


## RESEARCH ARTICLE

# Strengthening supply chain resilience during COVID-19: A case study of JD.com

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## Abstract

The coronavirus/SARS-CoV-2 (COVID-19) outbreak has caused severe supply chain disruptions in practically all industries worldwide. Online e-commerce platforms, which interact directly with various industries and service numerous consumers, have become remarkable interfaces to observe the impacts of the pandemic on supply chains. Using quantitative operational data obtained from JD.com <https://www.jd.com>, this study analyzes the impact of the pandemic on supply chain resilience, summarizes the challenging scenarios that retailing supply chains experienced in China, and presents the practical response of JD.com throughout the pandemic. To summarize, the pandemic caused exceptional demand and severe logistical disruptions in China, and JD.com has handled well its supply chain management in response based on its integrated supply chain structure and comprehensive intelligent platforms. In particular, the existing intelligent platforms and the delivery procedures were modified slightly but promptly to deal with specific disruptions. Moreover, the entire market scenario in China was effectively controlled through the joint efforts of multiple firms, the government, and the entire Chinese society. Our study provides an example of using practical operational indicators to analyze supply chain resilience, and suggests firms pay attention to *operational flexibility* and *collaboration beyond supply chains* to deal with a large-scale supply chain disruption, such as the COVID-19 outbreak.

## KEYWORDS

COVID-19, operational strategy, supply chain resilience

## 1 | INTRODUCTION

The coronavirus/SARS-CoV-2 (COVID-19) outbreak was declared as a “public health emergency of international concern” on January 30, 2020 (WHO, 2020a). Since the announcement of the first case in late 2019, it has caused over 991,000 deaths and infected over 32.7 million individuals worldwide as of September 27, 2020 (WHO, 2020b). In addition to public health effects and medical pressure, the unexpected and rare pandemic has caused a

ripple effect on global economics, and severely damaged the supply chains worldwide (Queiroz et al., 2020; Verma & Gustafsson, 2020). Fortune (2020) reported that as of February 21, 2020, 94% of the companies listed on the Fortune 1000 list were experiencing supply chain disruptions owing to COVID-19. For small companies, a survey completed on April 4, 2020, reported that mass layoffs and closures had already occurred a few weeks into the crisis (Bartik et al., 2020). In April 2020, the economists of the World Trade Organization estimated

that world trade would decrease by 13%–32% in 2020 because of the global disruption of normal economic activities and lives caused by the COVID-19 pandemic (WTO, 2020a).

Although supply chain management during a crisis has been studied effectively in operations management literature, this type of catastrophe (i.e., influencing almost all industries of all countries) has not occurred in recent years. Many measures have been implemented by governments to flatten the curves of infection rates, such as social distancing, self-isolation, travel restrictions, and closure of physical shops and businesses (Michie, 2020). Cities, such as Wuhan in China, have been locked down owing to safety concerns, thereby resulting in severe supply chain disruptions. Governments worldwide have severely restricted cross-border movements of individuals by imposing temporary travel and immigration restrictions, thereby hindering international trade and investment (WTO, 2020b). In addition, lockdown measures have resulted in a shortage of labor (Singh et al., 2020) and severe supply and demand issues owing to spillover effects (Pantano et al., 2020). Compared with the times of previous pandemic outbreaks, the world has developed to become much more integrated, which has amplified the effects of the pandemic even further (Fernandes, 2020).

Consumer behavior has also been altered significantly by the pandemic and the resultant measures (Sheth, 2020). Andersen et al. (2020) reported that consumer spending in Denmark reduced by 27% in the 7 weeks following lockdowns. During the pandemic, medical supplies and food are experiencing significantly increased demand due to panic buying, whereas the need for other commodities and manufactured products has decreased (Gereffi, 2020; Nicola et al., 2020). This new scenario has resulted in new demands. For example, widespread social distancing measures have substantially increased the demand for pickup and delivery services (Gray, 2020). Moreover, the dynamic market has shifted rapidly during this unprecedented pandemic (Donthu & Gustafsson, 2020), which has forced firms to adopt novel strategies to survive.

Digital technologies have been widely used and recommended for sustaining businesses. Schools are adopting online classes (Sheth, 2020), and companies, such as Google and P&G, are encouraging their employees to “work from home” (Coolidge & Enquirer, 2020; Copeland, 2020). Other firms have also attempted to transform their business models based on innovative technologies. A private music school in Hong Kong rented a long truck, renovated it, and utilized it as a mobile classroom for bringing services to the homes of the consumers (Choi, 2020). Singh et al. (2020) proposed a “truck–drones synchronized delivery system” for reaching customers residing in high-rise buildings in

severely infected areas. In New York, Unilever, supported by Terra Drone (a Japanese startup), used drones to provide last-mile delivery of Ben and Jerry’s ice cream (Kan, 2020).

To summarize, the COVID-19 outbreak has disrupted supply, demand, and the logistics infrastructure simultaneously. The pandemic highlights the need to transform traditional supply chain models, structural consumption models, and digitalization in the marketplace (Kilpatrick & Barter, 2020; Kim, 2020), and the long-term effects are still unknown owing to its unpredictable scale (Ivanov, 2020). In this context, it is worthwhile to study the various sources of uncertainties and understand the best response strategies for companies in such a dynamic environment (Cohen & Lee, 2020). This study considers JD.com (<https://www.jd.com>) (one of the largest online retailers in China) as an example. It shows how retailers have addressed the supply chain disruptions caused by the pandemic in practice as well as the critical roles of technologies in these processes. We innovatively link the operational indicators of firms with their supply chain resilience in practice and provide a novel analysis of the variation in resilience of retail supply chains throughout COVID-19. By summarizing the specific characteristics of the supply chain of JD.com as well as its practical strategies and the resulting performance during the pandemic, our study provides relevant insights into how firms should address long-term disruptions. In particular, we suggest that firms improve their ability in operational flexibility and volunteer to undertake social responsibility by collaborating with the whole society.

The remainder of this paper is organized as follows. In Section 2, we review the related literature, including that on supply chain disruption, practical resilience strategies, and supply chain management in this unprecedented pandemic. Before we discuss the impact of COVID-19 on supply chains and the coping strategies of a firm, in Section 3, we introduce the investments that JD.com made prior to the pandemic that enabled high resilience. The main investments included an integrated supply chain structure led by a specific business model and several intelligent platforms supporting its daily operations. In Section 4, we quantitatively present the scenario of supply chain resilience during the pandemic and summarize two significant difficulties experienced by JD.com: exceptional demands and delivery network disruptions. In Section 5, we describe the practical strategies of JD.com to address these difficulties. Specifically, utilizing the intelligent platforms built before the pandemic, JD.com flexibly adjusted its operational strategies to deal with the volatile market conditions as well as the external requirements caused by COVID-19. Finally, the main conclusions are summarized and discussed in Section 6.

## 2 | LITERATURE REVIEW

### 2.1 | Disruptions, resilience, and strategies for supply chains

Supply chain disruptions have been well studied in the operations management literature (e.g., Bhattacharya et al., 2012; Tang, 2006; Tomlin, 2006). Herein, supply chain disruption is defined as the combination of an unintended and unanticipated triggering event that occurs at a certain point in the supply chain and the consequent scenario that presents a severe threat to the normal course of business operations of the focal firm (Bode & Wagner, 2015). In general, disruptions in supply chains are caused by events with a low probability of occurrence and very high impact, such as natural disasters (e.g., the 2011 earthquake, tsunami, and nuclear disaster in Japan [Sheffi, 2017]), manmade accidents (e.g., US coal mining disaster [Madsen, 2009]) and pandemics (e.g., SARS [Chou et al., 2004] and Ebola [Calnan et al., 2012]). Our study focuses on COVID-19, a pandemic that has been spreading substantially since late 2019. Unlike other disruptions, pandemic outbreaks are distinctively characterized by long-term disruptions, disruption propagations, and high uncertainty (Ivanov, 2020). A single natural/industrial disaster is generally geographically centered, whereas a pandemic extends beyond a particular region or time (Ivanov & Das, 2020).

The ability to rapidly and effectively recover from a disruption is called resilience (Behzadi et al., 2020). As supply chain disruptions can cause significant financial and operational losses to firms (Tukamuhabwa et al., 2015), resilience is considered as a fundamental attribute that supply chains need to adopt. Furthermore, it is dynamic instead of static (Ali et al., 2017). To improve the understanding of resilience for both firms and supply chains, Kamalahmadi and Parast (2016) undertook a comprehensive survey of related literature. In addition, we refer the readers to Ali et al. (2017) and Golan et al. (2020) for similar reviews.

Supply chain resilience is a complex and multi-dimensional research subject (Ali et al., 2017), and there have been considerable efforts to identify its constituent elements. Although diverse factors have been identified by various studies, the elements mainly include flexibility (e.g., Hosseini et al., 2019; Jüttner & Maklan, 2011), agility (e.g., Christopher & Peck, 2004; Hosseini et al., 2019), visibility (e.g., Hosseini et al., 2019; Jüttner & Maklan, 2011), collaboration (e.g., Christopher & Peck, 2004; Jüttner & Maklan, 2011), information sharing (e.g., Hosseini et al., 2019), and culture of risk management (e.g., Christopher & Peck, 2004). These factors, which are also described as supply chain resilience principles (Kamalahmadi & Parast, 2016), can be refined to evaluate and analyze practical

supply chain resilience. According to Pettit et al. (2010), two key factors that influence supply chain resilience are vulnerabilities (which are determined by the forces of change) and capabilities of the supply chains (which can be improved by management control). Seven vulnerability factors and 14 capability factors were identified using a focus group methodology. Cardoso et al. (2015) adopted 11 indicators to assess supply chain resilience, including network design, centralization, and operational indicators. However, these factors lack practical relevance. Both network design and centralization indicators require a detailed network structure with flow information, which is challenging to calculate in practice. To summarize, there are no universal indicators to analyze supply chain resilience in real scenarios. This topic is discussed further in the next section.

### 2.2 | Analyzing supply chain resilience in practice

Literature provides insights into the enhancement in resilience for both firms and supply chains. Lee (2004) indicated that top-performing supply chains should be agile, adaptable, and aligned, which can help them recover rapidly from abrupt setbacks. Specifically, he emphasized the importance of data and collaborative relationships in building an agile supply chain. In a review, Snyder et al. (2006) summarized a series of models for designing supply chains that are resilient to disruptions. Based on the constituent elements for supply chain resilience, the most commonly cited strategies are increase in flexibility, creation of redundancy, formation of collaborative supply chain relationships, and improvement in supply chain agility (Tukamuhabwa et al., 2015).

However, there is a distinct difference between the theoretical strategies and actual methods for supply chain resilience (Tarei et al., 2020; Tukamuhabwa et al., 2015). It is reported that firms address disruptions most commonly with increased safety-stock, dual- or multi-sourcing, and improving forecasting (Katsaliaki et al., 2021). Although resilience strategies are closely related to the concept of resilience, the practical strategies of firms are generally closer to risk management rather than resilience. Risk management comprises risk avoidance strategies (e.g., supplier evaluation, technology adoption, flexible process, and information security) and risk sharing strategies such as revenue sharing, insurance, collaboration, and public-private partnership (Tarei et al., 2020). Therefore, although a wide range of supply chain resilience strategies has been identified, empirical studies that investigate detailed practical responses of firms are relatively few. An exception is a study by Lee et al. (2020), which reviewed the reflections of organizations in a crisis.

However, it focused mainly on reflections from individual firms, instead of the entire supply chain.

A significant difficulty encountered while performing empirical studies for analyzing supply chain resilience is defining resilience based on the operational data of firms. The resilience metrics in theoretical models are mainly of three categories: time to recover (e.g., out-of-service time, on-time delivery), recovery level (e.g., service level, unfulfilled demand rate), and profit lost during recovery period (Behzadi et al., 2020). Similar indicators are also defined for empirical studies. Simchi-Levi et al. (2014) proposed a risk exposure index to quantify the impact of a disruption for certain supply chains: time-to-recover (TTR). It is defined as the time required for a particular node to be restored to full functionality after a disruption. As accurate TTR information is unavailable in many cases, Simchi-Levi et al. (2015) introduced a similar index called time-to-survive (TTS). It is defined as the maximum amount of time a system can function without performance loss if a particular node is disrupted. The above two risk exposure models assisted Ford Motor Company to effectively identify and manage its risks. Based on the theoretical concept of a resilience triangle, Baghersad and Zobel (2021) evaluated resilience as an overall system performance loss after a disruption. Although this indicator reveals the resilience variation of supply chains with stable demands, cases of retailing supply chains are extremely complex for it. Furthermore, the prolonged disruption caused by the COVID-19 pandemic adversely affects prediction accuracy, which, in turn, hinders the calculation of the indicator.

