

Game Analysis in Necessity Purchase-Supply during COVID-19

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During the COVID-19 pandemic, panic buying, price inflation, and the pollution of production processes led to economic and social unrest. In response to the current situation, the current entry takes less account of the subjective perception of public panic buying and the lack of reference to the reality of effective governance.

Keywords: environmental pollution ; COVID-19 pandemic ; panic buying

1. Introduction

The COVID-19 pandemic has maintained continued outbreak throughout the world since 2019, resulting in the frequently occurred problems such as public panic buying, price hikes by enterprises and contamination of the production process. This seriously threatens the stability of purchase and supply market of necessities and environmental issues. As of 2020, more than 90 countries have seen panic buying during the COVID-19 pandemic ^[1]. Some enterprises expect to sell at high prices by hoarding emergency supplies and necessities ^[2], and some have high emissions of pollutants in the COVID-19 pandemic control period ^[3]. However, panic buying rarely happens in China ^[4] because local governments have taken active measures in controlling it and guiding public opinion to prevent public panic buying ^[5]. The governments punished the enterprises for their illegal behaviors ^{[6][7]}. According to the data released by the National Bureau of Statistics of China, the Consumer Price Index for the whole year of 2021 increased by 0.9% only on a year-on-year basis.

The outbreak of the COVID-19 pandemic has severely disrupted the global supply chain in manufacturing, transportation, logistics, and demand shifting areas ^[8]. That can be explained: it is impossible to efficiently coordinate enterprises immediately, so that interruptions and shutdowns in supply chains occur ^[9] to exacerbate the imbalance between the supply and demand of necessities ^[10]. Enterprises at each node of the smart supply chain supported by a new generation of information technology play an important role in achieving price and supply stability in the necessities market and preventing the public from panic buying. For example, JD.com took advantage of its smart supply chain to immediately mobilize warehouse materials around Wuhan when the COVID-19 pandemic erupted in just two months with supplying 220 million necessities to the public across China by its established 700 warehouses. The smart supply chain is a comprehensive integrated technology and management system that combines the Internet of Things, Internet technology, modern supply chain management theory and other related methods and technologies, and it is used to realize the intelligence, networking and automation of inter-enterprise business in the smart supply chain ^[11], where those enterprises can easily communicate in real time in terms of information flow, logistics, and capital flow, thereby improving the operation efficiency of the supply chain ^[12]. However, there is also the problem of environmental pollution in the process of ensuring the supply of essential goods by smart supply chain enterprises.

With the concept of circular economy, the green transformation of the supply chain has become an inevitable trend of supply chain development. The management process of the COVID-19 pandemic requires not only the smart of the supply chain to ensure the supply of essential goods but also the greening of the supply chain to realize the coordinated development of economic benefits and environmental protection. A green supply chain is based on the basic concept of attaching importance to the low-carbon circulation of commodities, energy saving and emission reduction, and it makes people more inclined to use advanced supply chain management technology, computer science and technology, etc., to strengthen the management of the supply chain, realize the optimal allocation of supply chain resources, reduce the input of resources and energy, and achieve the purpose of energy saving and emission reduction ^[13]. Supply chain smartness and greening is the inevitable trend of supply chain development. A green smart supply chain is based on the traditional supply chain, incorporating environmental factors into all circulation activities of supply chain products, and realizing intelligence, digitalization, networking, and automation by integrating modern information technology and management ^[14]

to achieve flexible management, rapid response, and intelligent collaboration ^[15], which can alleviate supply–demand mismatch and public panic buying with environmental factors in mind.

Due to their responsibilities, local governments need to deal with public panic buying and illegal acts such as price increases and productive pollution by green smart supply chain enterprises, while green smart supply chain enterprises are direct actors that can stabilize the market of essential goods as well as avoid environmental pollution problems. However, since the local government has limited resources and budget, its response measures may be untimely and less active; green smart supply chain enterprises, as “rational people”, make behavioral decisions in the pursuit of profit maximization and often find it difficult to take the responsibility of managing emergencies; the public will also make purchase decisions according to their own perceived expectations, which will cause panic buying by the public and the recurrence of productive pollution incidents, and the local government, green smart supply chain enterprises and the public will constantly adjust their strategic choices and play a continuous game.

