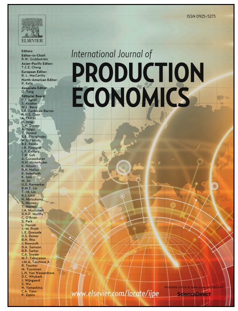

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Data Availability

The figure data generated in this study are provided in the Source Data file. All figures, codes, simulation implementation steps, and source data are available in the script files of the following repository: https://github.com/zhumenghan1019/Codes-and-data.git. Source data are provided with this paper. Please contact P.B. with any questions.

Can Gen-AI promote community group buying? A tripartite evolutionary game analysis

Abstract: As a new retail model, community group buying (CGB) quickly caught consumers' attention with its relatively preferential prices and high delivery efficiency. However, issues such as delayed response and unsatisfactory after-sales service have severely plagued the further development of CGB. Generative AI (Gen-AI), as a disruptive innovation of artificial intelligence, offers significant potential for CGB promotion due to its excellent performance. This paper endeavors to introduce Gen-AI to the CGB scenario, and a tripartite evolutionary game model is formulated to help better understand the stakeholders' behavior including the supplier, CGB platform, and group leaders. The evolutionary stable strategies of participants under different constraints are scrutinized, which assists in exploring the impact of Gen-AI empowerment on the decision strategies of the three involved parties. Besides, simulation experiments are performed to investigate the impact of different parameter changes on the game's tripartite decisions. Results indicate that the costs, profits, and potential risks associated with Gen-AI empowerment are crucial considerations for the supplier and platform. Moreover, even with Gen-AI empowerment, the platform's revenue may decline if customers reduce their purchase frequency due to passive service from the group leader. As a result, the platform is more inclined to adopt Gen-AI empowerment when the group leader provides active service.

Keywords: Generative Artificial Intelligence (Gen-AI); Community Group Buying (CGB); Tripartite Evolutionary Game; Strategic Behaviors.

1. Introduction

Urbanization and the fast-paced nature of modern life have led to a growing demand from consumers for convenient and varied fresh product buying scenarios. In response to these changing needs, the concept of community group buying (CGB) first emerged in the fresh products market of Changsha in 2016 (Lan and Yu, 2022). As an innovative retail model, CGB utilizes social connections within communities and the role of group leaders to facilitate the flow of goods. Group leaders interact with community residents, promoting products through WeChat groups. Consumers place orders through the CGB platform after receiving messages from the group leader (Yu et al., 2022). The platform consolidates order information and sources goods directly from suppliers, employing a logistics system for community-based delivery. One notable advantage of this model is that community residents can conveniently pick up their orders the following day (Li et al., 2022), addressing common challenges faced by urban customers, such as limited time after work to visit local markets, long supermarket queues, and the distance to traditional markets. Moreover, CGB offers competitive prices and enhanced delivery efficiency compared to traditional supermarkets and other e-commerce channels (Sun and Zhang, 2022). In the Chinese market, CGB has quickly become a popular consumption model and is now competing fiercely with established supermarket chains.

The academic literature has discussed a wide range of management practices to support the sustainable development of the CGB retail model, including operational management (Yu et al., 2022), coordination mechanisms (Lan and Yu, 2022), and pricing strategies (Ali et al., 2023a). However, despite its rapid rise in popularity, CGB faces several challenges. One key concern is product traceability, which is hindered by less transparent business processes. Additionally, customer feedback and specific needs are typically relayed through the group leader, resulting in delays in response and inadequate after-sale support. Furthermore, CGB now faces dual competition from both online and offline channels, driven by the expanding offline retail sector and the quick growth of e-logistics (Kumar et al., 2022). Therefore, for CGB to continue its development, it must find ways to address these challenges and enhance service quality for customers.

Digital and big data technologies have demonstrated their efficacy in fostering the development of CGB by means of creative management strategies that have been examined and implemented in the Chinese market (Dennehy et al., 2021). Huang and Zhuang (2021) proposed the optimizations of CGB product procurement strategies through big data systems to achieve cost control plans. These systems also enable the rapid distribution of warehoused products and dynamic adjustments to transportation routes. However, even if big data and digital technologies have addressed some of the present CGB challenges and reduced the need for personnel engagement, they still require substantial hardware to implement requisite automation levels (Dubey et al., 2019; Papadopoulos et al., 2022). This poses a barrier for non-experts and hinders the involvement of members with less online sales experience and lower platform operating skills in CGB (Eskandarzadeh et al., 2023). In contrast, generative artificial intelligence (Gen-AI), which is based on large language models (LLMs), has achieved ground-breaking progress in understanding and responding to human language instructions (Chung, 2024). Gen-AI makes a lot of tasks simpler for non-experts by supporting a variety of functions, such as order management, inventory tracking, automated warnings, interactive instructions, and vendor management based on user prompts. In light of these developments, this study explores the prospects of Gen-AI to further promote the development of CGB.

Gen-AI is an artificial intelligence system that can learn joint probability distributions within data, enabling the creation of entirely new content by leveraging historical data and employing different kinds of machine-learning models (Tapeh and Naser, 2023). Renowned for its remarkable capabilities, Gen-AI has attracted significant public attention due to its broad and innovative applications. As a representative Gen-AI product, ChatGPT garnered 100 million users just two months after its release in November 2022, setting the record for the fastest consumer application growth (Wu et al., 2023). The innovative potential and wider application prospects of Gen-AI have provided opportunities for various applications. For example, it can assist doctors in improving the efficiency and accuracy of writing patient diagnosis reports (Liu et al., 2023), while models like GPT-3 can generate high-quality news segments with coherence and accuracy comparable to those written by human journalists (Fatima et al., 2023). Additionally, it also can be applied in banks for backend operations, data analysis, and marketing financial services (Fosso Wamba et al., 2023b). Raj et al. (2023) conducted a study in a real retail environment and concluded that ChatGPT had great potential to provide 24-hour customer service, which obviously facilitated enhancing the service quality for corporations.

The adoption of Gen-AI offers enormous potential in the CGB sector. Gen-AI can effortlessly generate product information text and transform it into realistic images tailored to specific environments, themes, or styles (Caruccio et al., 2024; Rapp et al., 2025), facilitating the rapid and efficient creation of essential visual infographics by suppliers. Furthermore, it can transform text information into vivid speech audio (Tapeh and Naser, 2023), offering additional options for advertising and marketing in the CGB sector. Through deep learning and big data analysis, Gen-AI can precisely depict users' consumption habits and preferences, facilitating personalized product recommendations. Moreover, by integrating seasonal, holiday, and regional factors, it can forecast trends in popular products, aiding platforms in precise product selection and enhancing sales conversion rates (Kirshner, 2024). Additionally, Gen-AI supports sentiment analysis by effectively evaluating feedback and reviews to promptly capture changes in user satisfaction, identify issues, and implement improvements. This process provides crucial decision support for optimizing products and services. The integration of Gen-AI further enhances the capabilities of customer service chatbots in the CGB sector, enabling them to respond more accurately to a broader range of questions, which not only reduces the workload on human customer service agents but also improves user experience (Zhu et al., 2022). Furthermore, Gen-AI exhibits advantages in intelligent scheduling and supply chain optimization (Fosso Wamba et al., 2023b), further contributing to enhanced operational efficiencies within the CGB sector.

The integrated development of Gen-AI has underscored its substantial potential across diverse fields. However, Gen-AI's industrial application is still in its early stages of development, and more research is needed to fully understand its practical application effects. We aim to examine the following research questions in the area of Gen-AI-powered CGB business processes.

RQ 1: What factors should suppliers and platforms consider when adopting Gen-AI?

RQ 2: How do these factors influence the strategic behaviors of suppliers and platforms?

RQ 3: Does the group leaders' service quality level, which is a crucial component of the CGB supply chain, affect the Gen-AI empowerment of platforms and suppliers?

For CGB members who want to use Gen-AI to seek improved business solutions, these are important but unanswered questions. Therefore, this paper focuses on the Gen-AI-empowered CGB and endeavors to analyze whether Gen-AI can promote CGB from the technology empowerment perspective. To address these important questions, a tripartite evolutionary game model is formulated to derive strategies of three key members involved in the CGB supply chain, including the supplier, the CGB platform, and the group leader. Evolutionary game theory (EGT) traces its origins to the imitator dynamics proposed by Abrams (2006) and Taylor and Jonker (1978). Evolutionary stability strategy (ESS) and imitator dynamics constitute the convergence process of the evolutionary game towards the equilibrium state and final stable state. Computer simulations are used to model the evolutionary dynamics of the strategies of key stakeholders. With advancements in the Internet and artificial intelligence (AI), EGT has been applied in various business applications to address challenges in forecasting, logistics and pricing (Wang et al., 2022). For enterprises, EGT offers a means to identify influential factors affecting enterprise development and to forecast future trends (Xing et al., 2023), making it particularly apt for addressing the issues explored in this paper.

The contributions of this research are threefold. Firstly, the paper introduces Gen-AI to the CGB sector, aiming at providing superior solutions for addressing the development challenges of CGB from the technology empowerment viewpoint. Secondly, while existing Gen-AI empowered management practices mainly focus on its advantages, it often overlooks the impact of Gen-AI adoption on related stakeholders' decision-making strategies. To bridge this gap, this study formulates an evolutionary game model to address the strategic behaviors of multiple key CGB stakeholders, including the supplier, the platform, and the group leader. Through evolutionary simulation experiments and sensitivity analysis under conditions of limited rationality, the detailed impacts of crucial factors related to Gen-AI adoption on strategic decision-making are derived. Finally, considering the practical challenges and potential errors associated with industrial applications (Choudhury and Shamszare, 2023), this paper highlights the potential risks and losses that may arise from integrating Gen-AI into CGB operations.

This paper is organized as follows. Section 2 presents an overview of the literature in line with the applicable work. Section 3 addresses the problem description and fundamental presumptions. The model analysis is performed in Section 4. The simulation experiments are conducted in Section 5. In Section 6, we highlight the research implications and key managerial insights. Finally, we present concluding remarks in Section 7.

2. Literature Review

In this section, we conduct a review of studies closely aligned with our research. These studies are categorized into two key streams: Community Group Buying (CGB) and Generative Artificial Intelligence (Gen-AI).

2.1. Community Group Buying (CGB)

In group-buying activities, sellers use group discounts to incentivize informed customers to act as sales agents, leveraging customers' interpersonal information and knowledge sharing to acquire more customers (Jing and Xie, 2011; Ni et al., 2015; Yan et al., 2017). With the growth of the internet, online group buying platforms have emerged. Compared to traditional offline group buying, those platforms significantly expanded the number of participants and the variety of products available to consumers. The more consumers interested in a product, the stronger the bargaining power between consumers and sellers, resulting in lower prices for the products they purchase (Lim et al., 2022). However, compared to other online trading mechanisms, insufficient participation in online group buying can lead to uncertainties regarding the final purchase price and the overall success of the group buying initiative (Sharma and Klein, 2020). Additionally, online group buying is less advantageous for products requiring fast delivery or with short shelf lives, especially fresh products.