Another critical difficulty is a result of the absence of coordination and information sharing. Studies tend to describe the resilience of entire supply chains, whereas, in reality, supply chain nodes act in isolation. In practice, the visibility of a supply chain extends only to a tier above and a tier below (Scheibe & Blackhurst, 2018). In this case, interviews with participants in different supply chain nodes is the only approach to understand the entire supply chain. For example, by interviewing seven supply chain managers with different positions in the Indian petroleum industry, Tarei et al. (2020) explored the differences between risk management strategies and practices. In addition, although quantitative measures of resilience level are required (Baghersad & Zobel, 2021), firms are likely to circumvent disclosure of information to maintain a competitive advantage. In this scenario, although cases and responses of firms are described in detail, discussions on the supply chain performance are limited. Representative examples include Norrman and Jansson (2004). In this study, the case of Ericsson was studied with regard to supply chain risk management in response to a fire at a sub-supplier in Japan, based on semi-

structured and open interviews. The study also reported the risk management process developed by Ericsson. Based on representative case studies and interviews, Shareef et al. (2020) explored supply chain operations during disaster scenarios in Bangladesh. The cases considered disasters including floods, cyclones, and landslides, and were described in detail. In addition, the elements that influence supply chain performance were identified. Ivanov (2018) reported five cases on the development of resilient supply chains by Nissan, Toyota, Volkswagen, and the British online fashion retailer, ASOS plc. The supply chain resilience measures were also described in detail. However, only some distinct indicators, such as sales and inventory level are used to describe the overall supply chain performance in each case, and the discussion on supply chain performance was inadequate.

Notwithstanding the difficulties mentioned above, the practical analysis of supply chain resilience is still an important research problem (Katsaliaki et al., 2021). Until now, the few available empirical studies have been mainly cross-sectional and confined to the context of developed countries (Tukamuhabwa et al., 2015). In addition, the data generally are acquired by case studies and interviews. Owing to its self-operated business model, JD.com owns an entire retail supply chain and connects directly with suppliers (e.g., factories and upstream manufacturers) and consumers across China. Therefore, information from the entire supply chain is available. Utilizing this data, we proposed a framework of resilience metrics that uses real operation indicators to describe supply chain resilience. The study contributes to the empirical literature on supply chain resilience analysis. Our investigation is the first resilience study to use quantitative data extracted from the operational practices of a firm. In addition, by empirically reporting both the resilience level and strategies to address the COVID-19 outbreak, we eliminate the difference between resilience strategy research and practice.

### 2.3 | Supply chain management during COVID-19

We finally review the supply chain management literature in the context of the COVID-19 outbreak and the resulting economic recession. The first stream of literature is purely theoretical and similar to traditional supply chain disruption literature. For example, Baqaei and Farhi (2020) modeled COVID-19 as a combination of exogenous shocks to the supply quantity, productivity of producers, and composition of the final demand. Ivanov and Dolgui (2020) proposed a model for an intertwined



supply network in which the supply chains in the market are entirely interconnected. They recommended that the impacts of COVID-19 be examined further from this novel perspective. Paul and Chowdhury (2020) proposed a mathematical production recovery plan for manufacturing supply chains during the COVID-19 pandemic. Although these studies provide relevant insights into supply chain management during a specific pandemic, these are highly impractical owing to the deficiency of real data.

Our study is closer to those that empirically estimated the impacts of the pandemic on supply chains. Most studies in this stream have focused on the supply chains of medical supplies and personal protective equipment (e.g., Armani et al., 2020; Gereffi, 2020; Ranney et al., 2020) and emphasized the importance of digital technology adoption (e.g., Armani et al., 2020) and government guidance (e.g., Ranney et al., 2020). Another focus has been on agricultural and food supply chains (e.g., Aday & Aday, 2020; Gray, 2020; Reardon et al., 2020; Richards & Rickard, 2020). For example, Hobbs (2020) discussed the shocks imposed by COVID-19 on the demand and supply sides and their corresponding effects on food supply chains in Canada. The above studies agree that agricultural and food supply chains are not experiencing severe disruptions and that their logistics services are still effective. However, the scenario for other supply chains is not as positive. Majumdar et al. (2020) studied the clothing supply chain operating in South Asian countries, based on interviews with experts, and found that the demand, supply, and manufacturing were completely disrupted and delinked in this supply chain. McMaster et al. (2020) examined global fashion supply chains and summarized the existing risks and mitigation methods. Different strategies have been recommended, such as sustainable sourcing models that incorporate disruption risk sharing (Majumdar et al., 2020), social distancing in factories (Bodenstein et al., 2020), increasing online presences and visual stores (McMaster et al., 2020), agile supply chains (McMaster et al., 2020), and resilient supply chains (Hobbs, 2020; Singh et al., 2020). The utilization of data-driven digital technologies, such as digital supply chain twins, has been emphasized (Ivanov & Dolgui, 2020). However, none of the previous studies can ensure that their recommendations will be productive as COVID-19 continues to expand worldwide.

In general, as realistic data are unavailable, simulations are frequently conducted to analyze the impact of disruptions. For example, Ivanov (2020) used a simulation-based methodology to examine and predict the impacts of COVID-19 on supply chain performance. He observed that the closing and opening times of facilities are expected to be significant factors. Ivanov and Das (2020) used a simulation method to analyze pandemic supply risk mitigation measures and potential recovery paths. Other studies were

comparatively more specific and focused on certain measures or certain industries. For example, Guan et al. (2020) used a global trade-modeling framework to analyze the impacts of COVID-19 lockdowns on supply chains. They found that a longer lockdown that can eradicate the disease would cause a smaller loss than shorter ones. Singh et al. (2020) developed a simulation model for a public distribution system network to demonstrate COVID-19 disruptions in a food supply chain.

Our study differs from previous ones in the following aspects. First, although simulations are commonly conducted to analyze the impact of COVID-19, we utilize the practical operational data of JD.com and reveal the difficulties throughout retail supply chains. Furthermore, unlike previous studies related to the COVID-19 outbreak, we advance beyond the analysis of the impact of a pandemic and consider supply chain resilience and the practical resilience strategies of firms. To our best knowledge, our study is the first one to focus on the practical resilience indicators and strategies of a specific firm during COVID-19, in addition to analyzing the impact of COVID-19. Finally, considering the characteristics of this retail supply chain, we analyze and discuss different industries, whereas previous studies examined only specific industries, such as medicine supply chains (e.g., Gereffi, 2020) or food supply chains (e.g., Hobbs, 2020).

### 3 | SUPPLY CHAINS AND INTELLIGENT PLATFORMS OF JD.COM

Note that supply chain resilience is not a static concept. In general, studies divide the entire process into pre-disruption (anticipation), during-disruption (response or resistance), and post-disruption (recovery) (Kamalahmadi & Parast, 2016; Sheffi & Rice, 2005). In this section, we introduce the efforts of JD.com and its improvement of the supply chain resilience undertaken before the pandemic. There are mainly two measures. First, as a result of its specific business model, JD.com possesses a highly integrated retail supply chain structure, which enables it to be highly resilient. In addition, JD.com has built comprehensive intelligent platforms supporting its daily operations, which benefit the firm in digitalization and intelligence.

#### 3.1 | Business model of JD.com

JD.com is an integrated retail giant with specific supply chains. The core of its business model, the “self-operated mode,” has been critical for the success of JD.com in China. In this mode, JD.com purchases all products for

its self-operated online stores from suppliers, with whom it has agreements for long-term cooperation. Furthermore, it is responsible for all subsequent processes, including inventory management, distribution, delivery, and after-sale service. Therefore, the company can effectively control the quality of products and services. Concurrently, in addition to having self-owned stores, JD.com is an open platform for affiliated stores operated by independent merchants and companies. Presently, the self-operated stores contribute to ~60% of the sales of JD.com, and its affiliated stores account for the remaining sales.

The self-operated mode results in a supply chain structure that is completely distinct from that of other retailers. As shown in Figure 1, traditional retail supply chains consist of several distinct stages, in which the products move from factories to brand manufactures to general agents to distributors to retailers and finally to consumers. Supply chains of this type do not possess information sharing and resilience. In general, each stage is composed of independent firms. Therefore, although it is critical for a firm in any stage to have information (e.g., supply and demand information) about the other stages, it does not have access to it. The deficiency of information is likely to cause delayed responses when disruptions occur. In addition, the multistage structure prolongs the process of demand satisfaction, and the effect of disruption is magnified owing to the bullwhip effect.

The integrated supply chain structure of JD.com is different. Because all intermediate stages are integrated, the supply chain can perform effectively and resiliently. In particular, the integrated supply chain displays the following characteristics.

### 3.1.1 | High level of collaboration

Supply chain collaboration is enhanced in several aspects. First, the positions of the general agents, distributors, and

retailers are merged; therefore, these three stages can function in close cooperation. Combining the stages also simplifies the supply chain structure and enables JD.com to influence the entire supply chain strategy. JD.com has occupied a leading position in the retail supply chain and has developed close relationships with suppliers and consumers. Thus, the collaboration between stages is improved.

### 3.1.2 | Effective information sharing

It is established that collaboration can involve information exchange (Christopher & Peck, 2004). In the integrated supply chain of JD.com, information is shared inside the company owing to the high level of collaboration. Therefore, timely information on supply and demand becomes available to all departments. Concurrently, the simple structure of the supply chain enables information flow by alternative channels. JD.com collects feedback from its consumers and shares the information with its suppliers. In return, the suppliers share a part of their operational data (e.g., inventory condition and capacity) with JD.com.

### 3.1.3 | High level of agility

Supply chain agility is the capability to respond rapidly to unpredictable variations in demand or supply (Christopher & Peck, 2004). Compared with the traditional supply chains having multiple independent stages, the integrated supply chain of JD.com can rapidly identify disruptions and effectively adjust the operational strategies for procurement, distribution, and promotion. The collaboration between the stages further improves the agility and performance of the entire supply chain. In addition, JD.com uses various intelligent platforms for prediction, automatic replenishment, and

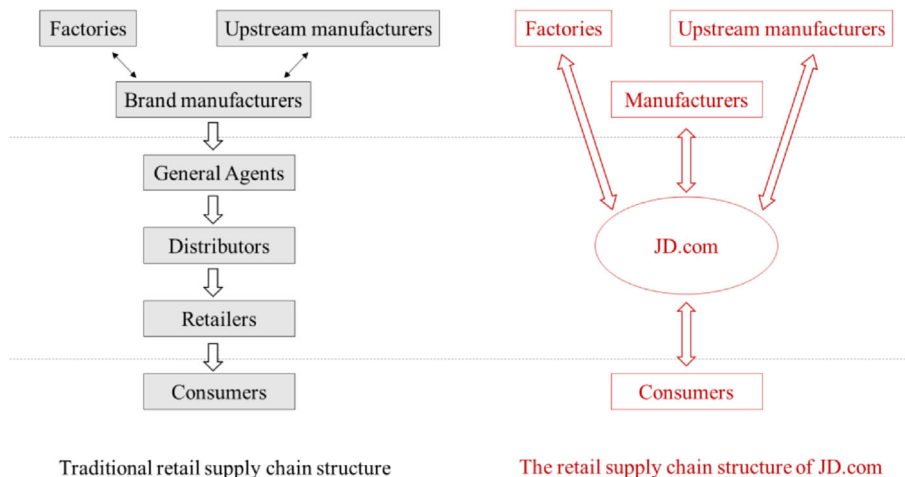


FIGURE 1 Comparison of supply chain structures of typical firms and JD.com

warehouse network optimization to assist and expedite adjustments of its operation strategies, which also improve the supply chain agility.