2. Game Analysis in Necessity Purchase-Supply during COVID-19

At the moment, research on panic buying mostly focuses on two aspects: internal formation factors and external influencing elements, with internal formation factors primarily investigated from the viewpoint of the general population. For example, Yuen and Wang et al. ^[16] conducted a systematic review of the literature on panic buying events during the COVID-19 pandemic and found that the factors of panic buying included cognitive and personality–psychological factors (i.e., perceived scarcity, anxiety, fear of inaccessibility and self-control) and psychosocial factors (i.e., observational learning, normative influence and trust). Yuen and Leong et al. ^[17] conducted an online survey of 508 respondents and investigated the survey data by constructing structural equation models. The results showed that several constructs of normative social influence, observational learning, perceived severity, and perceived scarcity had significant effects on consumer panic buying, which were mediated by controls. Arafat et al. ^[18] identified the contributing factors of panic buying by analyzing media reports, and they found that the most frequently cited attributes of panic buying in online reports were perceived product scarcity, increasing demand, and expected price soar. Yuen and Tan et al. ^[19] synthesized various social and behavioral theories and developed a theoretical model along with an online survey to empirically study people's perceptions of scarcity through data. It was found that perceived scarcity can directly or indirectly motivate panic buying behavior through anticipated feelings of regret. The above studies are mainly based on theoretical analysis and empirical research to explore the public's psychological factors of panic buying, and perceived product scarcity is the main internal influencing factor; however, few scholars have quantified the public's perceived value of items in panic buying scenarios and analyzed the internal formation factors of panic buying by constructing mathematical models.

The analysis of the external influences on panic buying is mainly studied from the perspective of external subjects such as government and enterprises. For example, Prentice et al. ^[4] collected data from five countries (Australia, India, China, Vietnam, and Indonesia) to explore the influence of external factors such as government, business, and social groups on panic buying during the COVID-19 pandemic, and they found that proactive government and business measures can instill a sense of security and reduce the frequency of panic buying. Chen et al. ^[20] used the idea of clustering dynamics to construct a model of the emergence of group panic buying behavior, quantified the internal and external factors affecting individual buying behavior, and found that government intervention plays an important role in reducing the size of group rush. Xie et al. ^[21] proposed an agent-based ABM model that incorporates government behavior into the risk analysis of panic buying, and they found that the higher the government's refutation of rumors and the greater the amount of aid, the higher the consumer's trust in the government. Dammeyer and Je' zewska-Zychowicz et al. ^{[22][23]} found that when public confidence in the government's ability to achieve effective governance increases, brick-and-mortar stores that ensure adequate supply can keep the public away from panic buying. The findings of the above studies were effectively demonstrated in practice in China during the COVID-19 pandemic. Most of the above studies use empirical and theoretical analyses to explore the influence of government and enterprises on public panic buying behavior; however, few scholars have studied the interaction behavior between the participating subjects during public panic buying and explored how the government and enterprises influence public panic buying behavior.

In addition, Wang and Li ^[24] structured a description of the snatch-and-grab event in a truck accident, and the article used prospect theory to construct a two-sided evolutionary game between the government and the public to investigate the evolutionary law of the event. The study found that the evolutionary outcome of the event was closely related to the perceived value of the public and the government for their respective gains and losses. Later, Wang and Nie et al. ^[25] used prospect theory to describe the public's perceived value of items in the benchmark and panic buying situation, and they constructed an evolutionary game model between the public and the government to explore public panic buying. Although the above literature considers the evolutionary process among subjects affecting public panic buying, it only considers the game between two subjects, the government and the public. Zhao et al. ^[26] constructed an evolutionary

game model of small and medium-sized enterprises and large enterprises to analyze consumers' purchase intentions under the situation of rumor spreading and demand disruption to maintain stable and sustainable market development. Although it considers firms as subjects influencing public panic buying and the scenario of demand disruption due to unexpected events, it does not consider the government and public participation process.