With the rapid development of mobile e-commerce and the increased commonality of urban residents, CGB emerged in 2016 and began to gain visibility in 2018 (Sun and Zhang, 2022). During the COVID-19 pandemic in 2020, the CGB mode leveraged its economies of scale to facilitate procurement and distribution at the community level, serving as a significant complement to fresh retail scenarios. The entry of internet giants such as Alibaba, Pinduoduo, Meituan, and Didi further catalyzed the explosive growth of CGB (Lan and Yu, 2022). The swift progress of the platform economy and big data have boosted the digital transformation of the residents' consumption, making CGB a significant mode of daily fresh product procurement for Chinese consumers (Cadden et al., 2022; Spanaki et al., 2021; Sutherland and Jarrahi, 2018). In comparison to offline shopping, its primary advantages lie in convenience, time-saving, and home delivery. Compared to online consumption, the CGB mode is more focused on meeting diverse needs and reducing selection costs, allowing consumers to pool their purchasing power to buy products at lower prices (Lan and Yu, 2022). Li et al. (2012) stated that CGB leverages the advantages of online communities, facilitating faster group formation among consumers and enabling retailers to easily reach their target audience. To address the challenge of maintaining the quality of perishable products in CGB, Yu et al. (2022) proposed a redesign of order delivery and transportation services. This approach aims to reduce quality issues and mitigate revenue losses caused by product deterioration during delivery.

Faced with an increasing number of competitors entering the market, there is a heightened emphasis on optimizing the supply chain and infrastructure of the CGB. Many scholars have studied and analyzed how to bolster CGB's competitive edge from perspectives such as coordination mechanisms and pricing strategies. Lan and Yu (2022) introduced the revenue sharing-commission coordination contract into the CGB supply chain composed of a supplier, a group buying platform, and a group leader. Their results showed that the cooperation of the supply chain is driven by external forces, and the product quality of the supplier and the service level of the platform are crucial to improving the revenue of the system. Zhu et al. (2020) found that high-quality online reviews on CGB websites positively influence consumers' purchase frequency. Li et al. (2022) found that consumers are more inclined to spread positive word-of-mouth when they are more satisfied with the services provided by CGB. Therefore, effectively responding to consumer comments and improving the platform's ability to meet consumer demands are urgent problems that need to be addressed. The integration of big data and artificial intelligence has significantly enhanced the service level of CGB. Zhu et al. (2022) proposed that CGB platforms could leverage big data market analysis to establish an interactive relationship between consumer shopping preferences and corporate profitability, thereby facilitating the on-demand production of goods. Huang and Zhuang (2021) found that big data technology can be utilized to analyze user evaluations, commodity quality feedback, and warehousing and distribution processes, offering solutions to improve the operational efficiency of the CGB supply chain. Liu (2023) suggested that CGB can leverage big data and artificial intelligence to connect markets and sources of goods, thereby forming a comprehensive digital infrastructure network.

In an increasingly competitive market with diverse consumers choices, the continued development of CGB depends on its ability to align more closely with consumer demands. To expand the network scale of CGB, supply chain members must enhance consumer trust and boost consumption frequency by strengthening platform optimization and improving the quality of goods and services. The integration of big data and artificial intelligence is key in elevating the competitive level of CGB. Among emerging technologies, Gen-AI has attracted significant attention due to its disruptive innovations. Its applications in pattern identification, data analysis, and automation present significant potential to reshape the CGB business model. Consequently, this paper analyzes the introduction of Gen-AI into the CGB model and explores the integrated development from the perspective of technological empowerment.

2.2. Generative Artificial Intelligence (Gen-AI)

Gen-AI refers to a category of artificial intelligence systems that can exhibit functionality akin to human creativity by learning from existing data and generating new data. Differing from traditional AI systems, Gen-AI achieves higher levels of intelligence through self-training and deep learning. They possess the ability to create entirely new content, as opposed to merely processing and categorizing data based on input (Lim et al., 2023).

In 2022, leading global AI technology companies released a variety of products with applications across various domains (Kim et al., 2023). For instance, OpenAI's DALL-E-2 can generate high-quality images and provide specific descriptions, while Meta introduced Make-A-Video, which directly converts text into videos (Wu et al., 2023). A representative product of Gen-AI is ChatGPT, known for its advanced natural language processing capabilities and text generation (Saggu and Ante, 2023). It allows users to pose questions and obtain answers through conversation in a prompt-based intuitive interface. Highlighting its strengths in creative content generation and data recognition, Dowling and Lucey (2023) assessed the use of ChatGPT in academic research processes. They found that ChatGPT can generate reasonable research ideas, literature reviews, and research recommendations based on input commands. Additionally, by incorporating proprietary data into the study, ChatGPT showcases its advanced data processing capabilities, underscoring its potential influence on the information dissemination ecosystem.

The application of Gen-AI facilitates the rapid generation of substantial volumes of creative content, presenting novel opportunities for various industries (Grewal et al., 2024). Mich and Garigliano (2023) outlined the key features of ChatGPT and provided initial guidelines for its application in the tourism sector. Dwivedi et al. (2023) proposed the integration of ChatGPT with voice assistants to support hotels in various stages and backend operations. With environmental research increasingly relying on data science, programming skills have become essential. Zhu et al. (2023) suggested that ChatGPT's programming capabilities can assist researchers with limited programming skills by customizing code tailored to specific needs and providing explanations for complex or unfamiliar syntax. In the agricultural sector, Zhao et al. (2023) explored the systematic application of ChatGPT in text classification, testing its potential benefits for sustainable agricultural information management and improve efficiency in digital transformation. Fosso Wamba et al. (2023b) pointed out that Gen-AI can significantly boost supply chain productivity and efficiency. They noted that with the empowerment of Gen-AI, low-skilled workers can elevate their productivity to levels comparable to those of skilled workers in production activities.

Gen-AI has rapidly developed in a very short period, yet its integration into the CGB model is still in the exploratory phase. Current research indicates that Gen-AI holds significant potential to reshape the CGB business model. Beyond its well-established capabilities in text and video generation (Ali et al., 2023a; Ali et al., 2023b; Stokel-Walker, 2022), Gen-AI also shows promise in transforming operations and supply chain management (O&SCM) processes. For instance, early evidence suggests that GPT-4 can support supplier selection by evaluating supplier profiles based on specific parameters and instructions (Hendriksen, 2023). This capability enables CGB platform to enhance supplier management and mitigate risks. Furthermore, Gen-AI can revolutionize collaboration and communication among supply chain members (Wamba et al., 2023), improving customer inquiries and after-sales services. Additionally, Gen-AI can be leveraged into sales, demand forecasting, logistics optimization, and customer interactions (Fosso Wamba et al., 2023a; Grewal et al., 2024), significantly enhancing operational efficiency for CGB. However, the adoption of Gen-AI also presents several challenges, including concerns related to data sources, privacy, and copyright compliance (Lim et al., 2023; Vaishya et al., 2023). Oviedo-Trespalacios et al. (2023) cautioned that ChatGPT, while a rapid and cost-effective method of information collection, may result in incomplete data acquisition. Therefore, to enhance user trust and satisfaction, it is essential to protect user privacy and comply with copyright laws in the practical applications of Gen-AI.

Technological advancements present new opportunities for the further development of CGB. However, as both CGB and Gen-AI themes are relatively new research areas, the practical empowerment of Gen-AI on CGB remains in its early stages. Considering the potential challenges associated with integrating Gen-AI into the emerging CGB model, further exploration is needed to assess its feasibility and accessibility. Building on the work of Lan and Yu (2022), which centered on suppliers, platforms, and group leaders in CGB, our study contributes by analyzing the impact of introducing Gen-AI to boost business and broaden CGB's reach. To provide a clear understanding of our study's unique contributions within the broader context of the existing research, a comparative summary of relevant literature is presented in Table 1.

Table 1: Summary of key studies related to this paper.

Key Related Studies	CGB	Technological empowerment	Research field	Evolutionary game	Research objective
Lan and Yu (2022)	✓		Decision-making and coordination mechanism		Win-win revenue strategy
Ai (2021)	✓		Green product market	✓	Development of green market
Liu et al. (2022)			Smart logistics ecology	✓	Trends in ecological cooperation
Zhu et al. (2022)	✓	Big data	Demand forecasting		Optimization of grey model
Huang and Zhuang (2021)	✓	Big data	CGB supply chain costs management		Supply chain model enhancement
Tan et al. (2023)		Blockchain	Agricultural products traceability	✓	Farmers-blockchain platform interaction
Zhou et al.		Blockchain	Cross-border e-	✓	Blockchain adoption

(2023)			commerce information traceability		on strategic behaviors
Rapp et al. (2025)		Gen-AI	Text-to-image		Response to Gen-AI images
Grewal et al. (2024)		Gen-AI	Marketing		Potential and limitations of Gen-AI
Wamba et al. (2023)		Gen-AI	Operations and supply chain management (O&SCM)		Trends of ChatGPT/Gen-AI
This study	✓	Gen-AI	O&SCM and marketing	✓	Gen-AI adoption on strategic behaviors

The exponential growth of Gen-AI is radically changing how key stakeholders operate in digital environments. While existing literature has explored the substantial potential and theoretical highlights of Gen-AI in industry, its practical applications in various sectors, particularly in the emerging CGB scenario, remains underexplored. Given the complexities of real-world implementation, further research is needed to evaluate the feasibility and accessibility of Gen-AI integration in CGB. To bridge this gap, we try to introduce Gen-AI into the CGB for business promotion, thereby expanding its industrial applications. We develop an evolutionary game model comprising the platform, the supplier, and the group leader to examine the strategic behaviors and explore the evolutionary dynamics of Gen-AI-empowered CGB. Furthermore, the potential risks of Gen-AI adoption on crucial decision-making of stakeholders are also analyzed to help better understand the potential influence of Gen-AI employment in CGB. To validate our findings, extensive simulation experiments are conducted to derive critical insights for CGB promotion through Gen-AI empowerment.

3. Problem Description and Model Formulation

3.1. Problem Description

In the CGB supply chain, the supplier fulfills orders generated by the CGB platform. With the integration of Gen-AI, the supplier can adeptly create promotional content for their products and distribute it on the platform in the form of videos and text. Subsequently, the platform disseminates pre-sale information derived from the supplier's product data and entrusts the group leader with promoting it throughout the community. A Gen-AI-empowered CGB platform has the capacity to offer distinct order combinations tailored to consumer preferences. Moreover, the integration of Gen-AI can elevate the platform's customer service and after-sales support.

Consumers can access purchase promotions either through information shared by the group leader in WeChat groups or by directly visiting the platform to view recommended products. Once the group-buying event concludes, the platform coordinates the distribution of products to the group leader. Before the products reach the consumers, the group leader is responsible for product storage, order distribution, or facilitating self-pickup services. Additionally, the group leader handles after-sales support, ensuring ongoing communication with consumers. The quality of service provided by the group leader is vital for improving consumer stickiness, as consumers rely on the leader's services from the initial purchase to the final acquisition of products. A group leader with inadequate service levels can pose substantial risks to the promotion of the CGB business and negatively affect community consumption. Consumers typically engage in small, multi-batch purchases, and their frequency of repeat purchases significantly impacts CGB's profitability. This factor is essential in determining the future adoption of Gen-AI technology by both the platform and the supplier.

To better understand the dynamics of CGB, we construct a tripartite evolutionary game theory (EGT) model, which accounts for the progress of data-driven industrial transformation and the challenges faced by CGB. The key players in the evolutionary game are the supplier, the CGB platform, and the group leader. Both the supplier and the platform decide whether to adopt Gen-AI, while the group leader chooses the level of service provided to consumers based on their interests. EGT is particularly useful in analyzing the strategic decision-making behaviors of different stakeholders and the evolutionary trends within complex systems. In this study, EGT is applied to explore how various factors influence the strategy selection of CGB members. Next, we explain the CGB model structure without and with Gen-AI empowerment.