To summarize, the integrated supply chain structure of JD.com ensures higher levels of collaboration, information sharing, and agility and results in better supply chain resilience than those of other firms. Furthermore, the integrated supply chain is expected to perform better than the traditional structure because JD.com almost dominates the supply chain and can improve the supply chain performance significantly by its strategies. The time, costs, and efforts for negotiating are saved owing to the high level of collaboration, and the consumers can receive higher benefits with better service.

It is worth mentioning that although the integrated supply chain structure of JD.com displays higher resilience than the traditional structure, it is reasonable for certain retailers to opt to maintain the latter. First, integration is challenging. Specifically, a firm has to develop a complete distribution network throughout the country, which requires substantial time and capital investment. The high operational costs are also a major concern. Retailers without a logistics network or a warehouse are required to only transfer the orders to their upstream suppliers and professional logistics companies to profit from each successful order. However, because JD.com has integrated the intermediate stages, it has to sustain the inventory and transportation costs. These are paid by the suppliers and distributors in the other mode. The integrated supply chain requires a higher cash flow than typical, which is difficult for most companies. Finally, it is risky to be responsible for the entire supply chain. If the supply chain is destroyed completely, the company with an integrated supply chain would have to bear all

losses. Therefore, resilience becomes a more critical attribute for JD.com than for other pure retailers.

### 3.2 | Intelligent platforms of JD.com

Another representative example of the pre-disruption resilience strategies of JD.com is its intelligent investment in digital technologies. Taking advantage of the effective information sharing led by its integrated supply chain structure, the company has been committed to building digital intelligent platforms since before 2014 (integrated into JD Big Data Platform). In this section, we introduce the composition of three core intelligent platforms supporting the daily operations of JD.com: intelligent forecast platform, smart replenishment platform, and distribution network optimization system. The processes by which JD.com utilized these platforms to improve its supply chain performance during the pandemic are discussed subsequently in Section 5. In particular, the intelligent forecast platform and the smart replenishment platform were used to deal with the extreme demand scenario (described subsequently in Section 5.1.1), whereas the distribution network optimization system was modified to address the logistics disruptions caused by the lockdown policy (described in subsequently Section 5.2.1).

#### 3.2.1 | Intelligent forecast platform

The dynamic and intelligent prediction platform operates as the basis of most operation strategies of JD.com. Its main structure is shown in Figure 2. In this system, first, data are collected from various sources and saved,

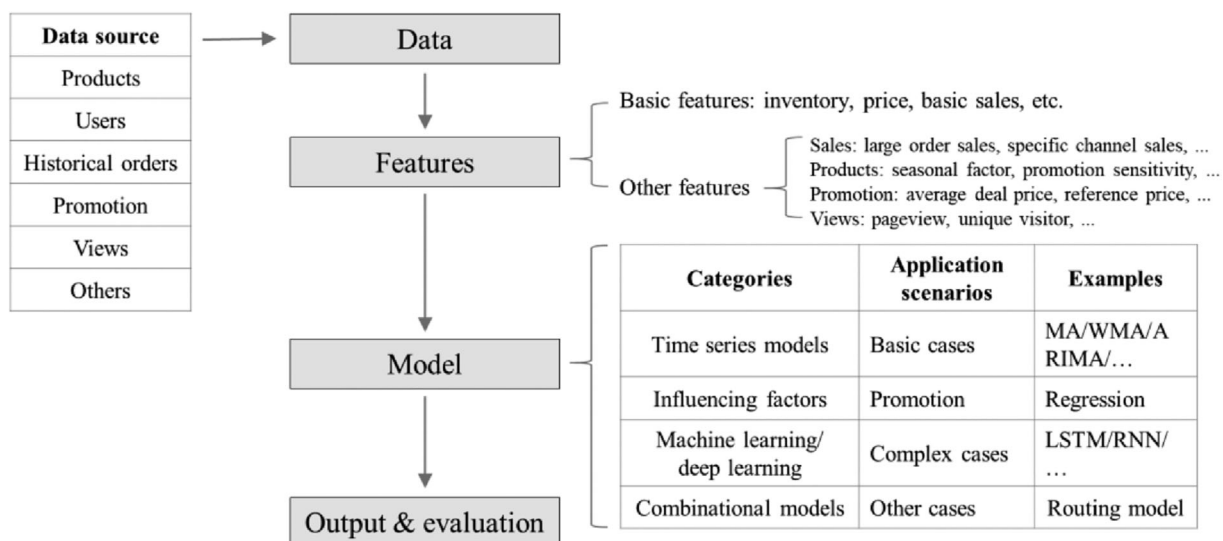


FIGURE 2 Structure of intelligent prediction platform of JD.com

including information on products, users, orders, promotional strategies, views, and other information such as micro-economic scenarios and strategies of competitors. Subsequently, specific numerical features are extracted from the data and input into mathematical models to derive the prediction results. Different models are adopted based on the application scenarios, and specific models are developed for specific cases. For example, for products for which none of the existing methods are effective, a routing model is developed to combine all existing models, and the most effective combination form is selected based on a loss function. If traditional forecasting methods are ineffective for certain products, machine learning models, including boosting trees, long short-term memory (LSTM), and neural networks, are used. A successful practice is the forecast of new arrivals without historical data. A machine learning model consists of two subsequent stages: a transformer model to identify similar products and a recursive neural network (RNN) model to forecast sales using the historical data of the similar products selected in the previous step.

### 3.2.2 | Smart replenishment platforms

In addition to intelligent prediction, JD.com is attempting to realize automated replenishment procedures (see Figure 3). JD.com classifies products into four categories based on supply stability and demand predictability. For products with highly predictable demands and stable supplies, a smart replenishment platform called TIBPA was developed and applied in late 2018. Essentially, TIBPA is a dynamic, automatic periodic replenishment model based on quantile prediction. It was upgraded to TIBPA 2.0 by updating the replenishment logics and applying multiple evaluation indicators.

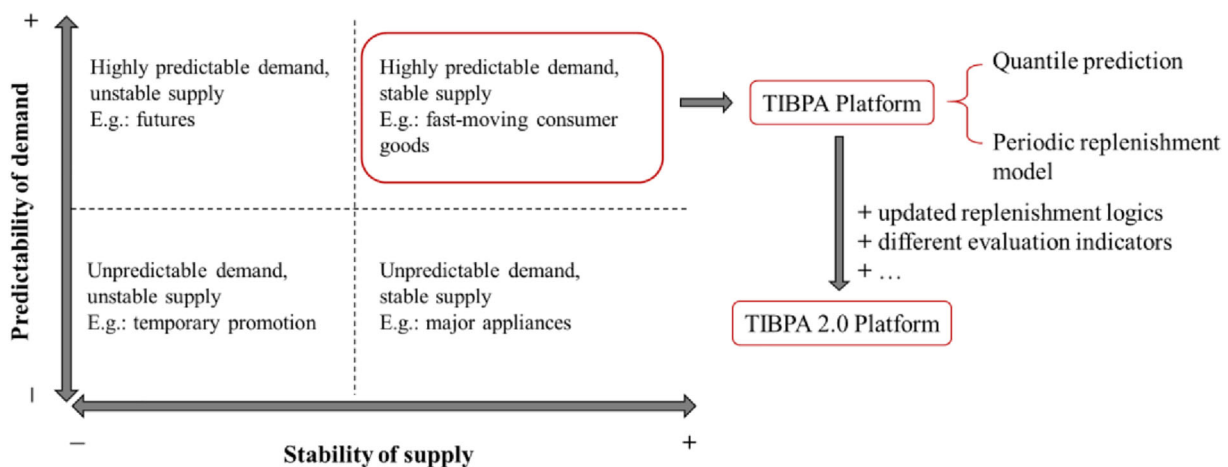


FIGURE 3 Smart replenishment platforms of JD.com before COVID-19

### 3.2.3 | Distribution network optimization

The final platform that supported the operational strategies of JD.com during the COVID-19 pandemic was a distribution network optimization system called JD-NetSIM. It is basically a nonlinear integer programming model for minimizing total related costs by warehouse network optimization (see Figure 4). The model is a network that consists of nodes for demands, nodes for alternative distribution centers (DCs), and paths between nodes. Constraints including path capacities, delivery time, and sales are considered, and the output includes the locations of the DCs and the resulting distribution plan (including the service region of each DC and the distribution route for each product).

## 4 | IMPACT OF COVID-19 PANDEMIC ON SUPPLY CHAINS

The COVID-19 pandemic has caused severe supply chain disruptions in China. Although we have qualitatively discussed the resilience of the integrated supply chain of JD.com in Section 3.1, the underlying intelligent platforms and powerful database provide a rare opportunity to analyze its resilience level quantitatively. In this section, based on the Big Data Platform of JD.com, we identify practical resilience indicators for the supply chain of JD.com, analyze the supply chain scenario based on the indicators, and summarize two main difficulties that the company experienced during the COVID-19 outbreak.

### 4.1 | Data and resilience indicators

A practical assessment of the resilience level is the first step for firms to acknowledge their readiness to



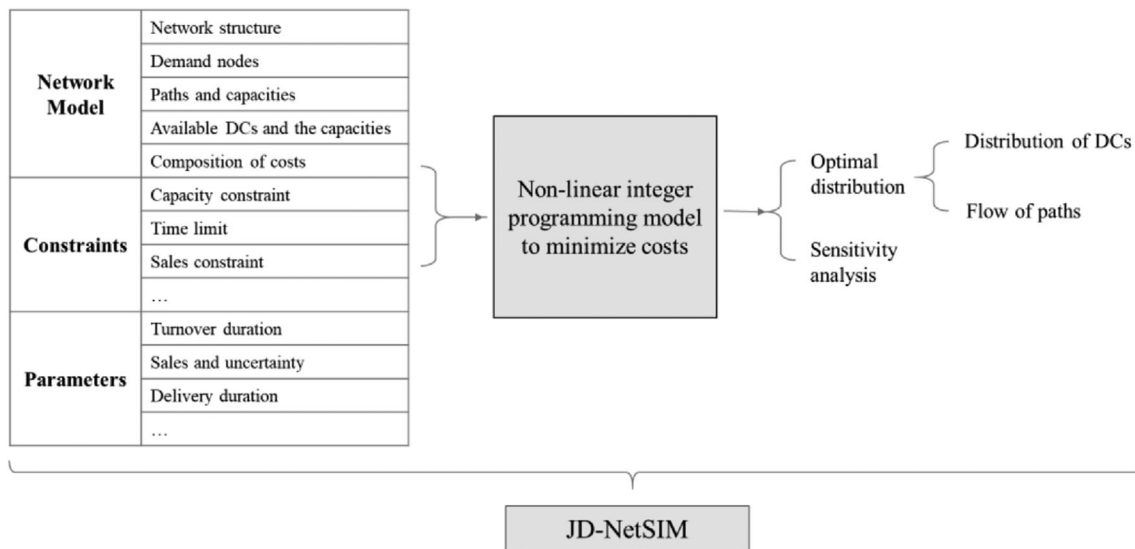


FIGURE 4 Structure of JD-NetSIM

disruptions (Katsaliaki et al., 2021), and can be used to estimate the effectiveness of their responses toward disruptions. However, specific indicators of supply chain resilience are few. Although indicators such as TTR and TTS have been proposed, they are not commonly used in practice. Therefore, based on the existing statistic indicators of JD.com, we propose a framework that uses the operational indicators of firms to analyze their supply chain resilience. In our case, supply chain resilience is closely related to the capability to satisfy the needs of consumers during the COVID-19 pandemic.

#### 4.1.1 | Data

Our data are mainly obtained from the Big Data Platform of JD.com (<https://bdp.jd.com>), which integrates all intelligent platforms that we introduced in Section 3.2 and records all transaction data in the daily operations of JD.com. Based on the powerful database, JD.com calculates various operational indicators to evaluate its performance in supply, logistics, and sales, which are the basis of our resilience indicators. After collecting and analyzing the common operational indicators, we select appropriate indicators following certain principles and link them with the corresponding aspects of supply chain resilience. The indicators and the selection process are described in Section 4.1.2 in detail. As required by JD.com, only monthly data are revealed owing to confidentiality reasons.

