} = 1, y^{n*} = M$. When $y^{n*} = M$, $S^n(x^n) \equiv 0$, so we discuss with M as the critical point.

a At $y^{n*} < M$, $S^{n\prime}(0) < 0$, and $x_1^{n*} = 0$, the evolutionary game is stable, i.e., the supplier's evolutionary stable strategy is the 'disincentive' strategy. At time $y^{n*} < M$, suppliers do not pay attention to the retailer's altruistic behaviour and believe that the retailer is only concerned with its own profit. In this case, all suppliers will eventually choose the disincentive strategy.

b At $y^{n*} > M$, $S^{n\prime}(1) < 0$, $x_2^{n*} = 1$ is the stable solution of the evolutionary game, i.e., the supplier's evolutionary stable strategy is the 'incentive' strategy. Suppliers who choose the disincentive strategy find that the retailer's altruistic preference leads to more profits for them, and they find that the supplier who initially chooses the incentive strategy sells more and makes more money, so more and more suppliers choose the incentive strategy, and eventually all suppliers choose the incentive strategy. 'They find that suppliers who initially choose the incentive strategy sell more and make more money, and then more and more suppliers choose the incentive strategy, and eventually all suppliers choose the Incentive strategy.

c At $y^{n*} = M$, $S^{n\prime}(x^n) = 0$, all x^n suppliers are in a steady state. When the probability of a retailer choosing 'preferred altruism' is fixed at $y^{n*} = M$, the proportion of incentivised and disincentivised suppliers in the supply chain remains constant, i.e., there is always a proportion of suppliers that adopt an 'incentivised' strategy and a proportion of suppliers that adopt a 'disincentivised' strategy in the supply chain. This means that there will always be x^n of suppliers in the supply chain who are incentivised and $1 - x^n$ of suppliers who are disincentivised. The dynamic trend and evolution of the supplier group is shown in Figure 3.

Figure 3 Schematic diagram of the supplier evolution process



Conclusion 1: Through the analysis of suppliers' individual evolution, it is found that under both linear and nonlinear demand functions, whether suppliers adopt 'incentive' strategies or not depends on the proportion of retailers choosing 'altruistic' preferences.

4.2.2 Evolutionary game analysis of retailers

The expected utility of a retailer adopting an 'altruistic preference' strategy is

$$E^{nA}\left(u_r^n\right) = x^n u_{r4}^{n*} + \left(1-x^n\right) u_{r2}^{n*} = \frac{x^n + \left(1-x^n\right)e^{\beta}}{b^n} a^n e^{-\left(2+b^n c\right)} \tag{5}$$

The expected payoff to the retailer for adopting the 'no preference for altruism' strategy is

$$E^{nNA}\left(u_r^n\right) = x^n u_{r3}^{n*} + \left(1-x^n\right) u_{r1}^{n*} = \frac{x^n e^2 + \left(1-x^n\right) e^{\frac{2-\beta}{1-\beta}}}{b^n} \times a^n e^{-\left(2+b^n c+\frac{2-\beta}{1-\beta}\right)} \tag{6}$$

The retailer's average utility $\overline{E}^n(u_r^n) = y^n E^{nA}(u_r^n) + (1-y^n) \times E^{nNA}(u_r^n)$.

The replication dynamic equation for the retailer is obtained from $R^n(y^n) = y^n[E^{nA}(u_r^n) - \overline{E}^n(u_r^n)]$.

$$R^n\left(y^n\right) = y^n\left(1-y^n\right) a^n e^{-\left(2+b^n c+\frac{2-\beta}{1-\beta}\right)} \left[\frac{\left(2x^n-1\right)e^{\frac{2-\beta}{1-\beta}}}{b^n} + \frac{\left(1-x^n\right)e^{\frac{2-\beta^2}{1-\beta}} - x^n e^2}{b^n}\right] \tag{7}$$

Let $R^n(y^n) = 0$, and get the possible steady state

$$y_1^{n*} = 0,\ y_2^{n*} = 1, \quad x^{n*} = \frac{e^{\frac{2-\beta}{1-\beta}} - e^{\frac{2\beta^2}{1-\beta}}}{2e^{\frac{2-\beta}{1-\beta}} - e^{\frac{2\beta^2}{1-\beta}} - e^2}.$$

Let $Z = \left(2x^n - 1\right) e^{\frac{2\beta}{1-\beta}} + \left(1-x^n\right) \times e^{\frac{2-\beta^2}{1-\beta}} - x^n e^2, \quad N = \dfrac{e^{\frac{2-\beta}{1-\beta}} - e^{\frac{2-\beta^2}{1-\beta}}}{2e^{\frac{2-\beta}{1-\beta}} - e^{\frac{2-\beta^2}{1-\beta}} - e^2}.$

An evolutionary analysis of the retailer replication dynamic equation yields Proposition 2.