3.2. CGB structure without & with Gen-AI

To better present the functional operations of the CGB, we study the daily actions of a group leader. Assuming the group leader receives "Q" orders per day, the platform procures a specific category of products from the supplier at a unit wholesale price denoted as "w". These products are then offered to consumers at a unit retail price denoted as "p". Group leaders play a pivotal role by disseminating product information within WeChat groups and reminding consumers to either pick up their orders in person or opt for delivery services on the following day. They charge a commission from the platform for their service, denoted as "r". Consumer advocacy serves as a crucial source for acquiring customers in CGB. The service level of the group leader is crucial to improve the loyalty of community consumers in the fan groups. The group leader with a tarnished reputation is at a disadvantage in subsequent development within communities characterized by high social cohesion. Active service provided by the group leader incurs a certain cost, denoted as "C". Passive service from the group leader can detrimentally affect both the reputation of the supplier and the platform. We assume that "L" represents the losses incurred by the group leader due to their passive service. To prevent profit loss, the platform imposes a penalty for the group leader engaging in passive service, denoted by "M. The interplay among the three entities engaged in the evolutionary game is first presented without Gen-AI in Fig. 1(a) and then with Gen-AI in Fig. 1(b).

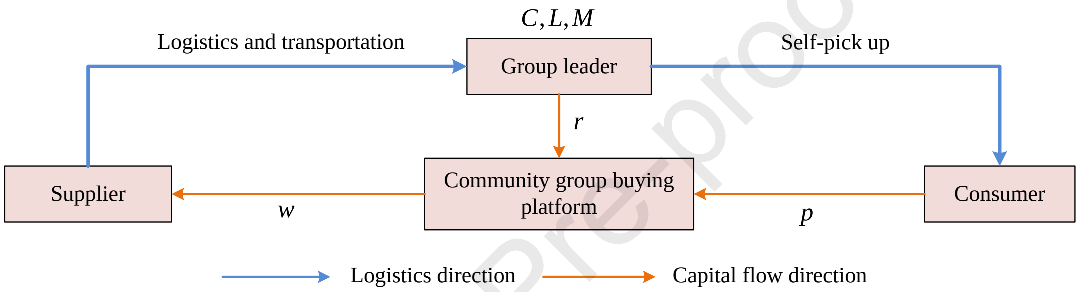


Fig. 1(a): CGB structure without Gen-AI.

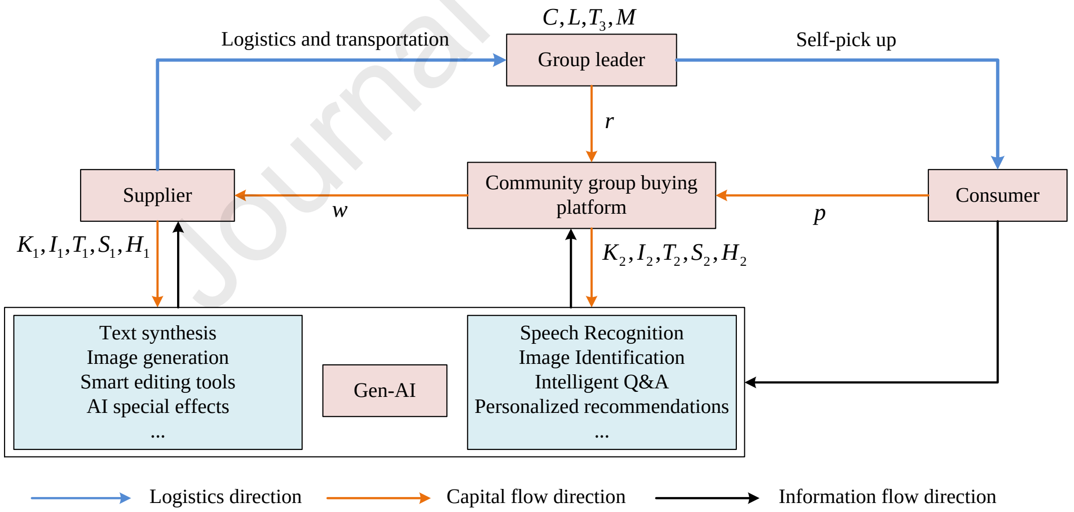


Fig. 1(b): The tripartite evolutionary game model of Gen-AI empowerment in CGB.

Fig. 1: CGB structure without & with Gen-AI.

3.3. Model Formulation

In constructing the game model, based on the problem description, the following assumptions are made. Given the complexity of the system, some intricate conditions are simplified without altering the essence of the research.

Assumption 1. The supplier is denoted as Participant 1, the community group-buying platform as

Participant 2, and the group leader as Participant 3. All three participants exhibit bounded rationality and engage in incomplete information exchange, leading to mutual influence in their strategic behaviors. Consequently, the game entities cannot obtain optimal decisions in a single play; instead, they engage in an ongoing learning process to optimize their strategic behaviors and obtain maximum revenue throughout the game (Hosseini-Motlagh et al., 2022; Zhou et al., 2023).

Assumption 2. The supplier and CGB platform make decisions regarding the adoption of Gen-AI empowerment based on their developmental needs, while the group leader autonomously determines the level of service they provide. Consequently, the strategies set for the supplier and the CGB platform are $\{$empower, not empower$\}$, while the group leader's strategy set comprises $\{$active service (AS), passive service (PS)$\}$. Assuming that the probability of the supplier choosing "empower" is denoted as x, and the probability of choosing "not empower" as $1-x$. The probability of the community group-buying platform choosing "empower" is denoted as y, with the probability of choosing "not empower" as $1-x$. Similarly, the probability of the group leader choosing "AS" is represented by z, while the probability of choosing "PS" by $1-z$.

Assumption 3. When the supplier and the CGB platform adopt Gen-AI empowerment, they are required to pay a certain service fee to the Gen-AI enterprise. The fees paid by the supplier and the CGB platform are denoted as "I_1" and "I_2", respectively. By using Gen-AI, the platform could offer more appropriate recommendations for consumers, providing necessary information during browsing and product selection. With more prompt and competent solutions, Gen-AI enhances the consumer experience, potentially increasing their platform preference and purchase willingness.

Assumption 4. The benefits of Gen-AI empowerment for the CGB platform and the supplier are analyzed, wherein the platform and its supplier gain from the beneficial influence on customers. It is assumed that the supplier and the CGB platform can achieve the benefit of "K_1" and "K_2" through the adoption of Gen-AI, respectively. However, when the supplier and the CGB platform employ Gen-AI technology, they may face risks such as providing false information, information leakage, and potential skepticism or aversion to technology. These risks can result in losses for the supplier and the CGB platform, represented by "S_1" and "S_2", respectively. In cases where the supplier and the CGB platform opt not to adopt Gen-AI empowerment, competitors in the market may choose to do so prematurely, which can have adverse effects on the market position of the supplier and the platform. The losses incurred due to missed competitive opportunities are denoted as "H_1" for the supplier and "H_2" for the platform.

Assumption 5. When the supplier and the CGB platform employ Gen-AI and the group leader provides active service, it results in an enhanced order response speed. Gen-AI technology empowerment aids in data analysis within the CGB system, improving the efficiency of logistics and warehousing operations. Particularly in CGB, it can reduce the spoilage of fresh products and improve consumer goodwill. Therefore, it can be posited that Gen-AI empowerment, in conjunction with active service by the group leader, can generate additional profits for each party, denoted as T_1, T_2, and T_3 respectively.

The variables and symbols mentioned above are presented in Table 2.

Table 2: Related parameters and assumptions.

Symbol form	Description
Q	Quantity of fresh food products handled by the group leader per day.
p	Unit retail price.
w	Unit wholesale price.
r	The commission rate charged by the group leader per unit of product. $(0 < r < 1)$
I_1	The cost of the supplier for Gen-AI empowerment.
I_2	The cost of the CGB platform for Gen-AI empowerment.
S_1	The risk losses incurred by the supplier when empowered by Gen-AI technology.
S_2	The risk losses incurred by the CGB platform when empowered by Gen-AI technology.
K_1	The benefits of Gen-AI empowerment for the supplier.
K_2	The benefits of Gen-AI empowerment for the CGB platform.
C	The cost of the group leader providing active service.
L	Losses incurred due to the group leader providing passive service.
T_1	The additional profits that the supplier can gain when the supplier and CGB platform employ Gen-AI empowerment, coupled with active service from the group leader.
T_2	The additional profits that the CGB platform can gain when the supplier and CGB platform employ Gen-AI empowerment, coupled with active service from the group leader.
T_3	The additional profits that the group leader can gain when the supplier and CGB platform employ Gen-AI empowerment, coupled with active service from the group leader.
M	The penalty imposed by the platform for the group leader engaging in passive service.
H_1	The losses faced by the supplier due to a lack of competitiveness.
H_2	The losses faced by the CGB platform due to a lack of competitiveness.

Based on the assumptions mentioned above, the payment matrix for the three-party game entities in CGB is presented in Table 3.

Table 3: Payment Matrix of the Supplier, CGB platform, and Group leader.

Supplier			Group leader: AS (z)	Group leader: PS $(1-z)$
Empower (x)	CGB platform	Empower (y)	$wQ - I_1 - S_1 + K_1 + T_1$ $(p-w-r)Q - I_2 - S_2 + K_2 + T_2$ $rQ - C + T_3$	$wQ - I_1 - S_1 + K_1$ $(p-w-r)Q - I_2 - S_2 + K_2 + M$ $rQ - L - M$
		Not empower $(1-y)$	$wQ - I_1 - S_1 + K_1$ $(p-w-r)Q - H_2$ $rQ - C$	$wQ - I_1 - S_1 + K_1$ $(p-w-r)Q - H_2 + M$ $rQ - L - M$
Not empower $(1-x)$	CGB platform	Empower (y)	$wQ - H_1$ $(p-w-r)Q - I_2 - S_2 + K_2$ $rQ - C$	$wQ - H_1$ $(p-w-r)Q - I_2 - S_2 + K_2 + M$ $rQ - L - M$
		Not empower $(1-y)$	$wQ - H_1$ $(p-w-r)Q - H_2$ $rQ - C$	$wQ - H_1$ $(p-w-r)Q - H_2 + M$ $rQ - L - M$

4. Model Analysis

4.1. Strategic Analysis of the Stakeholders

4.1.1. The Supplier Strategy

The fitness for the supplier choosing Gen-AI empowerment is represented as E_{11}.

$$\begin{gathered} E_{11} = yz[wQ - I_1 - S_1 + K_1 + T_1] + y(1-z)[wQ - I_1 - S_1 + K_1] \\ +(1-y)z[wQ - I_1 - S_1 + K_1] + (1-y)(1-z)[wQ - I_1 - S_1 + K_1] \\ = wQ - S_1 - I_1 + K_1 + yzT_1 \end{gathered} \tag{1}$$

The fitness for the supplier not choosing Gen-AI empowerment is denoted as E_{12}.

$$\begin{gathered} E_{12} = yz[wQ - H_1] + y(1-z)(wQ - H_1) + (1-y)z(wQ - H_1) \\ +(1-y)(1-z)(wQ - H_1) \\ = wQ - H_1 \end{gathered} \tag{2}$$