To facilitate analysis and discussion, we also incorporate two external data sources to present the general scenario during COVID-19 in China. Data of new COVID-19

patients in China are obtained from the official website of National Health Commission of the People's Republic of China (<http://www.nhc.gov.cn/>). Note that although the raw data are measured in days, monthly indicators are required in our analysis to be consistent with the operational indicators. Moreover, considering that COVID-19 cases were not reported until January 11, 2020, we finally choose *the daily average quantity of new COVID-19 patients in a certain month* as the monthly indicator for the severity of COVID-19 in China. To show the negative impacts of COVID-19 on the development of the Chinese national market (particularly on logistics and transportation), we present two statistic economic indicators reported by the National Bureau of Statistics (n.d.) of China (<https://data.stats.gov.cn>): *year-on-year growth rate of ton-mileage and freight volume*. Using the year-on-year growth rate instead of the absolute value enables focusing on the impact on development. It is worth mentioning that while we only choose two of the indicators, almost all economic indicators show the exact same trend during the period of analysis.

#### 4.1.2 | Identifying indicators for resilience

Based on the operational indicators provided by the Big Data Platform of JD.com, we identify appropriate indicators for the supply chain resilience of JD.com. Motivated by Tang (2006) and the supply chain structure of JD.com, we classify the approaches for enhancing supply chain resilience into three fundamental categories, as depicted in Figure 5. For each category, we select one representative operational indicator for performance assessment to keep the analysis concise. Similar to the case of economic

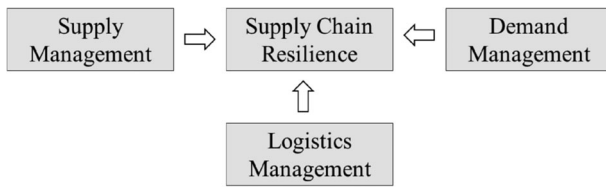


FIGURE 5 Fundamental approaches for improving supply chain resilience of JD.com

indicators summarized by the National Bureau of Statistics of China, although only selected indicators are utilized in our study, no other indicators led to conflicting results based on our analysis.

### Supply and demand

For supply management, we use the *order fill rate* to depict the supply scenario. It is defined as the percentage of orders (by value) that are satisfied by suppliers. Order fill rate is a direct indicator of the supply capacity relative to the demand. The indicator of demand management is the *proportion of dull sales*. A product is defined as *dull* when it remains in the warehouses longer than its expected inventory turn-over days, and *the proportion of dull sales* can be interpreted as the proportion of products that should have sold but did not. This indicator mainly describes the demand scenario of slow-moving categories, which is the primary theme of demand management. For illustration, other auxiliary indicators are also employed when discussing practical strategies and the resilience level. For example, *procurement amount* is a direct indicator of the supply capability (particularly for categories that are out of stock), and *sales* preforms as a direct indicator of demand management.

### Logistics

Indicators of the final category present the resilience of the logistics system of JD.com, which is composed of inventory and distribution systems. The common operation indicators include *inventory level* and *inventory turn-over days*. Although lead time is a key indicator of the velocity of a supply chain (Jüttner & Maklan, 2011), it cannot be revealed owing to confidentiality reasons. Therefore, we use the *inventory turn-over days* to depict the performance of a delivery system, and the *inventory level* to describe the inventory performance.

Finally, we introduce a composite operation index proposed by JD.com, which can be used to evaluate the performance of the entire supply chain: *available rate per pageview*. It is defined as the average percentage of the available products (in stock) when consumers click on a product page during a period. This indicator is effective because JD.com does not adjust the product display based

on availability. Specifically, if a product is out of stock, consumers can still view the product page; however, they cannot place an order. Therefore, this indicator in effect depicts the possibility that JD.com can satisfy the demand of consumers without unnecessary delay.

These indicators reflect the supply chain resilience in terms of both flexibility and agility. The indicator values before the COVID-19 pandemic are considered as baselines, and the variations throughout the pandemic present the variation in the performance of different aspects of the supply chain. Most of the indicators in our study are normalized or transformed into an index for confidentiality. Nonetheless, the trend remains consistent with that of real data.

## 4.2 | Shocked resilience

As explained in Section 4.1.2, we use the available rate per pageview to depict the resilience level of the entire supply chain throughout the pandemic. As shown in Figure 6, the entire disruption lasted for ~3 months, from late January 2020 to late April 2020. The indicator decreased abruptly at the end of January 2020, demonstrating the speed and severity of the supply chain damage caused by COVID-19. There was a decrease of ~10% in the supply chain performance and the resilience level. The supply chain started recovering from February 20, 2020 and required another 2 months to return to the normal state. It recovered fully before May 2020. It is worth mentioning that the regional distribution center (RDC) of JD.com for the entire central China region is located in Wuhan, the core city of COVID-19 in China; therefore, it plays a critical role in the logistics network of JD.com. At the starting point of the COVID-19 outbreak, the Wuhan RDC was responsible for ~120 subordinate warehouses in Hubei, Hunan, Jiangxi, and Henan provinces, and was the fourth largest DC in China, following the Beijing, Shanghai, and Guangzhou RDCs. Although Wuhan was under lockdown until April 8, 2020 (China News Service, 2020a), the recovery of the supply chain of JD.com started a long time before the lockdown was lifted, which is a strong evidence of the agility and resilience of its supply chain.

Subsequently we use the four identified operational indicators to describe the resilience variation of the sub-systems of the supply chain of JD.com, which are shown in Figure 7. We normalize the data based on the values in January 2020, and only monthly data are disclosed owing to confidentiality constraints. The plot in the upper left corner depicts the supply scenario. Compared with the other three indicators, the variation in the order fill rate is relatively smooth. This suggests that the supply

side was not damaged severely. Regarding the demand management, the indicator shown in the upper right corner presents a distinct scenario—the proportion of dull

sales increased by over 60% in February 2020 as the demand for most categories, except emergency supplies, decreased abruptly. In the following 2 months, JD.com adopted effective measures to improve this scenario by ~40%.

The latter two indicators at the bottom of Figure 7 depict the resilience level of the logistics system of JD.com. Overall, the inventory level indicator shown in the bottom left corner suggests a stable performance of the inventory system, and inventory turn-over days indicator displayed in the bottom right corner indicates a delivery system that received a remarkable shock in February 2020 but rapidly recovered. It is worth mentioning that although the inventory level decreased by ~20% in February 2020, this does not suggest a decline in the inventory performance. In fact, as shown in Figure 8, the inventory levels of the products with strong demands fluctuated significantly owing to the joint effect of demand and supply, and there is no indicator that the inventory capacity was full to cause restriction of the supply. However, products with stagnant demands remained very stable as a result of effective procurement strategies. In general, the

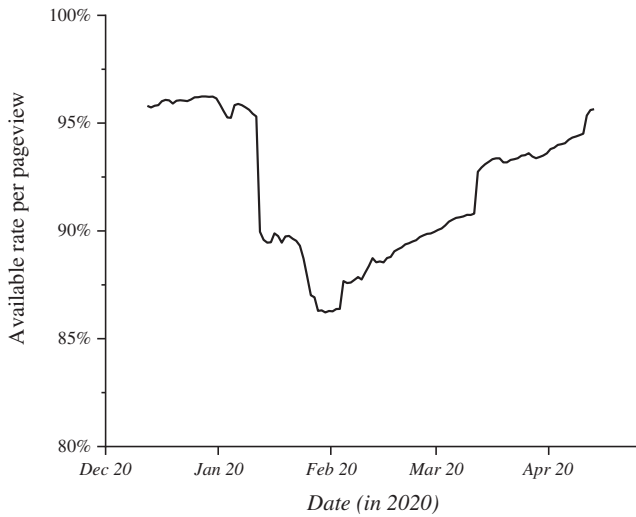


FIGURE 6 Available rate per pageview of JD.com (January 2020–May 2020)

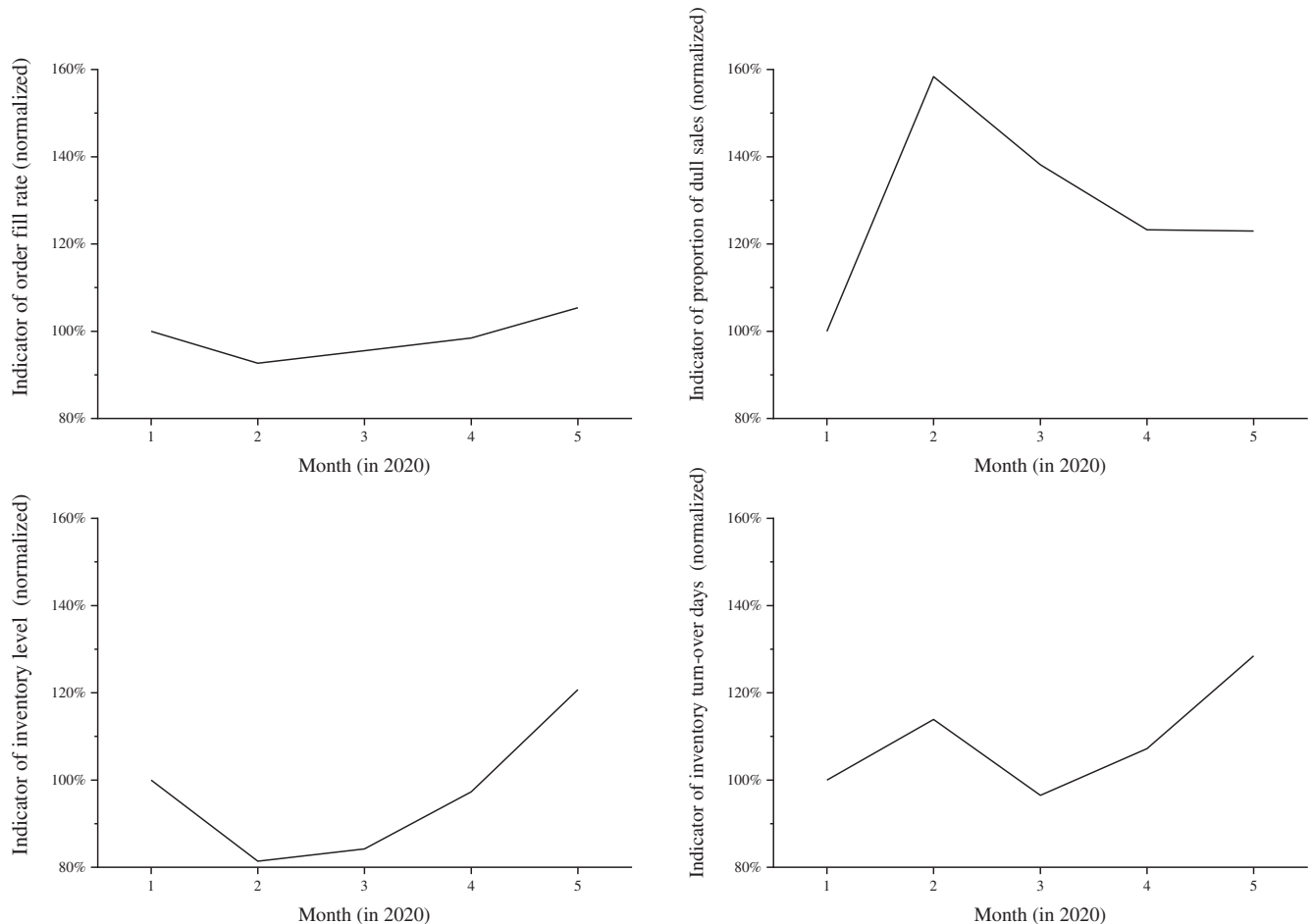


FIGURE 7 Resilience indicators of supply, demand, and logistics (January 2020–May 2020)