Proposition 2: Under the nonlinear demand function, when $x^{n*} \neq N,$ the retailer evolves a stable strategy of 'preferred altruism'; when $x^{n*} = N,$ the proportion of retailers in the retailer population choosing 'preferred altruism' and 'no preferred altruism' remains unchanged. The proportion of retailers choosing 'preferred altruism' and 'non-preferred altruism' in the retailer population remains unchanged.

Proof: From equation (7), we have $R^{n'}\left(y^n\right) = \left(1 - 2y^n\right) \frac{Z}{b^n} a^n e^{-\left(2 + b^n c + \frac{2-\beta}{1-\beta}\right)}.$

Where $Z \geqslant 0.$ The evolutionary game stabilisation strategy requires that $R^n(y^n) = 0,$ $R^n(y^n) < 0$ at the same time. When $x^{n*} = N, R^{n'}(y^n) \equiv 0,$ so N is used as the critical point for discussion.

a When $x^{n*} \neq N, R^{n'}(1) < 0,$ then $y_2^{n*} = 1$ is a stable solution of the evolutionary game, i.e., the retailer's evolutionary stable strategy is 'preferred altruism' strategy. The retailer, who occupies a passive role in the supply chain, prefers to demonstrate its sincerity by encouraging long-term cooperation between the two sides in order to maximise its own usefulness. When $x^{n*} \neq N,$ retailers who initially adopt the 'no altruism preference' strategy find that retailers who adopt the 'altruism preference' strategy gain higher utility through their own altruistic behaviour, more and more retailers choose to adopt the 'altruism preference' strategy, and eventually all retailers adopt the 'altruism preference' strategy.

b Figure 4 illustrates the retailing group's steady evolution and dynamic trend. When y^n and $x^{n*} = N, R^{n'}(y^n) \equiv 0$ are in a stable state. Insofar as the percentage of suppliers within the supplier group opting for the 'incentive' approach is set at $x^{n*} = N,$ the percentage of retailers selecting 'preferred altruism' and 'non-preferred altruism' will stay stable and steady. Retailers who have x^{n*} in their supply chain are considered to be altruistic, whereas those that have $1 - x^{n*}$ are not.

Let

$$S = e^{\frac{2-\beta}{1-\beta}}\left(e^{\frac{2-\beta^2}{1-\beta}} - e^{\frac{2-\beta}{1-\beta}}\right), v = e^{-\frac{2-\beta}{1-\beta}}\left(e^{\frac{2-\beta}{1-\beta}} - e^2\right), r = -1 + \beta + e^{-\frac{\beta}{1-\beta}},$$
$$z = 1 - e^{\beta} + e^{\beta}\beta, k = 1 - \beta.$$

The findings of the equilibrium point's stability analysis can be obtained, as illustrated in Table 2. According to the above analysis, the evolutionary stability phase diagram can be obtained, as shown in Figure 5. The Jacobi matrix J corresponds to the determinant value of $\mathrm{Det}(J) = J_1J_4 - J_2J_3$, and the trace is $Tr(J) = J_1 + J_4$. The analysis of the system of dynamical equations (28) leads to the equilibrium points of the supply chain system as (0, 0), (1, 0), (0, 1), (1, 1), (N, M).