The average fitness for the supplier is given by $\overline{E_1}$.

$$\begin{gathered} \overline{E_1} = xE_{11} + (1-x)E_{12} \\ = wQ - (1-x)H_1 + x(K_1 - S_1 - I_1) + xyzT_1 \end{gathered} \tag{3}$$

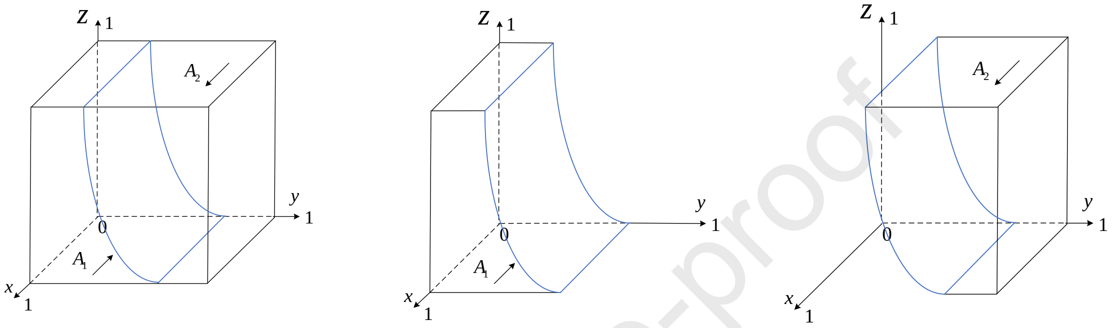
The replicator dynamics equation for supplier strategy selection is expressed as:

$$F(x) = \frac{dx}{dt} = x\left(E_{11} - \overline{E_1}\right) = -x(x-1)(H_1 - S_1 - I_1 + K_1 + yzT_1) \tag{4}$$

The first derivative of x is represented as：

$$\frac{dF(x)}{dx} = (1-2x)(H_1 - S_1 - I_1 + K_1 + yzT_1) \tag{5}$$

Let $G(y) = H_1 - S_1 - I_1 + K_1 + yzT_1$. Since $\frac{\partial G(y)}{\partial y} = zT_1 > 0$, $G(y)$ is an increasing function with respect to y. When $y = \frac{S_1 + I_1 - H_1 - K_1}{zT_1} = y^*$, we can get $G(y) = 0$, and in this case, $F(x) = 0$. Regardless of the probability at which the supplier chooses Gen-AI empowerment, the final strategy becomes a stable strategy. When $y \neq y^*$, let $F(x) = 0$, and we obtain two solutions, $x = 0$ and $x = 1$. When $y^* < y < 1$, we can obtain that $G(y) > 0$. In this case, $\left.\frac{dF(x)}{dx}\right|_{x=1} < 0$, and $x = 1$ is the Evolutionarily Stable Strategy (ESS) for the supplier. This means that when the probability of the supplier choosing Gen-AI empowerment is greater than y^*, the supplier chooses the "empower" strategy. Conversely, when it is less than y^*, $x = 0$ becomes the ESS. The evolutionary phase diagram for the supplier is depicted in Fig. 2.



$y = y^*$ $\quad$ $0 < y < y^*$ $\quad$ $y^* < y < 1$

Fig. 2: The evolutionary phase diagram for the supplier.

Based on the aforementioned analysis, in Part A_1, as x approaches 0, the supplier does not choose to empower with Gen-AI, with a probability denoted as V_{A_1}. In Part A_2, as x tends towards 1, the supplier opts to empower with Gen-AI, with a probability denoted as V_{A_2}, and $V_{A_2} = 1 - V_{A_1}$.

4.1.2. The CGB Platform Strategy

The fitness for the CGB platform choosing Gen-AI empowerment is represented as E_{21}.

$$\begin{aligned} E_{21} &= xz[(p-w-r)Q - I_2 - S_2 + K_2 + T_2] + (1-x)z[(p-w-r)Q - I_2 - S_2 + K_2] \\ &\quad + x(1-z)[(p-w-r)Q - I_2 - S_2 + K_2 + M] \\ &\quad + (1-x)(1-z)[(p-w-r)Q - I_2 - S_2 + K_2 + M] \\ &= (p-w-r)Q - I_2 - S_2 + K_2 + (1-z)M + xzT_2 \end{aligned} \tag{6}$$

The fitness for the CGB platform not choosing Gen-AI empowerment is denoted as E_{22}.

$$\begin{aligned} E_{22} &= xz[(p-w-r)Q - H_2] + x(1-z)[(p-w-r)Q - H_2 + M] \\ &\quad + (1-x)z[(p-w-r)Q - I_2 - S_2 + K_2] \\ &\quad + (1-x)(1-z)[(p-w-r)Q - I_2 - S_2 + K_2 + M] \\ &= (p-w-r)Q - H_2 + (1-z)M \end{aligned} \tag{7}$$

The average fitness for the CGB platform is given by $\overline{E_2}$.

$$\begin{aligned} \overline{E_2} &= yE_{21} + (1-y)E_{22} \\ &= (p-r-w)Q + (1-z)M - (1-y)H_2 + y(K_2 - S_2) + xyzT_2 \end{aligned} \tag{8}$$

The replicator dynamics equation for CGB platform strategy selection is expressed as:

$$F(y) = \frac{dy}{dt} = y(E_{21} - \overline{E_2}) \\ = -y(y-1)(H_2 - I_2 + K_2 - S_2 + xzT_2) \quad (9)$$

The first derivative of y is represented as:

$$\frac{dF(y)}{dy} = (1-2y)(H_2 - I_2 + K_2 - S_2 + xzT_2) \quad (10)$$

Let $P(z) = H_2 - I_2 + K_2 - S_2 + xzT_2$. Since $\frac{\partial P(z)}{\partial z} = xT_2 > 0$, $P(z)$ is an increasing function with respect to z. When $z = \frac{I_2+S_2-K_2-H_2}{xT_2} = z^*$, we can get $P(z) = 0$, and in this case, $F(y) = 0$. Regardless of the probability at which the CGB platform chooses Gen-AI empowerment, the final strategy becomes a stable strategy. When $z \neq z^*$, let $F(y) = 0$, and we obtain two solutions, $y = 0$ and $y = 1$. When $z^* < z < 1$, we can obtain that $P(z) > 0$. In this case, $\frac{dF(y)}{dy}\Big|_{y=1} < 0$, and $y = 1$ is the Evolutionarily Stable Strategy (ESS) for the CGB platform. This means that when the probability of the CGB platform choosing Gen-AI empowerment is greater than z^*, the CGB platform chooses the "empower" strategy. Conversely, when it is less than z^*, $y = 0$ becomes the ESS. The evolutionary phase diagram for the CGB platform is depicted in Fig. 3.

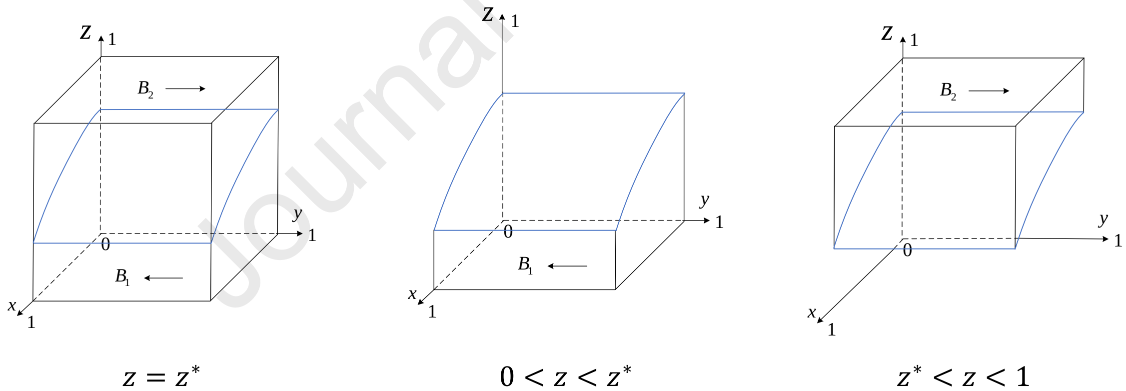


Fig. 3: The evolutionary phase diagram for the CGB platform.

Based on the aforementioned analysis, in Part B_1, as y approaches 0, the CGB platform does not choose to empower with Gen-AI, with a probability denoted as V_{B_1}. In Part B_2, as y tends towards 1, the CGB platform opts to empower with Gen-AI, with a probability denoted as V_{B_2}, and $V_{B_2} = 1 - V_{B_1}$.

4.1.3. The Group Leader Strategy

The fitness for the group leader choosing active service is represented as E_{31}.

$$E_{31} = xy(rQ - C + T_3) + x(1-y)(rQ - C) \\ +(1-x)y(rQ - C) + (1-x)(1-y)(rQ - C) \\ = rQ - C + xyT_3 \quad (11)$$

The fitness for the group leader choosing passive service is denoted as E_{32}.

$$\begin{gathered} E_{32} = xy(rQ - L - M) + x(1-y)(rQ - L - M) \\ +(1-x)y(rQ - L - M) + (1-x)(1-y)(rQ - L - M) \\ = rQ - M - L \end{gathered} \tag{12}$$

The average fitness for the group leader is given by $\overline{E_3}$.

$$\begin{gathered} \overline{E_3} = zE_{31} + (1-z)E_{32} \\ = rQ - zC - (1-z)(L+M) + xyzT_3 \end{gathered} \tag{13}$$

The replicator dynamics equation for group leader strategy selection is expressed as:

$$\begin{gathered} F(z) = \frac{dz}{dt} = z(E_{31} - \overline{E_3}) \\ = -z(z-1)(L - C + M + xyT_3) \end{gathered} \tag{14}$$

The first derivative of z is represented as:

$$\frac{dF(z)}{dz} = (1-2z)(L - C + M + xyT_3) \tag{15}$$

Let $Q(x) = L - C + M + xyT_3$. Since $\frac{\partial Q(x)}{\partial x} = yT_3 > 0$, $Q(x)$ is an increasing function with respect to x. When $x = \frac{C-L-M}{yT_3} = x^*$, we can get $Q(x) = 0$, and in this case, $F(z) = 0$. Regardless of the probability at which the group leader chooses active service, the final strategy becomes a stable strategy. When $x \neq x^*$, let $F(z) = 0$, and we obtain two solutions, $z = 0$ and $z = 1$. When $0 < x < x^*$, we can obtain that $Q(x) > 0$. In this case, $\left.\frac{dF(z)}{dz}\right|_{z=0} < 0$, and $z = 0$ is the Evolutionarily Stable Strategy (ESS) for the group leader. This means that when the probability of the group leader choosing active service is less than x^*, the group leader chooses the "PS" strategy. Conversely, $z = 1$ becomes the ESS when the probability of the group leader choosing active service is greater than x^*. The evolutionary phase diagram for the group leader is depicted in Fig. 4.