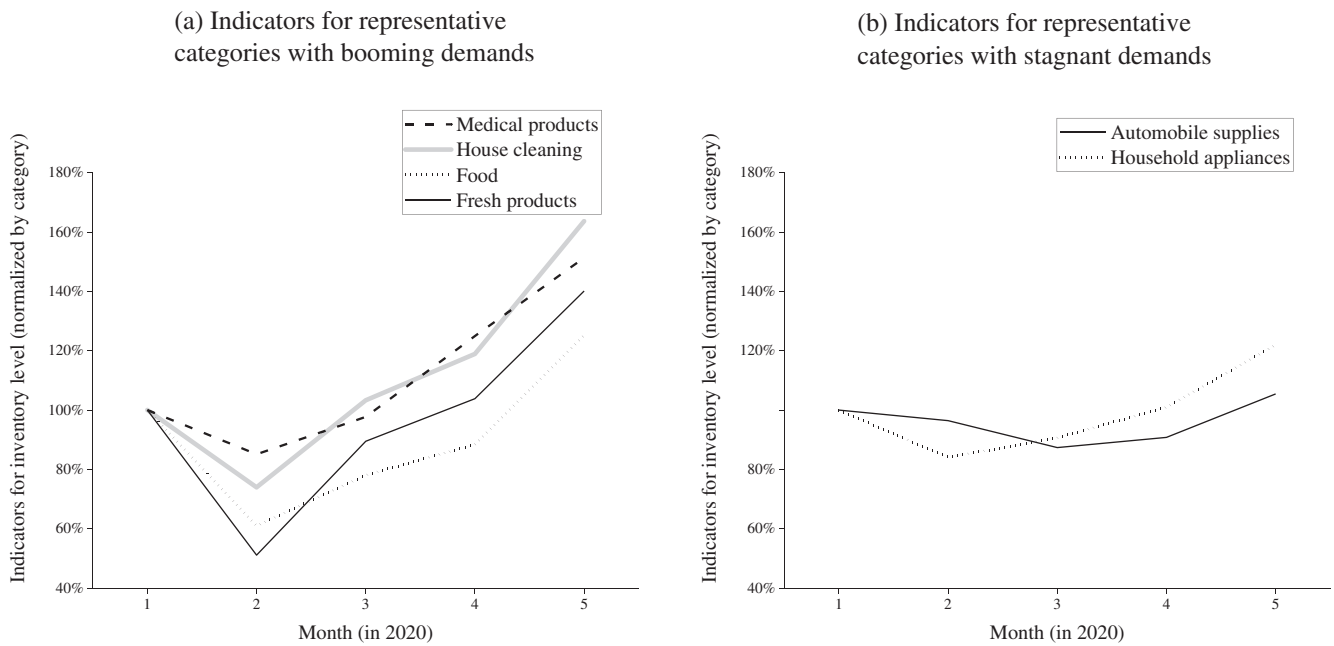


FIGURE 8 Inventory level indicator for representative categories (January 2020–May 2020)

stability of the latter products mitigated the impact of the former, and the relative stability of the overall inventory levels avoided excessive inventory costs. Finally, we need to clarify that the significant increase in both the inventory level and turn-over days in May 2020 was unrelated to the pandemic. At that time, JD.com was stocking up in preparation for an annual promotion on June 18, 2020; therefore, the resulting indicators do not indicate any supply chain disruption or inefficiency.

Typical supply chain risks include supply shortages, logistics disruptions, supplier financial failures, and supplier responsibility problems (Chen & Lee, 2016). From the discussion above, the supply chain of JD.com performed well in terms of supply and inventory management, whereas the performance in terms of demand and delivery management was adversely affected significantly. In the following, we describe these two main difficulties in detail.

### 4.3 | Exceptional demands

The most critical problem that JD.com has experienced during the COVID-19 outbreak is exceptional demands. The scenario in China is essentially similar to that addressed in previous studies in the context of other countries (e.g., Gray, 2020; Reardon et al., 2020). The demands for medical products, house cleaning, food, and fresh products increased abruptly owing to the pandemic, whereas other products such as automobile supplies and household appliances experienced dull sales.

The pandemic altered the relatively stable and predictable demands. The demands for products such as masks, medical alcohol, and liquid soap increased abruptly. Because individuals attempted to stay home to the maximum extent, the demands for food and fresh products also increased. In Figure 9, we show the year-on-year growth rates of the sales for four representative product categories on JD.com from January to May 2020. We use the daily average quantity of new patients in each month to understand the severity of the pandemic. It is evident that the COVID-19 outbreak resulted in demand peaks for the categories shown in the figure in February 2020. The sales of fresh products increased by over 130% and those of medical products and food increased by over 50%. Correspondingly, reports on the scenarios of shortages described a similar phenomenon. The in-stock rates of these categories decreased abruptly in January and February 2020, particularly for medical, food, and fresh products.

The demand for emergency supplies and necessities increased dramatically, whereas the products in other categories experienced challenging scenarios, that is, severe reduction in sales (see Figure 10). In February 2020, the sales of automobile supplies decreased by over 30%. For products such as household appliances and personal digital products, the spring festival holiday (which started at the end of January 2020) was expected to grow sales. However, the COVID-19 outbreak subverted that trend. The rates of redundant products (in warehouses) comprising automobile supplies and household appliances were almost 50% during the most difficult period,



and the scenario did not return to normal until 5 months later. The in-stock rates of the slow-moving products (e.g., automobile supplies) also decreased during the pandemic, suggesting that the supplies of these products may also have experienced certain problems simultaneously.

The exceptional demands caused a series of problems for the supply chain management. Demand predictions, procurement plans, and delivery strategies had to be adjusted rapidly to consider factors related to the pandemic. Resources for calculation, optimization, and operation were frequently being operated at full loads to address the unprecedented scenario. Emergency products such as masks were frequently out-of-stock, which adversely affected consumer satisfaction and platform advantages. It was necessary to incur additional costs for emergency replenishments to satisfy consumer needs, including increased prices, communication costs, and delivery costs. For other products that were in stock but had lower-than-expected sales, the additional inventory costs further intensified the economic pressure.

#### 4.4 | Logistical disruptions due to lockdown policy

In contrast to the substantial demand for emergency supplies, COVID-19 and the necessary countermeasures almost destroyed the corresponding distribution and delivery systems. On January 23, 2020, Wuhan became the first “blocked” city, that is, ordinary people were not permitted to leave or enter. After 5 days, this policy was implemented in all cities in Hubei province, except those in the Shennongjia forest region (Lin & Han, 2020). This hindered the operation of the existing distribution network. Road travel required a traffic permit, and drivers

were required to establish their health condition by different methods, such as body temperature measurements and COVID-19 tests. Workers were forced to remain in their cities of residence, and the resulting labor shortage further intensified the challenge. Based on the data from the National Bureau of Statistics of China (see Figure 11), the year-on-year growth rate of both ton-mileage and freight volume decreased abruptly in February 2020, the period in which China was most severely affected by the pandemic (National Bureau of Statistics, 2020).

The distribution and delivery systems of JD.com experienced similar dynamics. There were obstacles in different stages. First, the warehouse network (comprising the DCs and their transport sequences, e.g., orders in Changsha city were transported as follows: suppliers → Wuhan RDC → Changsha Front DC → consumers) was affected by the lockdown policy. Owing to the lockdown, the RDC in Wuhan (which functioned as the main DC for the four provinces in central China) could not dispatch any products from Hubei province. A manually prepared emergency plan (as shown in Figure 12) was adopted, and the DCs from Beijing, Xi'an, Shanghai, and Guangzhou were temporarily assigned to operate as alternatives. It is estimated that this alteration of the warehouse network reduced the delivery performance by over 20%, with the delivery costs being higher than those before. In addition, the deliveries in pandemic-hit areas were compelled to slow down in the interest of security and to address the concerns regarding the health of workers and the risk that the products may carry the virus. Finally, the lockdown policy resulted in a revolution in last-mile delivery. In addition to labor shortage (which reduced the delivery capacity of JD.com), many demand nodes became unavailable. Communities, schools, and other places were closed, and individuals from outside were

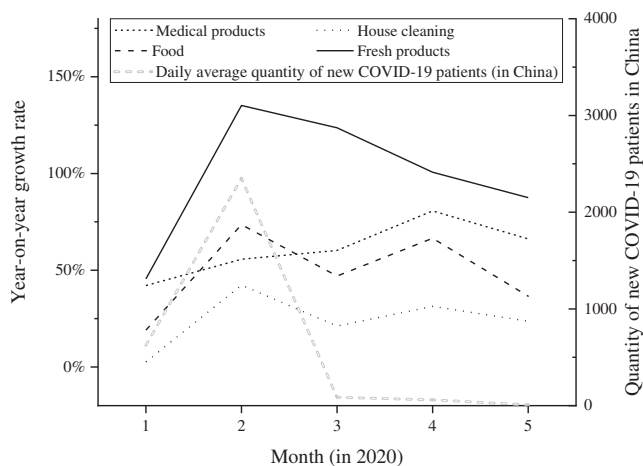


FIGURE 9 Growth rates of sales for representative product categories on JD.com (January 2020–May 2020)

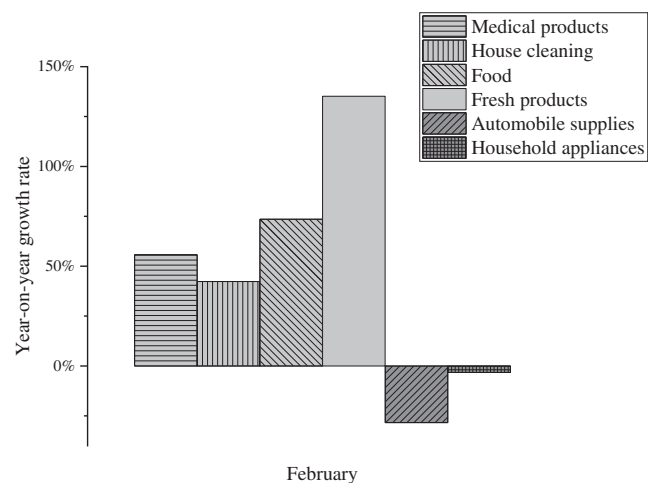


FIGURE 10 Growth rates of sales of representative product categories on JD.com in February 2020

not permitted. Deliveries to other emergency locations, such as hospitals and hotels for isolation, were impossible owing to the exceptionally high risk of infection.

## 5 | PRACTICES OF JD.COM IN RESPONSE TO COVID-19 PANDEMIC

In this section, we describe the resilience strategies that JD.com adopted to improve its supply chain resilience during the pandemic. The main strategies included widespread application of advanced digital technologies, flexible adjustment of operational strategies to address specific problems caused by the pandemic, and undertaking of measures to help control the pandemic and the normal order of the market.

### 5.1 | Managing exceptional demands

As described in Section 4.3, products of different categories experienced different demands, and the categories with growing and dull sales exerted converse impacts on the supply chain during the pandemic. We use the available rate per pageview and the proportion of dull sales to illustrate this scenario in Figure 13. Although the ordinate values are omitted considering confidentiality constraints, we have ensured that the vertical coordinates of two graphs in a row have identical ranges.

Recall that the available rate per pageview presents the resilience level and that a high proportion of dull sales results in high costs and low efficiency. Therefore, the decrease in the resilience level was mainly due to the categories with growing demands, and the products with

dull sales negatively influenced the supply chain performance. To improve the supply chain resilience as well as performance, the capacities of supply and demand management were re-allocated to different product categories. The focus of supply management shifted to the products with high demands. As a result of the coordination of JD.com with its suppliers, the resilience indicator improved significantly after February 2020. Concurrently, promotions (which function as the core operation of demand management) were conducted to improve the sales of slow-moving products. Subsequently, the capital accrued from the promotions was re-invested to improve the supply chain performance. This resulted in a virtuous circle. Concurrently, the intelligent platforms, including the intelligent forecast platform and the smart replenishment platform, provided comprehensive support during the entire process.