Figure 4 Evolutionary stabilisation strategies of retailers

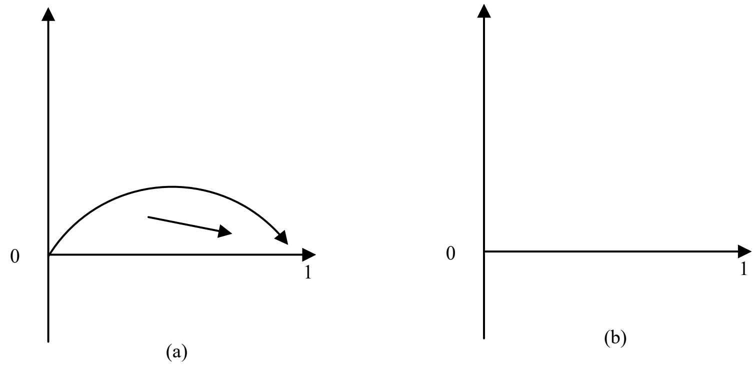


Table 2 Analysis of equilibrium points' local equilibrium stability

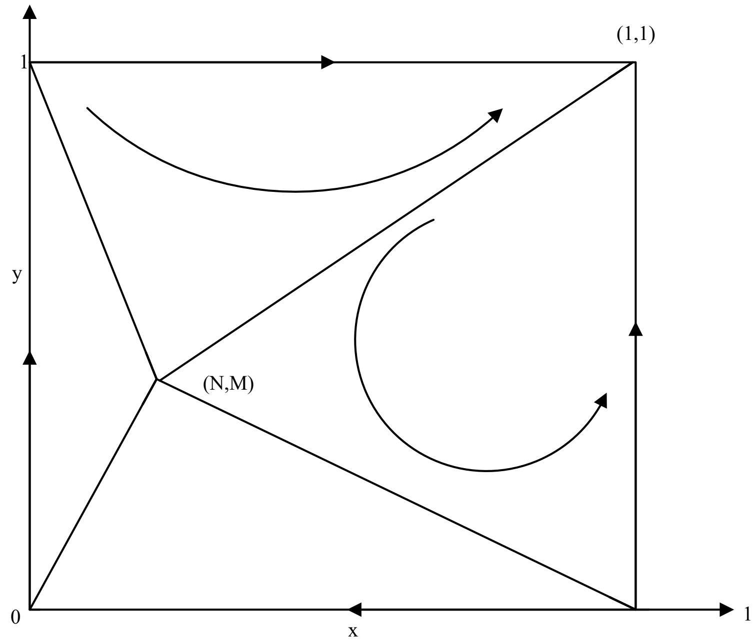
Balance point	*Det(J)*		*Tr(J)*		*Stability*
$x = 0, y = 0$	g^2kst	–	$g(ks + r)$	+	Saddle point
$x = 1, y = 0$	$-g^2kvr$	+	$g(kv - r)$	+	Unstable point
$x = 0, y = 1$	$-g^2kdz$	–	$g(-ks + z)$	–	Saddle point
$x = 1, y = 1$	g^2kvz	+	$-g(kv + z)$	–	ESS
$x = N, y = M$	$-g^2k\frac{svrz}{(s-v)(r-z)}$	–	0	0	Saddle point

Conclusion 2: The long-run equilibrium strategies of the supply chain, under both linear and nonlinear demand functions, are the retailer's 'altruistic preference' strategy and the supplier's 'incentive' strategy.

In both linear and nonlinear demand functions, retailers set their retail prices in the long run with the objective of maximising their total utility, including their own profit and the positive utility of their altruistic preferences. In reality, the retailer, as a follower, will show its willingness to cooperate through its own altruistic behaviours in order to maintain a stable long-term cooperation between the two parties. In the long-term game between retailers and suppliers, retailers will accept the higher wholesale prices set by suppliers to give benefits to suppliers in order to maintain a stable cooperative relationship. At the same time, in order to avoid a decrease in their own utility, retailers will maximise their own utility by adopting the strategy of 'preferential altruism'. The supplier, as the dominant player in the supply chain, has a first-mover advantage and can make enough profit without lowering the wholesale price, and when it adopts the 'incentive' strategy, the supplier's profit is maximised.

Therefore, under both linear and nonlinear demand functions, the long-term equilibrium strategy of the supply chain is that the retailer adopts the 'preference altruism' strategy and the supplier adopts the 'incentive' strategy.

Figure 5 Dynamic phases of suppliers and retailers



5 MATLAB numerical simulation analysis

In order to reflect more intuitively the strategy choices of suppliers and retailers under different market demands, illustrate more intuitively the above conclusions and verify the stable equilibrium strategy of the supply chain, based on the Stackelberg evolutionary game model and algorithm constructed in this paper, MATLAB evolutionary simulation is used to carry out the simulation analysis of the stability of the evolution of the above calculations.