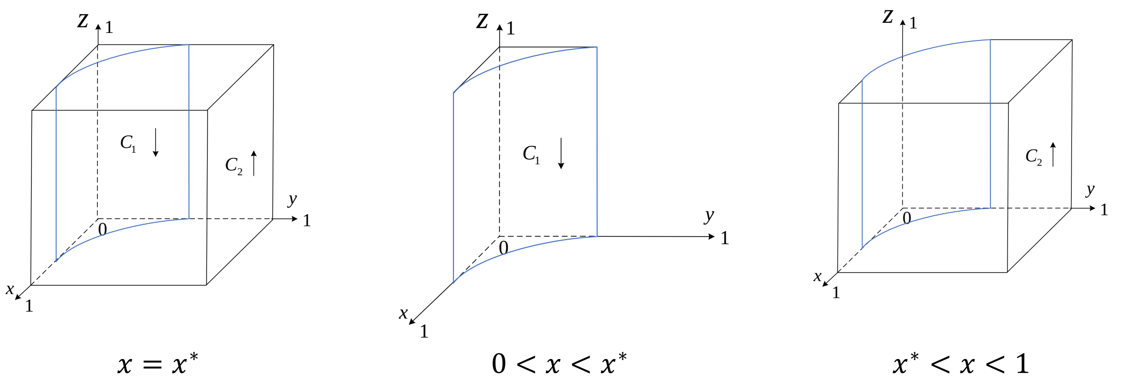


Fig. 4: The evolutionary phase diagram for the leader group.

Based on the aforementioned analysis, in Part C_1, as z approaches 0, the group leader chooses the

"PS" strategy with a probability denoted as V_{C_1}. In Part C_2, as z tends towards 1, the group leader opts to choose the "AS" strategy with a probability denoted as V_{C_2}, and $V_{C_1} = 1 - V_{C_2}$.

4.2. Equilibrium Points in the Evolutionary Game Model

Let $F(x) = 0$, $F(y) = 0$, and $F(z) = 0$, which yields eight system equilibrium points: $D_1 = (0,0,0)$, $D_2 = (1,0,0), D_3 = (0,1,0), D_4 = (0,0,1), D_5 = (1,1,0), D_6 = (1,0,1), D_7 = (0,1,1)$, and $D_8 = (1,1,1)$. Based on the replicator dynamics equations for the supplier, CGB platform, and group leader, we can derive the Jacobian matrix J for the dynamic evolutionary system.

$$J = \begin{bmatrix} \frac{\partial F(x)}{\partial x} & \frac{\partial F(x)}{\partial y} & \frac{\partial F(x)}{\partial z} \\ \frac{\partial F(y)}{\partial x} & \frac{\partial F(y)}{\partial y} & \frac{\partial F(y)}{\partial z} \\ \frac{\partial F(z)}{\partial x} & \frac{\partial F(z)}{\partial y} & \frac{\partial F(z)}{\partial z} \end{bmatrix}$$

$$J = \begin{bmatrix} (1-2x)\begin{pmatrix} H_1 - S_1 - I_1 \\ +K_1 + yzT_1 \end{pmatrix} & -xz(x-1)T_1 & -xy(x-1)T_1 \\ -yz(y-1)T_2 & (1-2y)\begin{pmatrix} H_2 - I_2 + K_2 \\ -S_2 + xzT_2 \end{pmatrix} & -xy(y-1)T_2 \\ -yz(z-1)T_3 & -xz(z-1)T_3 & (1-2z)[L - C + M + xyT_3] \end{bmatrix} \tag{16}$$

We calculate the eigenvalues of the equilibrium points by substituting them into the Jacobian matrix, as presented in Table 4.

Table 4: Eigenvalues and stability conditions for each equilibrium point.

Equilibrium points	Eigenvalues	Attributes	Conditions of ESS
$D_1 = (0,0,0)$	$H_1 + K_1 - S_1 - I_1$ $H_2 + K_2 - S_2 - I_2$ $L - C + M$	ESS	A
$D_2 = (1,0,0)$	$S_1 + I_1 - H_1 - K_1$ $H_2 + K_2 - S_2 - I_2$ $L - C + M$	ESS	B
$D_3 = (0,1,0)$	$H_1 + K_1 - S_1 - I_1$ $S_2 + I_2 - H_2 - K_2$ $L - C + M$	ESS	C
$D_4 = (0,0,1)$	$H_1 + K_1 - S_1 - I_1$ $H_2 + K_2 - S_2 - I_2$ $C - L - M$	ESS	D
$D_5 = (1,1,0)$	$S_1 + I_1 - H_1 - K_1$ $S_2 + I_2 - H_2 - K_2$ $L - C + M + R_3 + T_3$	ESS	E
$D_6 = (1,0,1)$	$S_1 + I_1 - H_1 - K_1$ $H_2 + K_2 + T_2 - S_2 - I_2$ $C - L - M$	ESS	F
$D_7 = (0,1,1)$	$H_1 + K_1 + T_1 - S_1 - I_1$ $S_2 + I_2 - H_2 - K_2$ $C - L - M$	ESS	G
$D_8 = (1,1,1)$	$S_1 + I_1 - H_1 - K_1 - T_1$ $S_2 + I_2 - H_2 - K_2 - T_2$ $C - L - M - T_3$	ESS	H

According to the Lyapunov stability criterion, it is known that a point is considered an ESS when all eigenvalues are negative (Johari and Hosseini-Motlagh, 2022; Tan et al., 2023). To determine whether points $D_1 = (0,0,0)$, $D_2 = (1,0,0)$, $D_3 = (0,1,0)$, $D_4 = (0,0,1)$, $D_5 = (1,1,0)$, $D_6 = (1,0,1)$, $D_7 = (0,1,1)$, and $D_8 = (1,1,1)$ satisfy the sign requirements for an ESS, an assessment is necessary.

Table 5: Description of conditions.

Conditions of ESS	Description of conditions
A	$H_1 + K_1 < S_1 + I_1, H_2 + K_2 < S_2 + I_2, L + M < C$
B	$S_1 + I_1 < H_1 + K_1, H_2 + K_2 < S_2 + I_2, L + M < C$
C	$H_1 + K_1 < S_1 + I_1, S_2 + I_2 < H_2 + K_2, L + M < C$
D	$H_1 + K_1 < S_1 + I_1, H_2 + K_2 < S_2 + I_2, C < L + M$
E	$S_1 + I_1 < H_1 + K_1, S_2 + I_2 < H_2 + K_2, L + M + T_3 < C$
F	$S_1 + I_1 < H_1 + K_1, H_2 + K_2 + T_2 < S_2 + I_2, C < L + M$
G	$H_1 + K_1 + T_1 < S_1 + I_1, S_2 + I_2 < H_2 + K_2, C < L + M$
H	$S_1 + I_1 < H_1 + K_1 + T_1, S_2 + I_2 < H_2 + K_2 + T_2, C < L + M + T_3$

Based on the industry life cycle theory, this study divides the adoption of Gen-AI empowerment in CGB into three stages: the introduction stage, the growth stage, and the maturity stage. An analysis of stable equilibrium points corresponding to the characteristics of each stage is outlined below.

Introduction stage: In the initial stage of Gen-AI empowerment, the supplier and CGB platforms often hesitate about the strategy selection as the effectiveness and risks of its use are both unknown. During this time, the group leader's active service does not significantly improve the competitiveness of CGB. Therefore, the costs of the game entities exceed the benefits when condition A is met. At this stage, the system's ESS is $D_1 = (0,0,0)$, indicating that the strategy combination chosen by the three parties is {Not empower, Not empower, NS}.

Growth stage: As Gen-AI advances and its applications in relevant fields grow, CGB with Gen-AI empowerment enters the growth stage. In this stage, there are six equilibrium points. When condition B is met, the benefits obtained by the supplier from Gen-AI empowerment outweigh the costs, resulting in a system ESS of $D_2 = (1,0,0)$. Condition C leads to a system ESS of $D_3 = (0,1,0)$, as the benefits obtained by the platform from Gen-AI empowerment outweigh the costs. However, when condition D is met, the losses incurred by the group leader for negative service and penalties are higher than the costs of active service, resulting in a system ESS of $D_4 = (0,0,1)$. Condition E results in a system ESS of $D_5 = (1,1,0)$, where both the supplier and platform benefit from Gen-AI empowerment, though the cost of active service by the group leader is relatively high. In condition F, the platform's cost and risk loss from applying Gen-AI empowerment outweigh its benefits, leading to a system ESS of $D_6 =$

$(1,0,1)$. Finally, condition G, where the costs and risk losses for the supplier applying Gen-AI empowerment are relatively high, results in a system ESS of $D_7 = (0,1,1)$.

Maturity stage: When Gen-AI-empowered CGB reaches a certain scale in the market, the model of improving competitiveness through Gen-AI empowerment in CGB enters the mature stage. The supplier and the platform applying Gen-AI empowerment can maximize their benefits, and the benefits obtained by the group leader from providing active services exceed the costs when condition H is met. At this stage, the system's ESS is $D_8 = (1,1,1)$, indicating that the strategic behaviors of the three entities are {Empower, Empower, AS}.

5. Simulation Experiments

From the analysis of system stability, it is evident that different parameter and variable relationships result in varying behaviors of the supplier, platform, and group leader. To further verify the accuracy of the model, we use MATLAB software to simulate the evolutionary process of the three entities under different parameter settings. To the best of our knowledge, this is one of the first attempts to simulate the operations of CGB with Gen-AI empowerment.

5.1. Evolutionary Results of the Initial Strategy

To verify whether the strategic behaviors of the three entities in conditions $S_1 + I_1 < H_1 + K_1 + T_1, S_2 + I_2 < H_2 + K_2 + T_2, C < L + M + T_3$ meet the criteria for D_8 to serve as an equilibrium point, a simulation experiment is conducted on the evolutionary game trajectory of the three parties. Based on research on the operation of CGB platforms such as Meituan Youxuan and Didi, it is found that group leaders typically receive commissions ranging from 10% to 15% of the unit product price. In this study, this commission rate is set as $r = 0.1$. In the CGB platform, consumers mainly purchase fresh fruits and vegetables. Although the quantity of each product is relatively small, there is a wide variety of items available. Therefore, product prices and quantities are set based on average community size and market prices as follows: $Q = 50, p = 5, w = 3$. According to the conditions for satisfying the equilibrium point and the assignment of references, the initial values of other related variables are as follows (Lan and Yu, 2022; Ma et al., 2021; Yu et al., 2022): $Q = 50, p = 5, w = 3, r = 0.1,\ I_1 = 30,\ I_2 = 50,$ $S_1 = 15,\ S_2 = 25,\ K_1 = 30,\ K_2 = 45,\quad C = 30,\ T_1 = 10,\ T_2 = 20,\ T_3 = 10,\ L = 20,\ M = 15,$ $H_1 = 20,\ H_2 = 20$. The initial probability of the model is set as $(0.3,0.3,0.3)$ (Tan et al., 2023).

Fig. 5 shows the flow of the key parameters from input to output, while Fig. 6 presents the tripartite strategy evolutionary trajectories. From Fig. 5 and Fig. 6, we find that the final stable strategy in the tripartite evolutionary game is (1, 1, 1). In this scenario, the supplier and the CGB platform opt for Gen-AI empowerment, while the group leader adopts the "AS" strategy. Upon validating the simulation analysis, the results presented in Fig. 5 and Fig. 6 are found to be consistent with the conclusions drawn from the strategy stability analysis of each party, which demonstrates the effectiveness of the model.