#### 5.1.1 | Flexible support by digital platforms

The exceptional demand scenario brought by the pandemic posed a serious challenge to the intelligent forecast platform. On January 22, 2020, the first day after COVID-19 was announced as a human pandemic (Dong, 2020), the forecasting error evaluated by the weight mean absolute error reached its highest level during the entire pandemic, almost double that in the same period the previous year. Mainly the following modifications were made to the intelligent forecast platform in response. First, in the modified model, products are re-allocated to categories based on their positions in the COVID-19 outbreak. The old model before COVID-19 is continued to be used for categories without significant changes in their demands. For the categories that are significantly influenced by the pandemic, the models are re-trained using modified features, in which features closer to the pandemic outbreak are created or assigned higher weights. Accordingly, the intelligent forecast platform could integrate the varying pandemic-related data and predict the variations in demands in real time. These prediction results enabled JD.com to conduct strategic purchases of key supplies rapidly. Concurrently, based on the real-time pandemic scenario, JD.com could allocate resources to areas with large demand gaps and flexibly cover regional variations. The platform also provided insights into the promotional design for slow-moving products requiring promotion.

For the smart replenishment platform, an “end-to-end model” combining prediction and replenishment strategies was launched immediately after the COVID-19 outbreak. It achieved better performance than the classic TIBPA system during the pandemic. As illustrated in

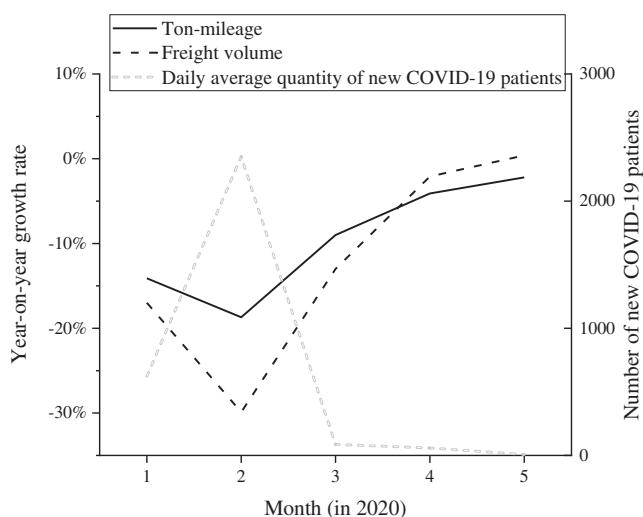


FIGURE 11 Year-on-year growth rate of delivery indicators (January 2020–May 2020)

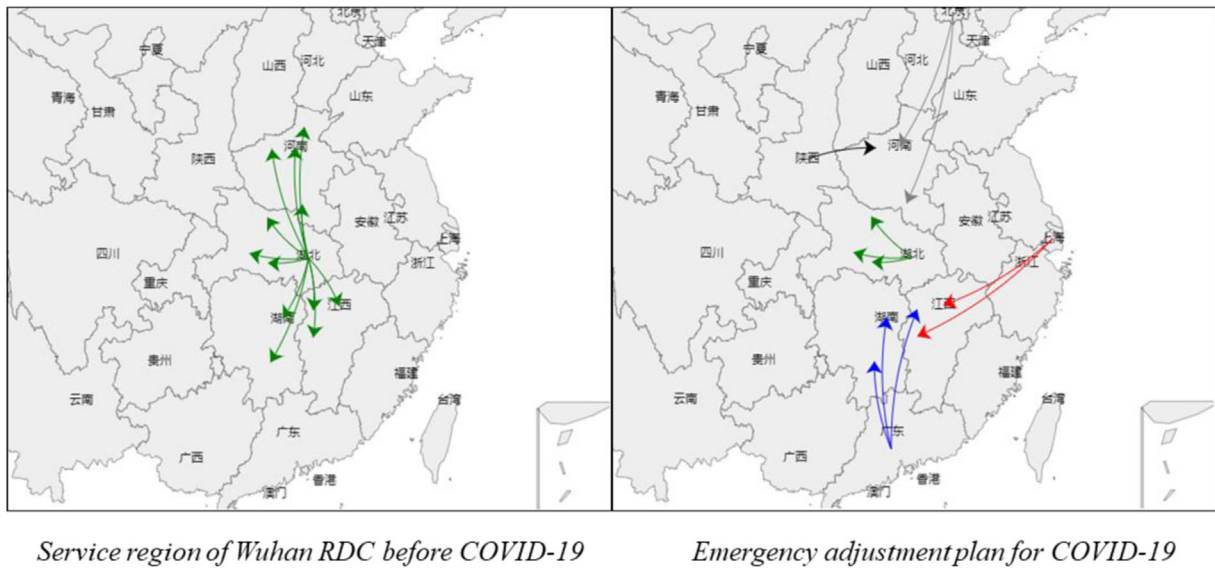


FIGURE 12 Warehouse network disruption and an alternative plan for Wuhan RDC

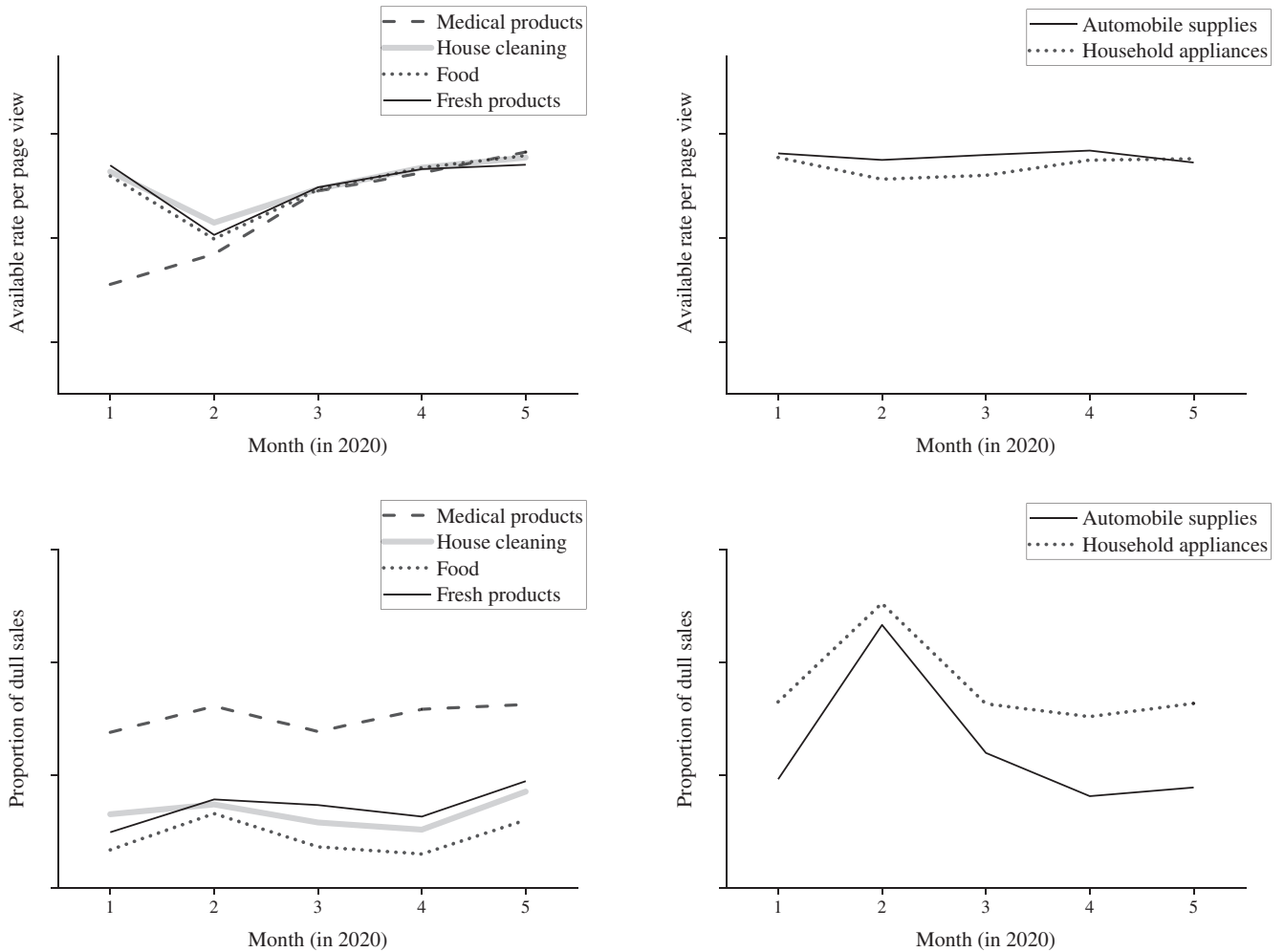


FIGURE 13 Resilience indicators for representative categories of JD.com (January 2020–May 2020)

Figure 14, sequential data including historical sales, vendor lead times, stock information, and review periods are processed using a multi-quantile RNN to predict sales and vendor lead times. The replenishment strategy is provided automatically based on the prediction results by the same multi-quantile RNN model. Details of the model are available in Qi et al. (2020). During the pandemic, both the “end-to-end model” and TIBPA 2.0 system were used to support the replenishment strategy. This accelerated the replenishment process and improved the performance with regard to inventory management.

### 5.1.2 | Coordinating with suppliers

The majority of self-operated stores in JD.com have close relationships with upstream partners. During the COVID-19 outbreak, JD.com actively coordinated with suppliers, which ensured strong supply capabilities for the products with growing demands. For example, until February 7, 2020, JD Fresh extensively coordinated with over 300 suppliers and over 30 warehouses across China to effectively respond to the surging demand for fresh products. Concurrently, the standardized, efficient procurement process for the suppliers of self-owned stores enabled JD.com to purchase rapidly without negotiation, thereby further accelerating procurement. Figure 15 illustrates the two key approaches of the procurement process of JD.com: automatic and artificial procurement. In the traditional artificial procurement process, procurement managers determine the purchase quantities based on the forecasted demand, product availability, related cost, or even personal preferences, and manually place orders with external suppliers or the self-owned warehouses of JD.com. Generally, a procurement manager is responsible for a group of products within a particular category, and these products are frequently supplied by different sources; thus, artificial procurement is both time-consuming and error-prone. Therefore, during the pandemic, the automatic method was extensively adopted to improve the procurement efficiency. Specifically, the expected inventory levels were determined by the smart replenishment platform (see Figure 3 and Figure 14 for details). Following this, the purchase quantities were calculated automatically based on the amount of in-transit stock. Subsequently, purchase orders were placed by the digital

system automatically. Procurement managers were required to only assess the procurement quantities and urge the suppliers to revert back in time. Supported by the strong capabilities of collaboration and digital innovation, the automatic procurement significantly expedited the procurement process and ensured the supply chain performance in supply chain management. As shown in Figure 16, JD.com achieved significant growth in the procurement quantities. The supply of fresh products achieved year-on-year growth rates of 259.52% and 186.90% in February and March 2020, respectively.

Many suppliers of self-operated stores are large enterprises, whereas the suppliers and owners of affiliated stores are mainly medium-, small-, or even mini-sized companies, which cannot overcome risk. As the turnover cycle in almost all industries was prolonged, such companies experienced severe capital problems. It has been reported that owing to the lockdowns, 69.7% of small- and medium-sized enterprises confronted cash flow problems, 42.0% faced raw material shortages, and 38.5% encountered shortage of labor resources (Li et al., 2020). To address these problems, JD.com adopted a series of measures to support such firms (including its affiliated stores as well as the suppliers of its self-owned stores). In particular, JD.com proactively expedited the payment cycle for the suppliers. For companies with turnover difficulties, JD.com took the initiative to prepay for goods. In the first quarter of 2020, the turnover duration of the company for payments reduced to 51.7 days, a year-on-year decrease of 5.7 days. Furthermore, JD.com used its supply chain capabilities to assist factories in procuring necessary raw materials and other necessities, and thereby, ensure the production of emergency supplies, such as masks. To address the delivery problems caused by labor shortages and lockdowns, JD.com shared its delivery system with other firms and volunteered to pick up supplies and help its suppliers with delivery. This aid to the suppliers helped alleviate the supply shortage for JD.com. In February 2020, the in-stock rate of masks on JD.com increased by ~50% from the previous month.