5.1 Numerical simulation analysis under linear demand function

According to the constraints on the range of the relevant parameters above, the kinetic equation of the interactive evolution of the game process of suppliers and retailers is obtained by taking $a^1 = 500$, $b^1 = 25$, $c = 10$, $\beta = 0.3$.

$$S^1 = \frac{dx^1}{dt} = 57.398x^1\left(1-x^1\right)\left(1.7y^1-1\right);$$
$$R^1 = \frac{dy^1}{dt} = 318.878y^1\left(1-y^1\right)\left(0.3381-0.0081x^1\right) \tag{8}$$

Figure 6 Evolutionary paths of strategy choices of retailers and suppliers under linear demand (see online version for colours)

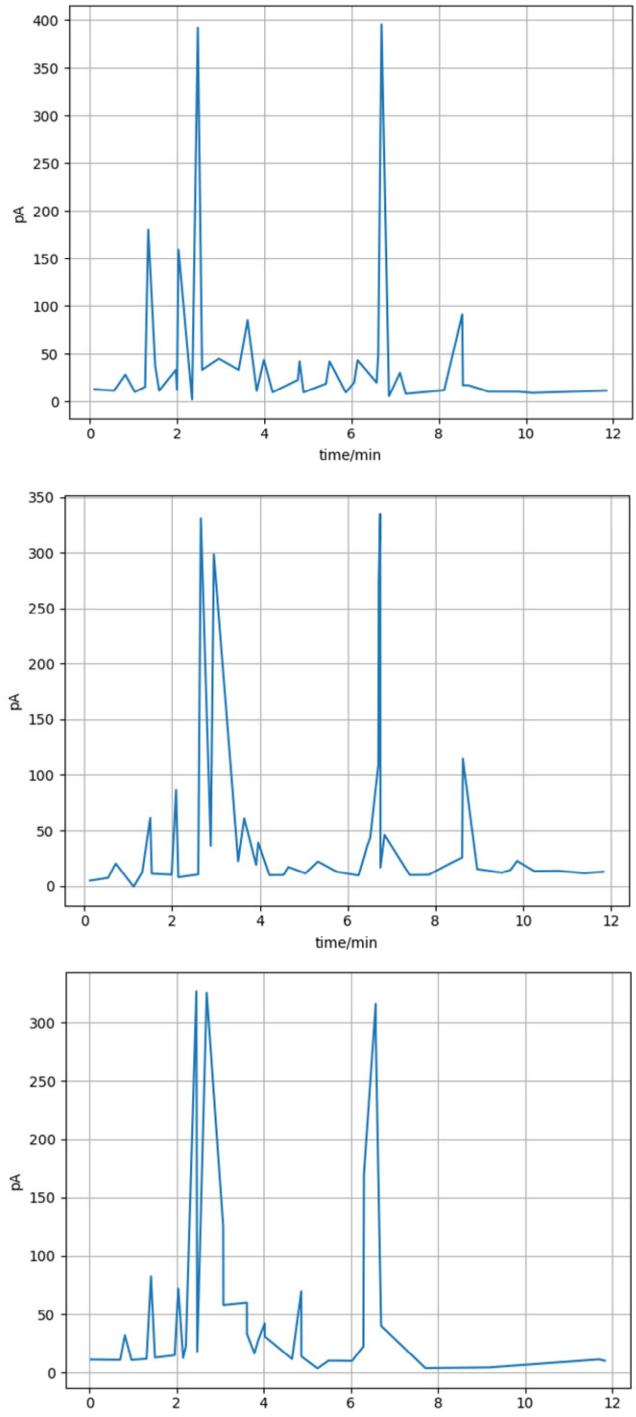
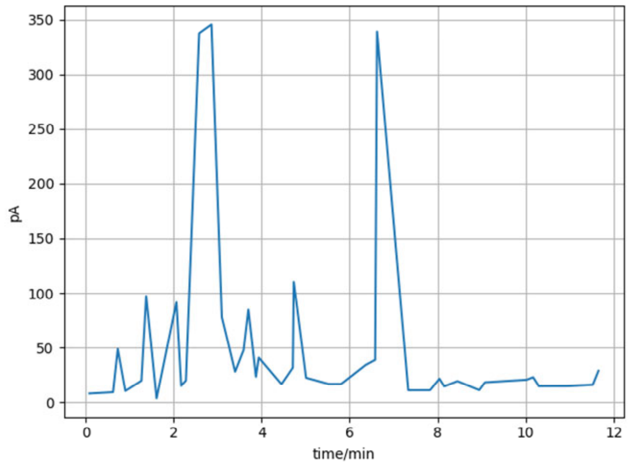


Figure 6 Evolutionary paths of strategy choices of retailers and suppliers under linear demand (continued) (see online version for colours)



After MATLAB numerical simulation analysis, the evolution path of supplier and retailer strategy selection under linear demand function is shown in Figure 6.