Regarding the impact of enterprises on public panic buying, previous studies have not defined the types of enterprises. However, the outbreak of the COVID-19 pandemic has caused a large-scale shutdown of enterprises and supply chain disruptions [27], resulting in an imbalance between supply and demand in the necessities market [28]. It is difficult for traditional companies to reduce panic buying by the public through aggressive measures. Some scholars have discussed from the perspective of smart supply chain. For example, Chitrakar et al. [29] studied the application and impact of smart technologies in the food supply chain during the COVID-19 pandemic. These technologies make food processing activities more intelligent and solve the problem of insufficient manpower in the food supply chain. Papadopoulos et al. [30] explored the deployment of digital technologies by SMEs to ensure business continuity in response to extreme disruptions such as COVID-19 and global social shocks. Gupta et al. [31] constructed a game-theoretic model to analyze the strategic combinations of all possible actions of different stakeholders in the food supply chain and explored the use of traceability technology in the food supply chain to reduce food losses. It can be seen that smart supply chain enterprises can connect their systems together to share information, reduce response time, and make effective decisions in the market [32], thus effectively responding to supply chain disruptions and shutdowns; however, the rapid response of smart supply chain enterprises may also lead to untimely pollution prevention and contamination of the production process. Under the pressure of COVID-19 pandemic management, enterprises are likely to deviate from the original sustainable development track in the process of ensuring the balance between the supply and demand of essential goods. Zhang [33] found that a blocked circular economy will lead to more serious global plastic pollution. Chen et al. [3] established an AERMOD-based steel enterprise pollution forecast model, simulated the impact on the atmosphere of a steel company in Hebei province during the COVID-19 pandemic control period and the late decommissioning period, and found that the polluting emissions were worse during the COVID-19 pandemic control period. Therefore, in the process of public panic buying, intelligent supply chain enterprises are effective subjects to deal with public panic buying. However, most of the previous studies only considered the application of intelligent technologies by enterprises during the COVID-19 pandemic to solve the problems of supply chain disruptions and production shutdowns, and few scholars have considered the problem of productive pollution by smart supply chain enterprises.

With the development concept of the circular economy, the transformation to green supply chains has become an inevitable trend of supply chain development, and green supply chain management can effectively alleviate the pollution problem of enterprises. In recent years, the application of game theory to study green supply chain management is a current research hotspot. Zhang and Su [34] analyzed the main influencing factors of green behavior of supply chain enterprises by constructing a game model of green behavior of supply chain enterprises. Liu et al. [35] applied the evolutionary game model to study a two-level green supply chain consisting of green suppliers and green manufacturers, and they analyzed various internal and external factors affecting the emission reduction behaviors of both sides of the game. Zhou et al. [36] used a game model to analyze the optimal innovation strategy choice of a recycling supply chain among two innovation paths: green autonomous innovation and green imitation innovation. Majeed et al. [37] constructed a game-theoretic model to study the effect of social preferences on supply chain management performance. Some other scholars have studied the evolutionary game process among the participants of corporate pollution events based on green supply chain management. For example, Zuo et al. [38] used evolutionary game theory to construct an evolutionary game model of green operation model of a pig supply chain, and they analyzed the evolutionary path and influence mechanism of a green operation model of the pig supply chain for the problems of environmental surface source pollution brought by the pig farming industry in China. Barari et al. [39] studied sustainability theory in combination with supply chain management and coordination in order to ensure the sustainability of ecosystems, constructing an evolutionary game approach that seeks synergistic alliances between environmental and commercial benefits by establishing coordination between producers and retailers to judge their strategies for triggering green practices. Mahmoudi et al. [40] modeled the contrast between government goals and producer goals using two swarm evolutionary game theory approaches to study government policies and the implementation of incentives to influence producers' pollution activities.

To summarize the above, existing studies can provide some theoretical and methodological support for the study of public panic buying and enterprise pollution problems during the COVID-19 pandemic. However, there are some shortcomings. (1) For the study of panic buying, on the one hand, most previous studies lacked a consideration of quantitative models of subjective perceived behavior as a finite rational public [16][17][18][19]. In recent years, prospect theory has been mostly used to portray the public's perceived value of items [24][25]. In the evolution of public panic buying, information asymmetry tends to motivate the finite rational public to form behavioral motives through the subjective perception of event triggers, which is consistent with the application basis of prospect theory to portray the subject's decision-making behavior. On the

other hand, most previous studies consider the evolutionary game between the government and the public ^{[24][25]} (on one hand) and the enterprise and the enterprise ^[26] as two subjects. However, in panic buying events, the government, the public and the enterprise are direct stakeholders, and few scholars consider the evolutionary process among the government, the public and the enterprise at the same time. (2) For the study of enterprise pollution, there are few studies related to the evolutionary process among the participants of enterprise pollution events under the scenarios of emergencies such as the COVID-19 pandemic, and few scholars have studied green smart supply chain enterprises as the subjects of evolutionary games.

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