To satisfy the substantial demand during the pandemic period, JD.com also developed a solution for offline stores encountering selling and delivery problems. By actively lowering the entry barriers to the retail platform, JD.com provided offline stores with the alternative

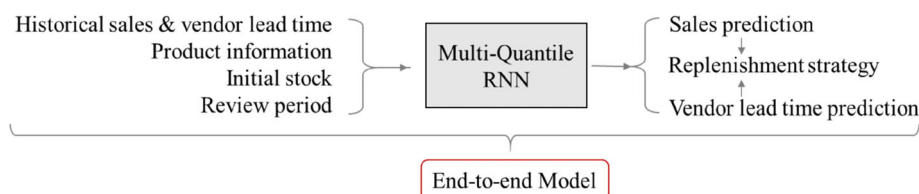


FIGURE 14 Schematic of “end-to-end” model



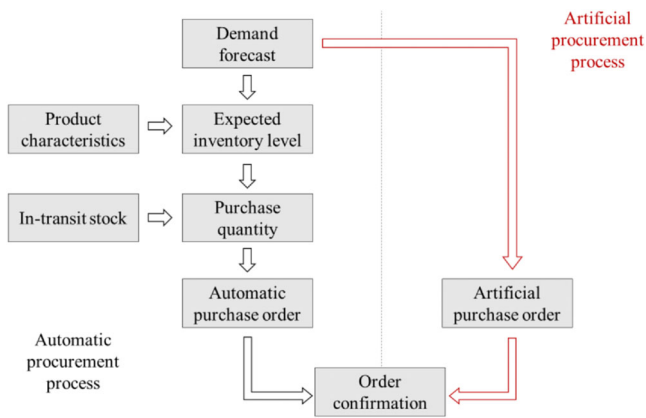


FIGURE 15 Standard procurement processes on JD.com

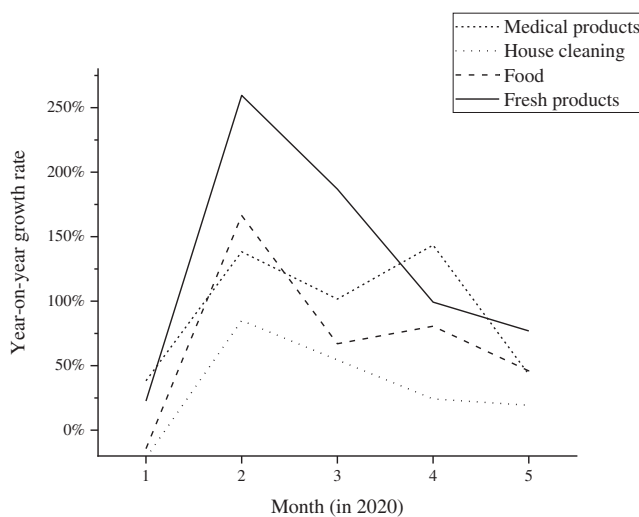


FIGURE 16 Growth rates of procurement quantities of representative product categories on JD.com (January 2020–May 2020)

of selling online. In addition, by incorporating Dada Delivery and JD Daojia (a subsidiary company of JD.com, which focuses on local instant retail delivery), JD.com shared its efficient delivery system with these offline stores and provided these with omnichannel service capabilities. During the pandemic, ~60,000 stores in 335 cities joined the offline store delivery. Most of the pharmaceutical supplies among these were delivered within half an hour.

### 5.1.3 | Promotions

During the pandemic, the demands for medicine, personal protective equipment, and necessities increased extremely drastically that their supply had to be increased through all possible approaches, whereas the demands of other products, such as automobile supplies

and household appliances, absolutely collapsed. Concurrently, JD.com had stocked up based on the sales predicted before the pandemic, which resulted in a large proportion of dull sales (as shown in the upper right corner of Figure 7). To support slow-moving products and brands, JD.com launched the “Spring Rain Promotion Project” during March and early April 2020.

Unlike previous promotion projects, the Spring Rain Promotion Project was designed to reduce unhealthy inventories (which were defined as in-stock products with dull sales), instead of to improve the total revenue or profit through incremental sales. In particular, the objective of the sales was determined by a proportion of the sales predicted before the pandemic, and the promotion was in the form of both additional exposure and discounts. Specific details of the promotion measures were determined by the sales manager of each product category and varied with time and products. The suppliers cooperated similar to the manner in past promotions: they were required to provide basic prices, and additional discounts were offered by JD.com.

By early April 2020, in the promotion project, JD.com invested in resources valuing over 1.5 billion yuan in the forms of additional exposure and additional discounts, and high performance was achieved. As illustrated in Figure 17, the proportion of unhealthy inventories decreased continuously during the promotion. Overall, JD.com cleared over 100 million products from its self-operated stores by the promotion and improved the turnover duration by ~5.6 days. Moreover, the project and the resulting conformity effect also enhanced the entire retail market of JD.com, with a year-on-year increase of over 45% in total sales. Over 31,000 affiliated stores actively joined the project, providing extra discounts to utilize the additional exposure brought by the Spring Rain Promotion Project, and products valued at over 1.56 billion yuan were sold during the process.

The success of the Spring Rain Promotion Project, in turn, facilitated the suppliers of JD.com. By April 19, 2020, inventories valued at over 56 billion yuan were sold out, and the capital accrued from the promotion was re-invested in the supply chains. After the Spring Rain Promotion Project, another project called the “New National Products Project” was launched in early May 2020 to increase consumption and assist in economic recovery. In contrast to the previous promotion project, this promotion was launched in the “post-pandemic period” in China, during which time most lockdown measures, such as traffic lockdown and remote working, were removed and the quantity of new COVID-19 cases in China was negligible. Throughout the month (May, 2020), the daily average quantity of new COVID-19 patients across China was only in single digits (see Figure 9), and the transportation-related statistic

economic indicators returned to the levels of the last year (see Figure 11). The Spring Rain Promotion Project had focused on self-owned inventories, whereas the New National Products Project aimed at helping the affiliated stores and suppliers of JD.com and improving the turn-over rate of the entire supply chain during the pandemic. For thousands of affiliated stores and suppliers, JD.com invested over 1.2 billion yuan in financial support, logistics assistance, additional exposure, and operation assistance. Financially, JD.com provided low-interest loans with lower barriers as well as lower prices for the services of JD.com (such as logistics and promotion expenses) to the companies that joined the New National Product Project. In addition, JD.com made available a free official design software program (ling.jd.com) for the affiliated stores for a year and provided guidance on product selection, advertising, and marketing. Based on (incomplete) statistics, over 100,000 small- and medium-sized companies achieved over 100% improvement in turn-over days on a year-on-year basis. These two projects significantly helped the slow-moving categories. As shown in Figure 18, for the slow-moving categories, such as automobile supplies and household appliances, notwithstanding the recession in sales in February 2020, the market grew during the next few months.

## 5.2 | Dealing with logistical disruptions

Herein, we introduce the measures that JD.com adopted to deal with the logistical disruptions. The coronavirus outbreak exposed the vulnerabilities of overreliance on just-in-time and lean delivery systems (Sarkis et al., 2020). As mentioned in Section 4.4, the COVID-19 outbreak and the resulting lockdown severely impacted both the logistics

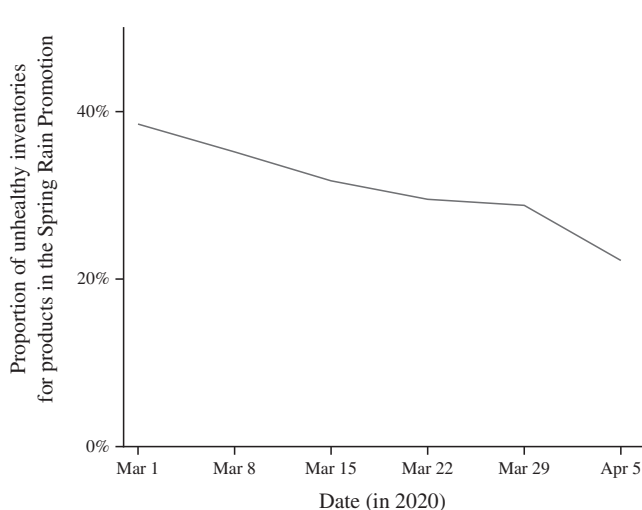


FIGURE 17 Proportion of unhealthy inventory during spring rain promotion project

network and delivery process of JD.com, particularly last-mile delivery. Specifically, the distribution network optimization system introduced in Section 3.2.3 was used to redesign the logistic network, and the process for last-mile delivery was modified to keep the deliverers at a safe distance from the customers.

### 5.2.1 | Redistribution of logistic network

Confronted with blocked DCs and a paralyzed distribution network in Hubei province, JD.com used JD-NetSIM, the distribution network optimization system, to redesign the entire distribution network with updated inputs. Herein, the network structure was adjusted after removing the unavailable paths and DCs. Parameters including costs, turnover duration, and sales were updated. The updated distribution network for the demands in Hubei province is shown in Figure 19. The DCs from Beijing, Shanghai, Guangzhou, and Xi'an were used to fulfill orders that should have been operated by the Wuhan DC, and the service regions of these DCs were re-divided. As estimated from previous data, the output plans improved the delivery performance by ~9.26% based on the percentage of deliveries within 48 h compared with the manually prepared plan, and the cost was reduced by over 3%.

### 5.2.2 | Modified process for last-mile delivery

Throughout the COVID-19 outbreak, challenges in last-mile delivery (the final leg of the path of a product to a consumer) became magnified because stay-at-home

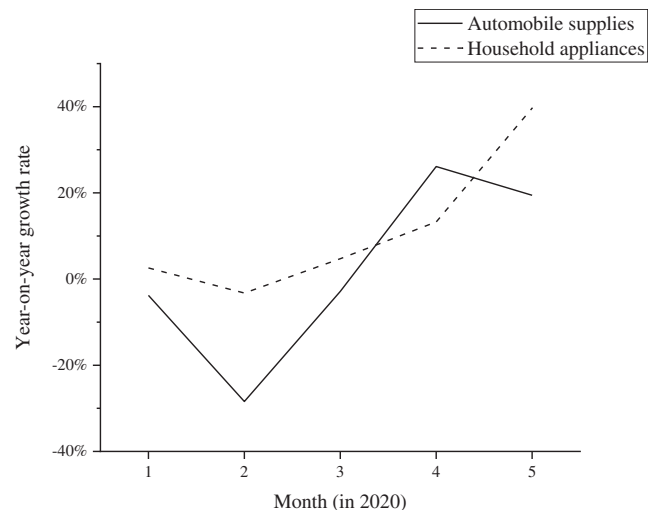
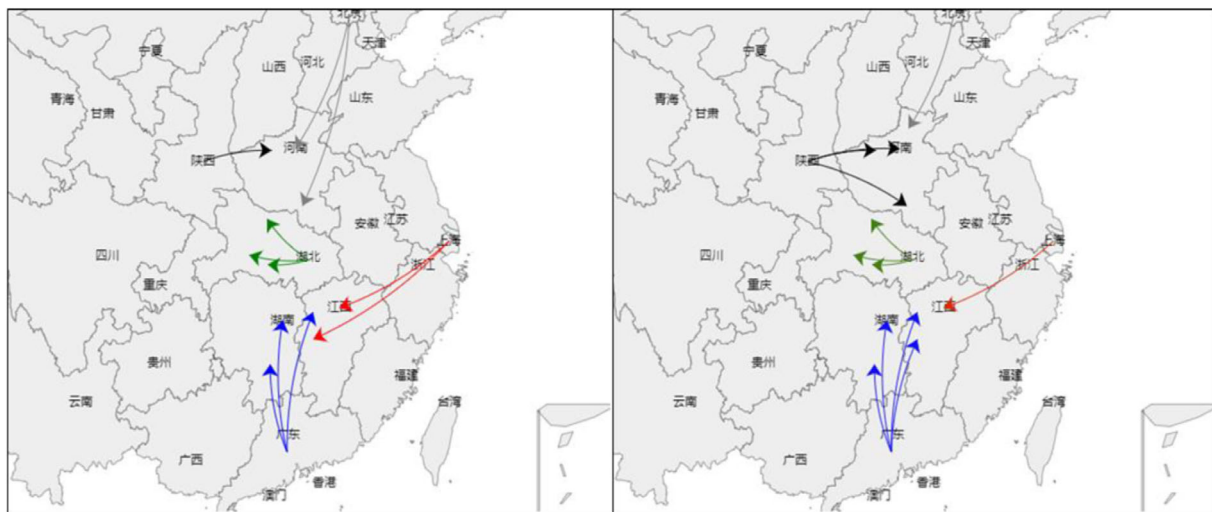


FIGURE 18 Growth rates of sales of representative slow-moving product categories on JD.com (January 2020–May 2020)



*Manually prepared emergency plan for COVID-19*

*Optimized plan developed using JD-NetSIM*

FIGURE 19 Comparison of manually prepared emergency plan and JD-NetSIM plan

orders compelled firms to rely highly extensively on online distribution (Ketchen & Craighead, 2020). Moreover, owing to the lockdown policy and for security purposes, previous delivery modes wherein orders were delivered directly to consumers were unavailable during the pandemic. In comparison, contactless delivery became the key approach for last-mile delivery. A few firms requested consumers to privately contact the deliverers to achieve contactless deliveries (e.g., Meituan, a Chinese food delivery company, requested consumers to specify a location for their deliveries and verify the delivery over phone [Chen, 2020]). In contrast, JD.com provided a structured process for last-mile delivery and pick-up without direct contact. At the final step of online order placement, consumers were presented with the positions of all available delivery terminals nearby and guided to select one (instead of selecting on-door delivery). The consumers received messages or notices after the products arrived at the delivery terminals. Subsequently, they provided their feedback on the delivery performance over a phone or computer after pickup and confirmation of receipt.