Figure 6 shows that the evolutionary stable strategies of suppliers and retailers under linear demand are (incentive, preference altruism), i.e., all points converge to (1, 1), which is consistent with conclusion 4. This means that under linear demand, the long-run equilibrium of the supply chain results in the supplier adopting the 'incentive' strategy and the retailer adopting the 'preference altruism' strategy.

The supplier, as the dominant player in the supply chain, can earn enough profit without lowering its own wholesale price. When the supplier adopts the 'incentive' strategy, it can always maximise its profit, so it will always adopt the 'incentive' strategy. The retailer, on the other hand, has a lower position in the supply chain, and in order to maintain long-term cooperation with the dominant player, it will show altruistic behaviour and consider the supplier's profit in its decision-making. Since 'preferred altruism' always brings higher efficiency to retailers, even if a small number of retailers initially adopt a 'non-preferred altruism' strategy, all retailers will eventually adopt a 'preferred altruism' strategy over time. So even if a small number of retailers initially adopt the 'no altruism' strategy, over time all retailers will eventually adopt the 'altruism' strategy.

5.2 Numerical simulation analysis with nonlinear demand function

According to the constraints on the range of the relevant parameters above, taking $a^n = 100$, $b^n = 0.2$, $c = 10$, $\beta = 0.3$, the kinetic equation for the interactive evolution of suppliers and retailers in the game process under nonlinear demand can be obtained.

$$\begin{cases} S^n = \dfrac{dx^n}{dt} = 13.083x^n\left(1 - x^n\right)\left(0.104y^n - 0.486\right) \\ R^n = \dfrac{dy^n}{dt} = 0.807y^n\left(1 - y^n\right)\left(3.968 - 0.015x^n\right) \end{cases} \tag{9}$$

After MATLAB numerical simulation analysis, the evolution paths of suppliers' and retailers' strategy selection under nonlinear demand function are shown in Figure 7.

Figure 7 Evolutionary paths of strategic choices of zero-supplier and supplier under nonlinear demand function (see online version for colours)

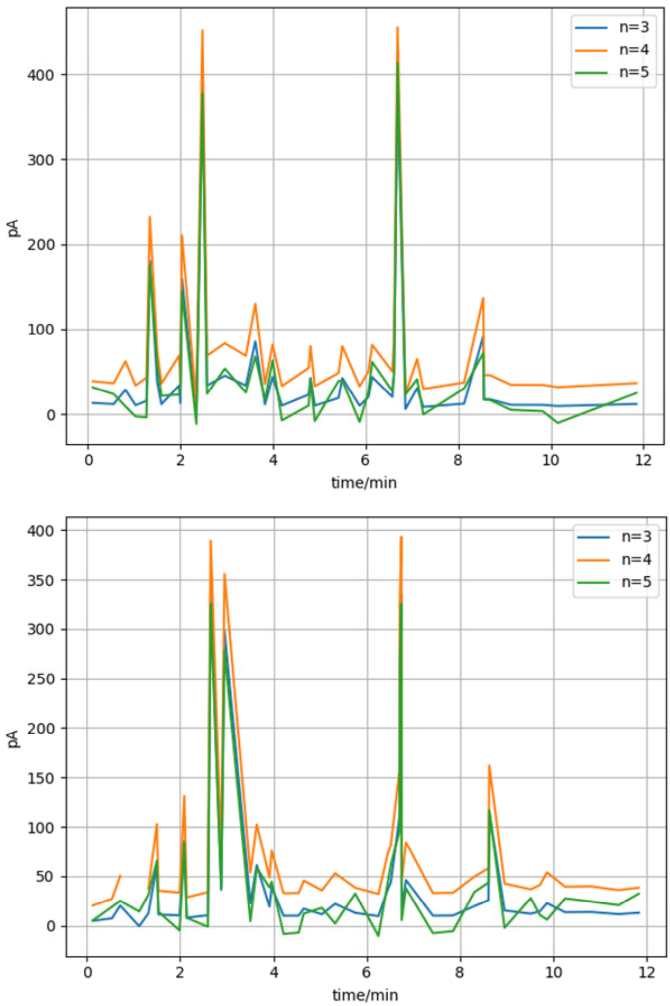
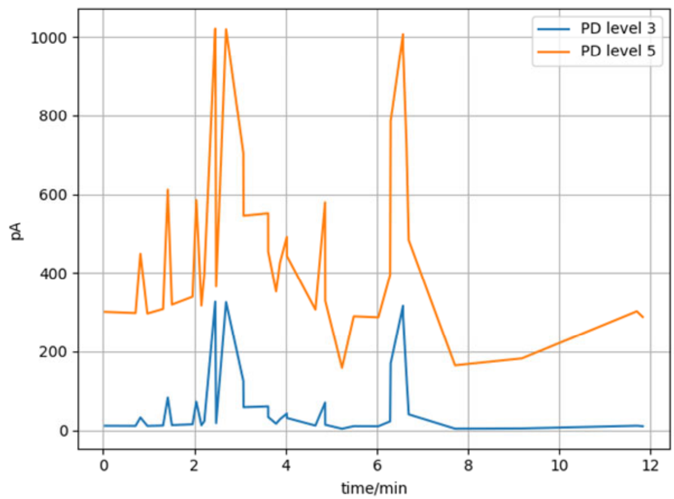