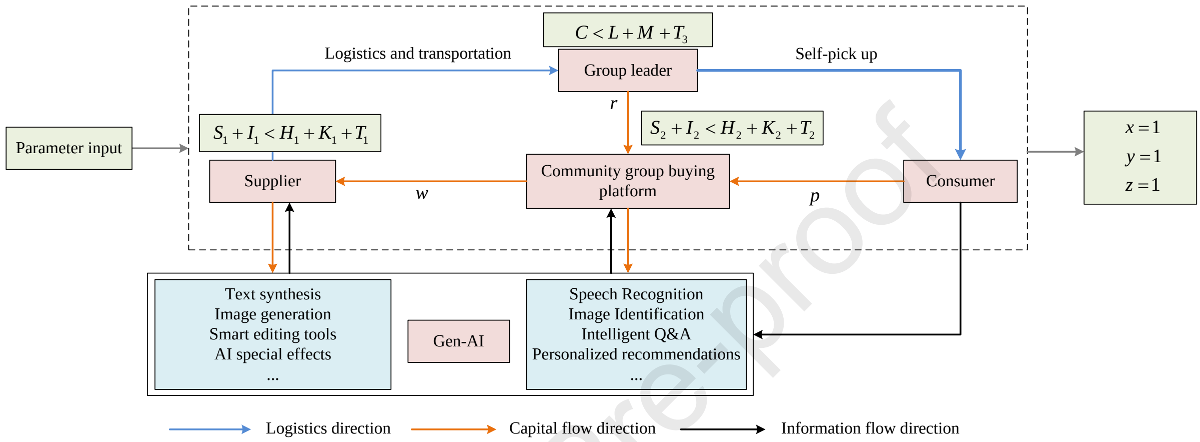


Fig. 5: The strategic behaviors of the three entities.

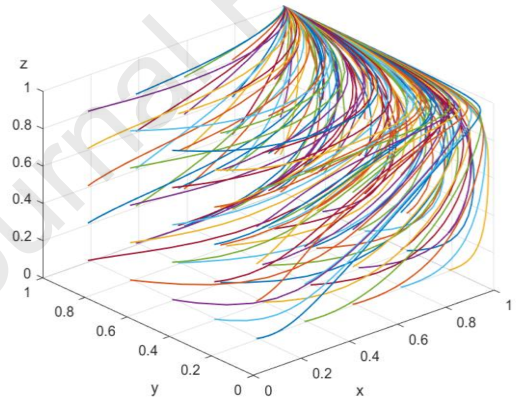
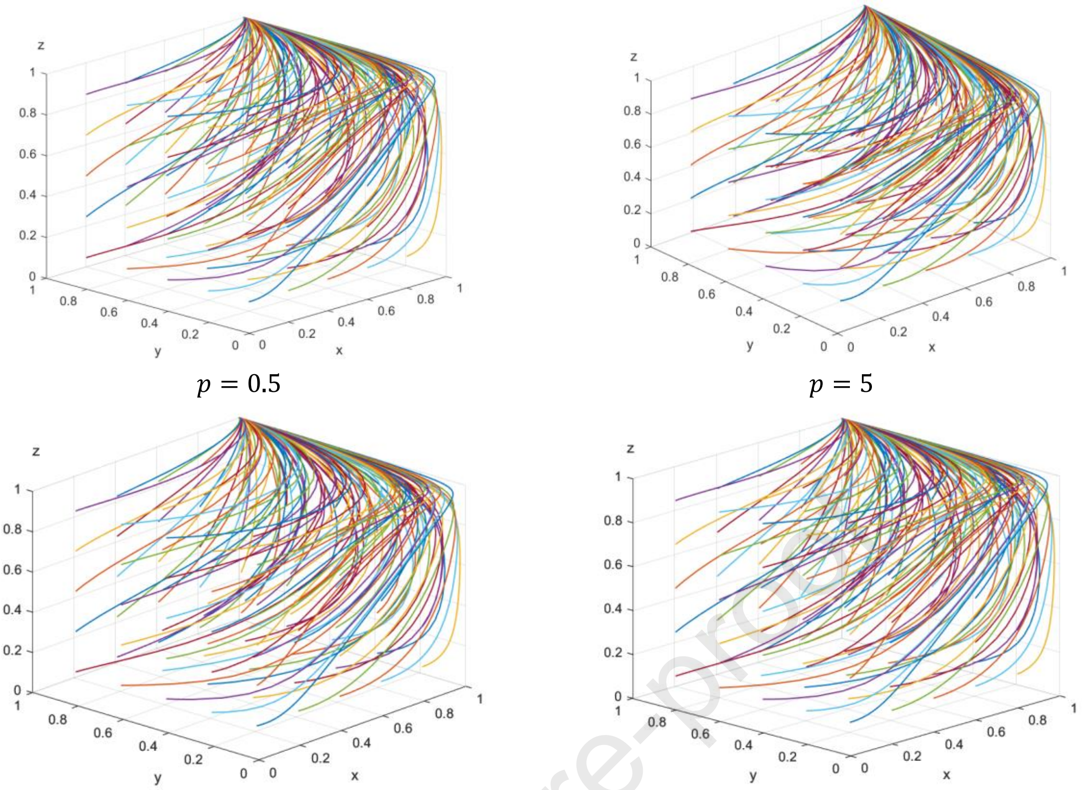


Fig. 6: The tripartite strategy evolutionary trajectories.

To assess the robustness of the formulated model, we conducted a sensitivity analysis by studying the specific influence of crucial parameters on the simulation results. We analyze the robustness of the model by setting different scenarios for retail price p ($p = 0.5, 5, 10, 20$) and wholesale price w ($w = 0.1, 3, 10, 20$). The detailed sensitivity analysis results are shown in the following figures.

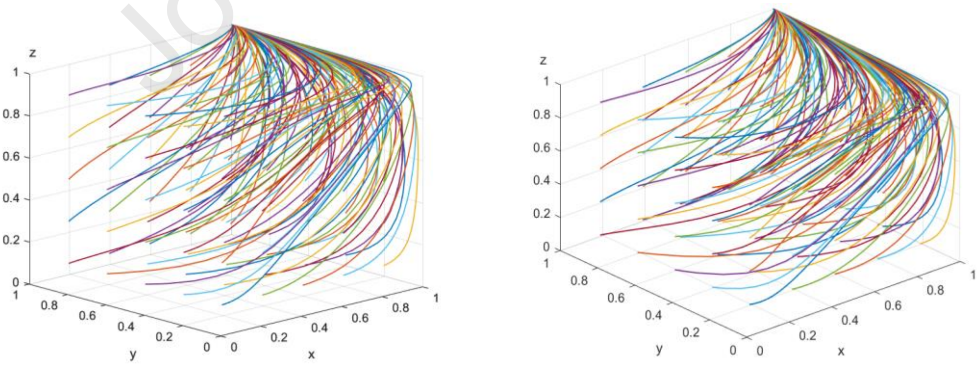


$p = 0.5$ $p = 5$

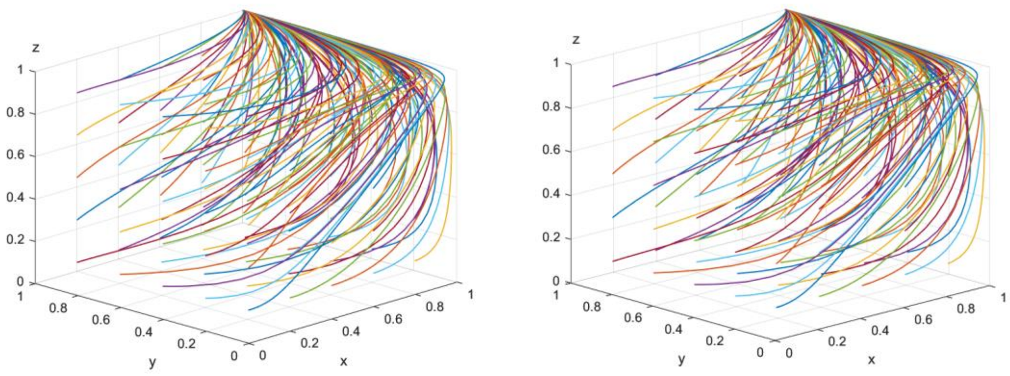
$p = 10$ $p = 20$

Fig. 7: The tripartite strategy evolutionary trajectories.

The tripartite strategy evolutionary trajectories are presented in Fig. 7 for different retail prices ($p = 0.5, 5, 10, 20$). From the sensitivity analysis, the stable strategies of the tripartite evolution game are all (1, 1, 1) for the four experiment scenarios. It means that the CGB platform and the supplier will adopt Gen-AI empowerment, while the group leader will adopt the AS strategy.



$w = 0.1$ $w = 3$



$w = 10$ $w = 20$

Fig. 8: The tripartite strategy evolutionary trajectories.

The tripartite strategy evolutionary trajectories are presented in Fig. 8 for different wholesale prices ($w = 0.1, 3, 10, 20$). Similar to the research findings with the sensitivity analysis on p, all these practical scenarios have the same final stable strategy in terms of different wholesale prices.

According to the above-mentioned sensitivity analysis, the stable strategies of different participants and the evolution process demonstrate robustness when p and w change. The sensitivity analysis confirms the effectiveness and robustness of the formulated model, ensuring the generality of the Gen-AI-empowered CGB business.

5.2. Simulation Analysis of Crucial Parameters

The equilibrium point D_8 (1, 1, 1) is regarded as the initial condition to examine the impact of changing one parameter while keeping the others constant. The initial probabilities of the model are uniformly set as (0.3, 0.3, 0.3).

5.2.1 The Impact of the Cost Changes on the Evolution Path

Fig. 9(a) and Fig. 9(b) illustrate how changes in the costs incurred by the supplier and CGB platform when choosing Gen-AI empowerment influence the evolutionary paths of the three parties in the CGB. Fig. 9(c) illustrates the impact of changes in the service cost of the group leader on the evolutionary paths of the three participants.

From Fig. 9(a), it can be observed that as I_1 increases, the convergence speed of x towards 1 gradually decreases. When I_1 exceeds a certain threshold, this convergence speed diminishes to 0. The strategies of the three parties transform from (1, 1, 1) to (0, 0, 1). In Fig. 9(b), as I_2 increases, the strategies of the three parties shift from (1, 1, 1) to (1, 0, 1), while the speed of y convergence towards 0 increases with the growth of I_2. It is evident that as C increases, the convergence speed of both y and z toward 1 decrease in Fig. 9(c). Furthermore, when C exceeds a certain threshold, y and z eventually, stabilize at 0. This leads to a transition in the strategy from {Empower, Empower, AS} to {Empower, Not Empower, PS}.

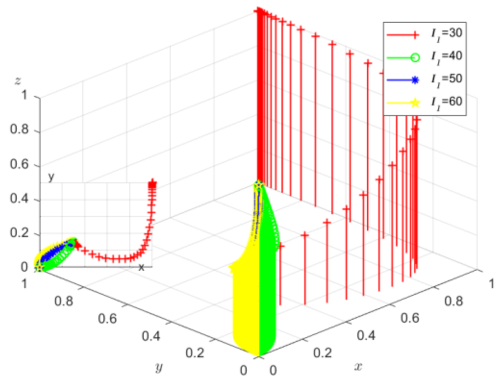


Fig. 9(a): Changes in the cost of the supplier when Gen-AI empowerment.