Different forms of distribution terminals were used during the pandemic. On February 20, JD.com launched its first “mini delivery station.” At this station, only a few packages were held and delivered, with stringent personal protective equipment for delivery and pickup services, as shown in Figure 20. The workers were specifically trained in processes to prevent direct contact and were required to take COVID-19 tests and report their body temperatures daily to confirm good health. Remote monitoring was used during the services. In addition, JD.com cooperated with parcel lockers, property

management offices, and security offices in communities and other locations such as stores and supermarkets. The contactless delivery process achieved good performance. During the pandemic, notwithstanding the large order volumes, the customer complaint rate was lower than typical owing to the flexible services of JD.com.

For the areas prohibited to the public during the pandemic, such as hospitals, automated logistics technology was adopted to deliver food and medical supplies. On February 6, 2020, JD became the first logistics company to use intelligent delivery robots in No. 9 Hospital in Wuhan (Chen, 2020). Each intelligent delivery robot had 24 locations for 24 packages, and the process of each delivery was completed in 20–30 min. Once all packages were delivered or the time limit was reached, the delivery robot returned automatically and started another delivery process after new packages were launched. During the pandemic, intelligent delivery robots developed in-house by JD logistics were used in various cities, such as Changsha, Guiyang, and Hohhot. In addition, automated logistics was employed in the smart logistics warehouse center of JD.com (e.g., the “Asia One” intelligent warehouse in Wuhan). Combined with other technologies, such as 5G networks and autonomous driving, the delivery efficiency improved.

### 5.3 | Undertaking social responsibility

Here, we introduce the measures that JD.com adopted to undertake social responsibility during the pandemic. As discussed earlier, the COVID-19 outbreak is significantly more impactful than a natural disaster or a manmade



FIGURE 20 Mini delivery station of JD.com during the pandemic (Chen, 2020)

accident, which breaks only a few nodes in a supply chain network. With COVID-19, owing to the extraordinary market conditions, delivery obstacles, and labor shortages, disruptions occurred in all stages of supply chains, and almost all industries were affected. Studies have suggested that the adoption of more stringent measures for controlling the pandemic can minimize the overall economic losses (Guan et al., 2020). As a commercial company, JD.com volunteered to help counter the pandemic by various approaches.

The logistics network was almost paralyzed at the beginning of this unforeseen pandemic. As one of only three logistics companies that remained operative in Wuhan during the lockdown (State Post Bureau of the People's Republic of China, 2020), JD Logistics undertook the task of delivering emergency supplies to pandemic areas. From January 20 to February 13, 2020, JD Logistics delivered over 160,000 tons of food across the country. For medical product delivery, the company provided over 1,000,000 medical masks and 60,000 medical supplies, and opened specialized, voluntary logistics routes for providing medical products to hospitals and related units. To assist in the rational distribution and scientific scheduling of emergency supplies, JD.com developed a specific supply chain management platform in cooperation with the government of Hubei province (China News Service, 2020b). This platform could trace the production, inventory, and distribution of all emergency supplies. Thus, the company contributed to the effective matching of supply and demand in this emergency scenario and ensured transparency of the distribution process.

Extraordinary social events generally result in market disorders. The pandemic has resulted in a substantially higher demand for certain products, such as masks and medical alcohol, than those for others. A few individual merchants or small companies with affiliated stores on

JD.com desired to earn enhanced profits by increasing the prices of such products. In addition, a few companies falsely reported inventories to the platform to mislead consumers and collect capital. To maintain the market order and ensure the rights of the consumers, a risk warning model was established based on digital technologies for effectively detecting unreasonable price increases and oversale risks. Based on the list of products displaying uncommon behavior as detected by the model, JD.com established a particular team to investigate each risky product. Most exceptions occurred in industries related to masks, cleaning, medicines, fresh products, and life essentials. The key problems included inflated prices and delivery costs, disqualification of stores, disorderly listings of categories, illegal sales of wild animals, oversold products, and loss of communication. During the pandemic, over 2 million products were investigated, 47,296 illegal products were removed from the platform, and 526 stores associated with illegal products were penalized. Moreover, 13 illegal merchants and companies were permanently removed from JD.com.

## 5.4 | Discussion

In this section, we describe how JD.com utilized the current mechanisms to address the supply chain disruption caused by the COVID-19 outbreak. In addition to the integrated supply chain structure and the intelligent platforms introduced in Section 3, the practical success of JD.com during the pandemic is owing to its *operational flexibility* and *collaboration beyond supply chains*.

While flexibility refers to the ability to encounter, resolve, and, when appropriate, exploit unexpected emergencies (Jüttner & Maklan, 2011), we define operational flexibility as the ability to slightly modify something existing to address disruptions. This concept is close to *adaptability* in Pettit et al. (2010), which is defined as the ability to modify operations in response to challenges or opportunities. In contrast, the operational flexibility to a larger scale including both intelligent platforms and operation processes. The reuse of JD-NetSIM is a successful example. Although JD-NetSIM was built for distribution network optimization, it was modified to provide an alternative for logistics network redistribution under a lockdown policy. The main structure of JD-NetSIM remained unchanged during the process, and only some constraints reflecting the lockdown scenario were added. Accordingly, the company could adapt to both the implementation and dissolution of the lockdown policy. In comparison, establishing a specific logistics re-distribution system is both inefficient and resource-wasting.

Another point that we want to address is the collaboration beyond supply chains of JD.com, but with the



entire society, particularly the government. As introduced in Section 5.3, JD.com actively participated in the delivery of emergency supplies. The voluntary project contributed to the recovery of both the society and company; this was because effective control of the pandemic allowed the market to rapidly recover. In addition, remaining engaged in the fight against COVID-19 enabled the company to adjust its market strategies timely. In contrast to those companies that were forced to shut down without knowing the current market scenario, the active engagement of JD.com collected detailed demands data, particularly for the products with enhanced demands, as well as updated the traffic scenario. Furthermore, the company remained in an effective, functional state. The first national promotion of JD.com during the pandemic, the Spring Rain Promotion Project, was launched only 40 days after the COVID-19 outbreak. The time was a fully month before the end of the lockdown of Wuhan.

While the success of JD.com during the pandemic partly owns to its integrated supply chain structure and a high level of digitalization, these two measures are long-term resilience strategies before disruptions. Therefore, we suggest firms pay attention to the remaining two points in practice. First, when a disruption occurs, firms should make use of current procedures/platforms to the maximum extent in the process of addressing specific problems, instead of coming up with a new plan. A high level of operational flexibility can help firms in both improving the resilience level, which is necessary in the early stages of a disruption, and getting back to normal in the post-disruption period. Secondly, based on the scale and severity of a disruption, firms need to determine a level of collaboration within and beyond supply chains. As indicated by our study, the performance of JD's supply chains varies inversely with the severity of the pandemic. For a large-scale disruption such as the COVID-19 outbreak, firms may need to work together with other forces to control the degree of disruption.

## 6 | CONCLUSION

The COVID-19 outbreak has caused severe disruptions in supply chains. By a case study of JD.com, we analyzed the impact of the pandemic on its supply chain resilience, summarized the key problems for the retail supply chain during the pandemic, and reviewed the practical strategies in response to the disruptions. Overall, the supply chains of JD.com exhibited good resilience, for the following reasons. First, owing to the specific "self-owned business mode," the integrated supply chain structure of JD.com exhibits a high level of collaboration, information sharing, and agility.

These ensure timely adjustments of its operational strategies. Additionally, prior to the pandemic, JD.com had developed various intelligent platforms for prediction, automatic replenishment, and warehouse network optimization. These strongly supported the practical strategies. Other advanced technologies such as automated logistics technology helped overcome other obstacles that resulted from the pandemic. During the pandemic, JD.com succeeded in modifying existing platforms and procedures slightly but efficiently to adapt to the new environment, indicating high *operational flexibility*. Finally, JD.com adopted measures to help control the pandemic across the country. These measures, although seemingly unrelated to the performance of the company, represent a high sense of social responsibility and benefit all stakeholders in the retail market.

Although JD.com has dealt well with the COVID-19 outbreak in China, it has to be mentioned that the company did not pay special attention to building its supply chain resilience in practice. We believe that other companies, including but not limited to those in the retail industry, exhibit similar phenomena. The performance indicators are related to the daily operations of the firms, such as supply, inventory, and delivery, and supply chain resilience is only an unclear concept far from reality. Interestingly, our study suggests that firms may not need to make significantly expanded efforts on resilience assessment. Our study provides a representative example for evaluating and analyzing supply chain resilience using current operational indicators, providing insights to both researchers and enterprises.

Our study also opens up research opportunities in supply chain resilience analysis and improvement strategies. First, until now, empirical studies on supply chain resilience were conducted mainly by case studies and interviews, which are expensive in terms of both time and energy. Our study revealed the feasibility of using the practical indicators of firms to analyze resilience, and innovatively addressed the difference between supply chain resilience strategies and practice. Similar analysis of other enterprises from other regions or industries is relevant considering that the scenarios in different countries vary greatly. In addition, practical resilience indicators assist supply chain managers to identify the weakness in supply chains, and a comparison of the resilience bottlenecks in different supply chains is also an interesting problem.

In the future, with the assessment of practical resilience levels becoming available, firms will be able to re-consider their supply chain strategies to consider both efficiency and resilience. Specifically, the decision-makers need to consider the maximization of the objective profit (or revenue) function as well as how easily it is disturbed by changing parameters. This leads to a series of multi-goal optimization problems. For instance, it has been mentioned in various studies that

firms should focus on supply chain integration, collaboration, and information sharing. What are the quantitative values of these measures in the supply chains? In Section 3.1, we have discussed the differences in the business models of JD.com and other retailing platforms. Which one is better from the perspective of efficiency, resilience, or both? For retailing platforms, such as JD.com, it is necessary to decide the proportion of self-owned and affiliated stores. What is the best proportion under a given possibility of supply chain disruptions? In fact, the research problem can be further conceptualized as the design of specific objects or procedures. For example, recall that we have defined *operational flexibility* as the ability to modify something existing slightly to address disruptions. How to design an efficient and operationally flexible intelligent platform?

Finally, although the main objective of commercial companies is to earn high profits, our case suggests that engaging in noncommercial activities to undertake social responsibility may be advantageous to a firm, in return. Our analysis indicates the existence of a close relationship between the severity of the pandemic and the performance of the supply chains of JD.com. However, to the best of knowledge of the authors, few studies have evaluated the impact of social responsibility on supply chain resilience. This is because supply chain disruptions are typically limited to specific regions or supply chains, and there is no need for social collaboration. The outbreak of COVID-19 provides a totally different case, in which the disruptions are intermittent over long periods. In this case, we believe it is interesting to find out how firms should cooperate and contribute to the society to achieve a win-win scenario for individual companies and the entire society or market.

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