Figure 7 shows that all the points in the evolution path of the strategic choices of both suppliers and retailers under the nonlinear demand function converge to (1, 1), i.e., the suppliers and retailers' strategic choices tend to be (incentive, preference for altruism) in the long-term dynamic change.

Since the supplier has the advantage of acting first in the game, it can see the retailer's reaction function and make the most favourable decision to gain more profit. In the long run, the supplier will choose to adopt an 'incentive' strategy and set a higher wholesale price to maximise its profit. As shown in Figure 8, in the supply chain, cooperation is the only way to maximise the overall benefits, so in the long run, retailers will actively show their own altruistic behaviours to promote cooperation, i.e., retailers will adopt the 'preferred altruism' strategy. The retailer's own utility is maximised when the retailer adopts the 'preferred altruism' strategy, so the long-run equilibrium strategy of the supply chain under nonlinear functional demand is that the supplier adopts the 'incentive' strategy and the retailer adopts the 'preferred altruism' strategy. Therefore, the long-run equilibrium strategy of the supply chain under nonlinear function demand is that the supplier adopts the 'incentive' strategy and the retailer adopts the 'preference altruism' strategy.

Figure 8 Comparative features (see online version for colours)



6 Conclusions

Flexible manufacturing, agile supply chain, digital capability and big data technology drive an important part of the value-added of the entire green food supply chain, and the establishment of a big data platform is of crucial strategic significance for the development of the latter. Aiming at the problems that the data in the chain cannot be transmitted and analysed in real-time, we have constructed a big data platform architecture with data collection, data storage and data processing as the core, and based on this model, we have proposed an integrated model of online and offline green fresh food with green food retailers as the main body, and an integrated model of online and offline green fresh food with the goal of promoting the upgrading of the consumption structure of consumers and improving the efficiency of the governmental department's food safety supervision. fresh food retailers of green food as the main online and offline integration model, and green food processors of green processed food as the main intelligent supply chain synergy model, in order to provide advice and suggestions for improving the added value of the entire green food industry chain. Although blockchain technology can solve the problems encountered in cross-border e-commerce to a certain extent, the development of this technology is still immature, for example, the high latency of its consensus algorithm, computational costs, encryption technology, cross-chain communication technology, and the occupation of a large amount of storage space to store the same data have not yet been effectively solved. Therefore, there are still limitations to the application of blockchain technology in scenarios where research and cross-border e-commerce are combined.

Acknowledgements

This work was supported by General Program of Hunan Philosophy Social Science Fund – A Study on the Effective Interface between Consolidating and Expanding the Achievements of Poverty Alleviation and Rural Revitalization in Hunan (21YBA285).

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