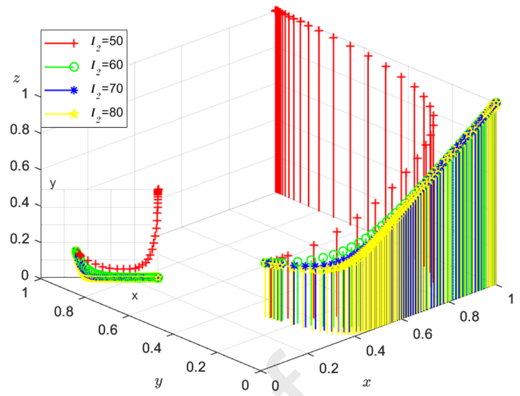


Fig. 9(b): Changes in the cost of the platform when Gen-AI empowerment.

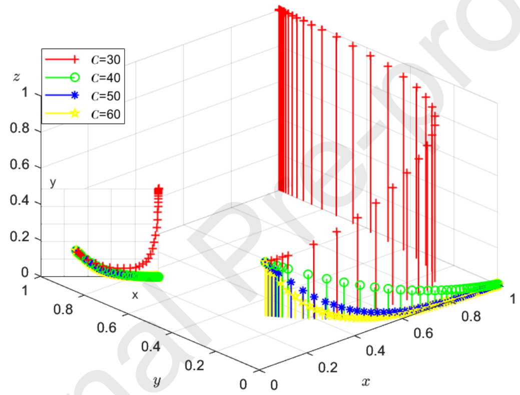


Fig. 9(c): Changes in the service cost of the group leader.

Fig. 9: Effect of the cost changes on the evolution of the tripartite game system.

Fig. 9(a) and Fig. 9(b) highlight that the probability of the supplier and platform choosing Gen-AI empowerment gradually decreases as the Gen-AI empowerment costs increase. Moreover, when the technological empowerment costs exceed a certain threshold, Gen-AI empowerment is no longer chosen. This underscores the significance of AI empowerment costs as a crucial factor in the technological adoption decisions of the supplier and platform. Elevated Gen-AI empowerment costs impose a heavier burden on the supplier and platform, reducing their likelihood of adopting the technology. Furthermore, an increase in I_1 can lead to the platform refraining from choosing Gen-AI empowerment. This is because if the supplier does not adopt Gen-AI, the supplier cannot provide effective product and logistics information, which hinders the platform's ability to enhance warehousing and delivery efficiency or attract consumers with robust support. Faced with substantial Gen-AI empowerment costs, the platform tends to opt out of Gen-AI empowerment.

According to Fig. 9(c), the service cost of the group leader is a critical consideration in strategic behaviors. An increase in service cost places a heavier burden on the group leader, lowering the probability of opting for active service. For the platform, when the group leader adopts a strategy of "PS", the products are directly delivered to consumers regardless of the product quality, leading to inadequate protection of consumers' rights. Even if the platform adopts Gen-AI empowerment, customers may reduce their purchase frequency due to the group leader's passive service. Given the high cost associated with Gen-AI empowerment, the platform is more inclined not to choose Gen-AI empowerment in such scenarios.

5.2.2. Evolutionary Results of the Change in Profits

Fig. 10(a) and Fig. 10(b) illustrate how the changes in profits obtained by the supplier and the CGB platform when adopting Gen-AI empowerment influence the evolutionary paths of the three main actors in the game. Fig. 10(c), Fig. 10(d), and Fig. 10(e) illustrate the evolutionary paths of the three-party strategy selection as additional benefits change when the supplier and CGB platform adopt Gen-AI empowerment, and the group leader chooses "AS" strategy to enhance the operational efficiency of the CGB system. From Fig. 10(a), it can be observed that when the value of K_1 is relatively low, both x and y converge to 0. As K_1 increases, the convergence speed of x and y towards 1 gradually increases. Consequently, the strategies of the three actors in the evolutionary game transition from (0, 0, 1) to (1, 1, 1). The strategies of the three parties shift from (1, 0, 1) to (1, 1, 1) when K_2 equal to 35 in Fig. 10(b). Additionally, the convergence speed of y towards 1 becomes more pronounced with the increase of K_2. In Fig. 10(c) and Fig. 10(e), as T_1 and T_3 increases, the convergence speed of the three parties towards 1 experience a slight increase, but the overall trend is not very pronounced. However, y tends to converge towards 0 when T_2 is set to 10 in Fig. 10(d). Beyond a certain threshold, y converges to 1, with the convergence speed gradually increasing as T_2 rises.

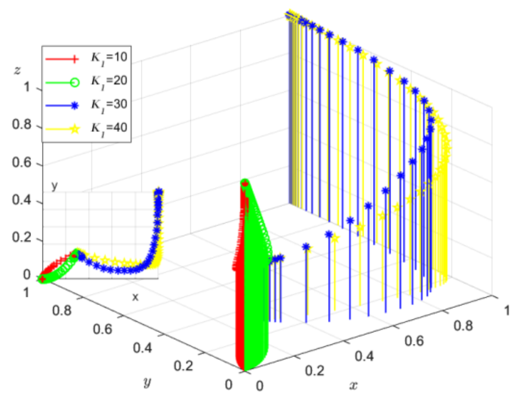


Fig. 10(a): Changes in profits obtained by the supplier when empowering Gen-AI.

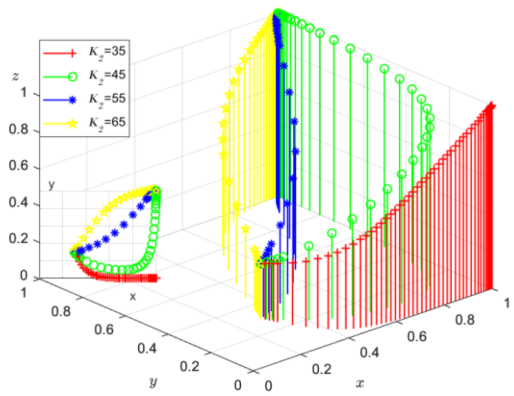


Fig. 10(b): Changes in profits obtained by the platform when empowering Gen-AI.

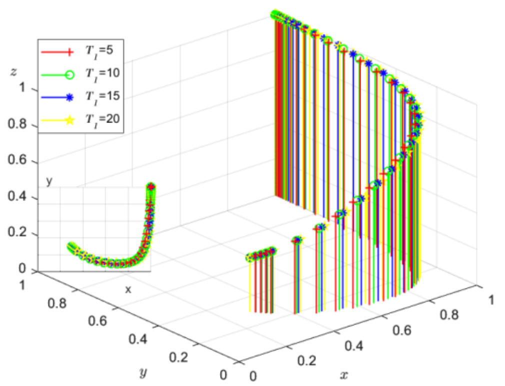


Fig. 10(c): Changes in the additional profits as the supplier opts for Gen-AI empowerment.

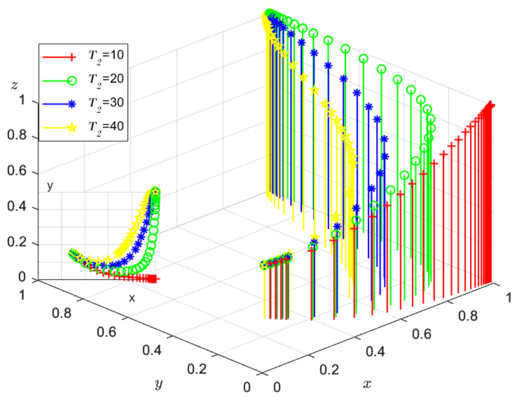


Fig. 10(d): Changes in the additional profits as the platform opts for Gen-AI empowerment.

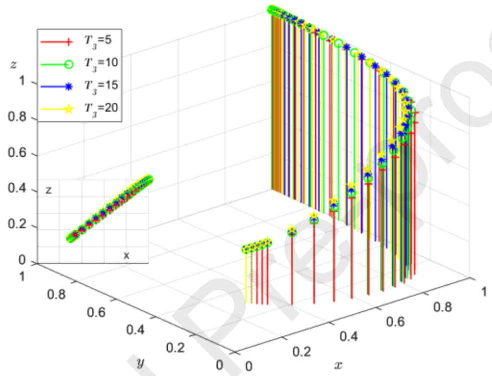


Fig. 10(e): Changes in the additional profits as the group leader chooses the "AS" strategy.

Fig. 10: Evolutionary path simulation of the tripartite game system as the profits change.

The findings from Fig. 10(a) and Fig. 10(b) indicate that the probability of the supplier and the platform choosing Gen-AI empowerment increases as the additional benefits derived from technology empowerment grow. Therefore, Gen-AI companies servicing CGB systems should focus on enhancing value-added services for the supplier and platform, including improving inventory and quality management efficiency, as well as optimizing and enhancing platform operations. Additionally, Gen-AI companies can offer personalized services to enhance customer satisfaction, making it a central focus of their operations. In Fig. 10(c), Fig. 10(d), and Fig. 10(e), it is evident that the impact on the platform is the most significant when the supplier and platform choose Gen-AI empowerment, and the group leader opts for active service. To enhance supply chain collaboration efficiency through Gen-AI empowerment, the platform can provide suitable incentives to the supplier and group leader, encouraging more proactive participation across the supply chain.

5.2.3. Effect of the Losses Change on the Evolution Path

Fig. 11(a) and Fig. 11(b) present how the changes in losses incurred by the supplier and the CGB platform as other competitors in the market adopt Gen-AI empowerment in advance influence the evolutionary paths of the three parties. Fig. 11(c) and Fig. 11(d) illustrate the evolutionary paths of the three-party strategy selection in response to changes in risk losses (S_1 and S_2) incurred by the supplier and platform when choosing the strategy of "empower". Fig. 11(e) depicts the evolutionary paths of the three parties as the losses of the group leader from passive service vary at values of 5, 10, 15, and 20.

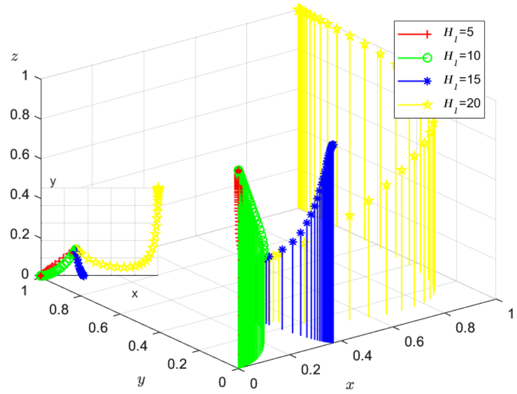


Fig. 11(a): Changes of losses of the supplier as other competitors adopt Gen-AI empowerment in advance.

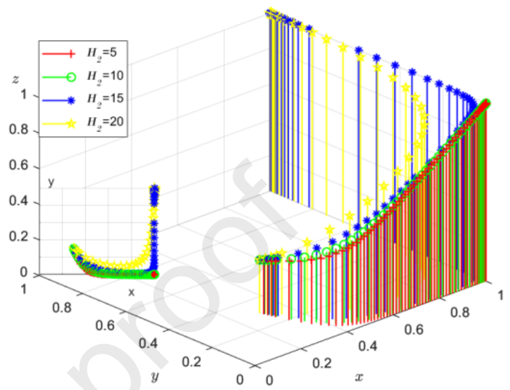


Fig. 11(b): Changes of losses of the platform as other competitors adopt Gen-AI empowerment in advance.

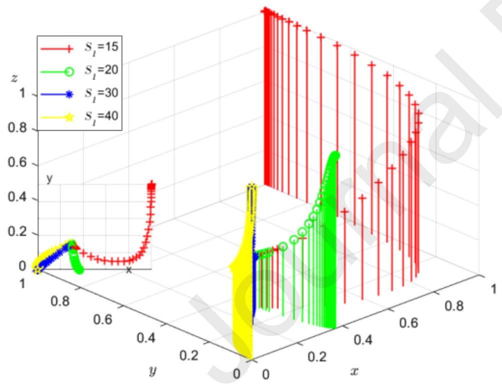


Fig. 11(c): Changes in risk losses of the supplier incurred by choosing Gen-AI empowerment.

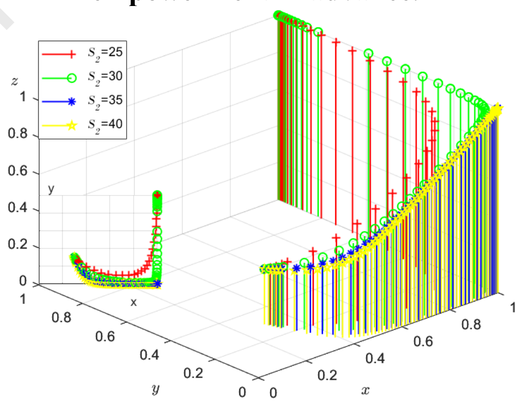


Fig. 11(d): Changes in risk losses of the CGB platform incurred by choosing Gen-AI empowerment.

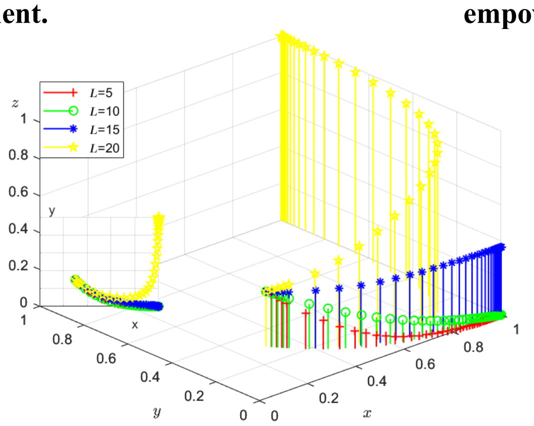


Fig. 11(e): Changes in the losses of the group leader due to passive service.

Fig. 11: Effect of the loss change on the evolution of the tripartite game system.

From Fig. 11(a) and Fig. 11(b), it can be observed that as H_1 and H_2 increase, x and y gradually converge towards 1. The higher the losses, the faster the x and y convergence toward 1. This suggests that the competitive intensity of other market rivals is a crucial factor for the supplier and platform when deciding whether to opt for Gen-AI empowerment. Intending to increase profits and enhance their appeal to consumers, the supplier and platform should conduct comprehensive market research before making decisions on adopting Gen-AI empowerment.

In Fig. 11(c), as S_1 increases, the strategies of the three parties shift from (1, 1, 1) to (0, 0, 1). The speed of convergence of y towards 0 is greater than x and y converges towards 0 when S_2 exceeds a certain threshold in Fig. 11(d). This indicates that the supplier faces higher levels of risk loss with Gen-AI empowerment compared to the platform. Consequently, the platform exercises greater caution in selecting Gen-AI empowerment. Therefore, Gen-AI enterprises can implement effective risk mitigation measures to alleviate buyer concerns while providing services.

From Fig. 11(e), it can be observed that when $L = 5$, the strategy of the three parties is {Empower, Not Empower, PS}. As L increases, the speed of z convergence towards 1 gradually accelerates. This indicates that as the losses of the group leader due to passive service increase, the group leader is more inclined towards active service. This, in turn, enhances consumer trust and increases the frequency of repeat purchases by consumers. Both y and z converge to 1 when L equals 20. At this point, the three-party evolutionary strategy becomes {Empower, Empower, AS}. This suggests that the passive service of the group leader can also cause some damage to the platform, reducing the probability of the platform choosing Gen-AI empowerment.

5.2.4 Analysis of the Penalty Impacts on the Evolution Path

To disclose the effect of penalty impacts on the evolutionary path, the simulation experiment is implemented. The following values of M are set to 5, 10, 15, and 20 respectively. The simulation result of the model is shown in Fig. 12.

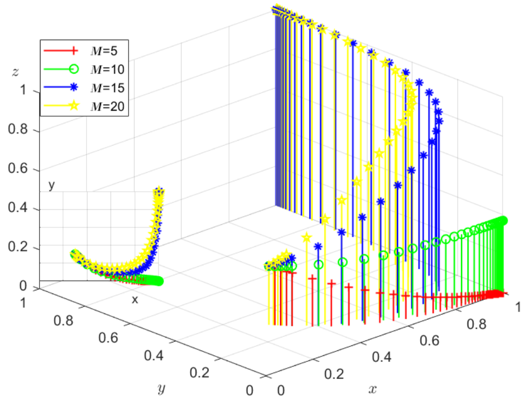


Fig. 12: Evolutionary path simulation of the game system as the penalty M changes.

It is evident that as M increases, both y and z eventually converge to 1 in Fig. 12. Moreover, the convergence speed of y and z to 1 gradually increases. This indicates that as the platform's punishment towards group leaders becomes more severe, the group leader is more inclined to adopt an active service strategy. Additionally, in scenarios with relatively low penalties, the probability of z choosing an active service strategy is reduced, though it does not drop to zero, remaining below the initial probability of 0.3. This indicates that if the platform's penalties for group leaders' passive service are relatively mild, there remains a probability that group leaders will choose to provide passive service. Therefore, the platform can consider implementing appropriate punitive measures based on the group leader's performance and consumer feedback. This can serve as an incentive for the group leader to improve their service quality.

6. Research Implications

This research contributes to the existing literature on Gen-AI and provides key managerial implications for practitioners within the CGB industry. The theoretical and practical implications are outlined below.

6.1 Theoretical Implications

The current study makes the following theoretical and methodological contributions to the existing literature. While the application of Gen-AI technology is in its infancy, previous publications have primarily focused on the industrial perspectives and potential benefits (Fosso Wamba et al., 2023b); Raj et al. (2023), often ignoring the practical implementation in the industrial sector, especially in the CGB scenario. Firstly, in an effort to offer better solutions for handling CGB's development issues from a technological perspective, this study introduces Gen-AI into CGB for business promotion, thus expanding its industrial application. Secondly, by formulating an evolutionary game model, this study addresses the strategic behaviors of key stakeholders in the CGB ecosystem, filling an important research gap from a theoretical viewpoint regarding the feasibility and accessibility of Gen-AI integration from a theoretical standpoint. Finally, considering the practical challenges and potential errors associated with Gen-AI implementation in CGB, the potential risks and losses that Gen-AI might incur in empowering CGB are highlighted in the theoretical model.

6.2 Managerial Insights

This research offers key takeaways for practitioners working in the CGB industry and willing to engage in Gen-AI practices. First, the CGB platform can appropriately levy fines for group leaders, using consumer feedback as a benchmark, to enhance service quality. Additionally, the platform could introduce certain pertinent incentives to support the supplier's Gen-AI empowerment, which would significantly increase the platform's ability to attract and retain customer.

To strengthen the likelihood of Gen-AI adoption, Gen-AI enterprises can provide value-added services, such as quality control, inventory optimization, and sales forecasting, all of which can significantly enhance the operational efficiency of CGB. It is also recommended that Gen-AI enterprises apply a supervisory function for the platform, assisting in assessing the service quality of the group leader. Moreover, as businesses, merchants, and users are sensitive to personal information, Gen-AI systems must prioritize safeguarding user information. Risk mitigation strategies should be developed to address user concerns and ensure secure and trusted service delivery.

7. Conclusion

As a new retail model, community group buying (CGB) quickly caught consumers' attention with its relatively preferential prices and high delivery efficiency. However, issues such as delayed response and unsatisfactory after-sales service have severely plagued the further development of CGB. In the context of Gen-AI popularity, this paper discusses whether Gen-AI could promote CGB mode from the viewpoint of technological evolution. Besides, the strategic behaviors of key stakeholders regarding Gen-AI empowerment are analyzed by formulating a tripartite evolutionary game model involving a supplier, a CGB platform, and a group leader. The effect of crucial parameters on the evolving trends of strategies among the supplier, the CGB platform, and the group leader are examined by conducting simulation experiments. In doing so, this study attempts to address the research questions mentioned in Section 1.

Regarding RQ 1 and RQ 2, this paper finds that the costs, benefits, and potential risk losses associated with Gen-AI empowerment are crucial factors influencing the technology adoption decisions of the supplier and the platform. The probability of the supplier and the platform choosing Gen-AI empowerment increases as the benefits from technology applications grow. Conversely, higher costs and risk losses reduce the probability of adopting Gen-AI systems. If these costs and losses exceed a certain threshold, the supplier and the platform may choose not to adopt Gen-AI empowerment.

Moreover, the competitive intensity of other market competitors significantly influences the decision to adopt Gen-AI. When competitors use Gen-AI empowerment to capture market share, the resulting higher losses for the supplier and the CGB platform increase the likelihood of them adopting Gen-AI systems. This indicates that the supplier and the platform should strategically seize Gen-AI empowerment opportunities and conduct comprehensive market research to enhance consumer appeal.

Furthermore, this paper also finds that if the supplier decides not to adopt Gen-AI empowerment, the platform is similarly less likely to adopt it. The lack of product information and advertising support limits the platform's ability to attract consumers, reducing the benefits of Gen-AI empowerment. In such cases, the high costs further discourage the platform from opting for Gen-AI systems.

Regarding RQ 3, when the group leader adopts a strategy of passive service, it hinders the rights and interests of consumers. Even with Gen-AI empowerment, the platform's revenue may suffer if customers reduce their purchase frequency due to the passive service from the group leader. The platform is more inclined to use Gen-AI empowerment when the group leader provides active service. In such cases, the platform may impose penalties on the group leader. The stronger the platform's penalties, the more the group leader is to adopt an active service strategy. However, when the platform's penalties for the group leader's passive service are less severe, there is a possibility that the group leader may choose to provide passive service. Additionally, when the group leader chooses an active service strategy, the platform can provide suitable incentives to the supplier and group leader to enhance the efficiency of CGB system collaboration through Gen-AI empowerment, fostering more proactive participation across the supply chain.

This paper primarily focuses on enhancing the competitiveness of CGB by considering the perspectives of the supplier, the CGB platform, and the group leader. However, within the operational processes of CGB supply chains, logistics, warehousing, and other businesses play crucial roles as well. With the empowerment of Gen-AI, logistics and transportation companies can enhance the efficiency of supply chain operations, while smarter inventory management can reduce product losses. Moreover, the promotional efforts of group leaders significantly contribute to enhancing the competitiveness of the CGB platform. Therefore, future research could investigate the impact of Gen-AI empowerment on the competitiveness of CGB with a particular focus on processes such as logistics and warehousing. Additionally, current research lacks analysis of supply chain operational decisions among Gen AI-enabled CGB members. Future research could delve into this area to further refine and enhance Gen-AI empowerment in CGB platforms.

Data Availability

All source data used for numerical experiments, MATLAB codes, and a detailed explanation of the simulation implementation steps (Supplementary Material) are provided in the GitHub repository: https://github.com/zhumenghan1019/Codes-and-data.git

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