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What are the right configurations of just-in-time and just-in-case when supply chain shocks increase?

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Abstract

Shocks caused by COVID-19 pandemic have compelled manufacturers to decrease their reliance upon just-in-time (JIT) and embrace a more just-in-case (JIC) approach. This study clarifies the right configurations of JIT and JIC under low/high upstream and downstream shocks. Drawing upon contingency theory and configuration theory, a framework is developed to differentiate configurations of JIT/JIC under low/high magnitude SC shocks. Survey data from China's manufacturing industry, which experienced SC shocks due to COVID-19, are analysed by regression and sub-group analyses. The results show that only upstream shocks have a negative impact on operational performance. The effect of JIC (but not JIT) on operational performance is strengthened by upstream and downstream shocks. When shocks are high, increasing JIC is effective only when JIT is low. These empirical findings demonstrate that manufacturers can improve operational performance by emphasising JIC models under high SC shocks. Those with high JIT benefit from low JIC under low shock settings.

Keywords: Just-in-time; Just-in-case; Supply chain shocks; Operational performance; COVID-19

1. Introduction

According to contingency theory, organizational performance depends on fit between two or more factors, such as environment, strategy, structure, etc. (Van de Ven and Drazin, 1985). Just-in-time (JIT) manufacturing principles fit with stable environments (Mackelprang and Nair, 2010). During 2020-22, JIT manufacturers were confronted with global supply chain (SC) shocks upstream and downstream, the magnitude of which were never encountered before. The COVID-19 pandemic created panic buying, stockpiling, rationing and shortage gaming (Ali et al., 2022; Choi et al., 2023; Yu et al., 2024). In addition, there were upstream shocks like the global semiconductor chip shortage that disrupted the automotive industry (Mehray, 2021). Likewise, the Russo-Ukrainian war has led to shortages in ingredients like sunflower oil, wheat, and increased prices of substitute ingredients (Castrodale, 2022). Many automobile giants e.g., BMW, VW, Ford, and Toyota, cut output and temporarily closed assembly lines due to a shortage of microchips. As such, JIT's fit with the environment and thus it is ability to drive operational performance was called into question.

JIT manufacturers must adapt when their strategy is no longer a fit with the new environment (Van de Ven and Drazin, 1985). In times of uncertainty, manufacturers may switch to a just-in-case (JIC) model, which differs in several production planning and stock control policies from the JIT model. The JIT model emphasizes reducing inventories and unused capacity, while the JIC model relies on increasing safety stock, alternate suppliers, and buffer capacity. For example, Huawei built a stockpile of chips for its telecom equipment and smart devices (Shead, 2021). Toyota, the pioneer of JIT, took steps to increase its inventory of electronic parts, e.g., semiconductors (Allen, 2022). A McKinsey report (Alicke et al., 2021) indicates that 61% of firms increased inventory, diversified supply bases, or localized or regionalized supply and production networks.

A report by SAP shows that about 84% of firms in the UK plan to proclaim the end of JIT inventory practices in favour of more JIC strategies (Barrett, 2022). Since supply and demand shocks may vary over time, both JIT and JIC practices may be required. Furthermore, some scholars argue manufacturers still need JIT during unstable times to reduce inconsistencies (Choi et al., 2023) or increase resilience (Alemsan et al., 2022; De Sanctis et al., 2018; Ruiz-Benitez et al., 2018). Others (e.g., Yu et al., 2020) show JIT fits well with innovativeness, suggesting it could help firms navigate unstable times by being more innovative. Rather than jettisoning JIT, firms may address varying levels of shocks with an appropriate mix of JIT and JIC. This requires manufacturers address issues of contingency and configuration to develop proper fit given the mission to improve operational performance.

Therefor, we pose the research question: *what are the right configurations of JIT and JIC when the magnitude of SC shocks vary from low to high?*

Therefore, this study addresses the fit between JIT-JIC configurations with varying levels of SC shock. While SC shocks can be detrimental to operations, this study argues both JIT and JIC can improve operational performance to varying degrees at differing levels of SC shocks. Since JIT suits stable environments, when the magnitude of SC shocks is low, a higher level of JIT with a low level JIC is logical. The opposite applies for high magnitude SC shocks. Differences in production planning and inventory policies may produce a misfit, which will in turn reduce operational performance. JIC may leverage scale economies and drive large inventory positions or unused production capacity whereas JIT tends to minimize inventory, maximize utilization, and produce based on demand signals. On the face of it this is an apparent misfit and operational performance could be expected to decline. However, the interactions between JIT and JIC do not necessarily create tensions; they may complement one another. For example, JIT principles can be used to reduce inconsistency in processes (Shah and Ward, 2007), while JIC can complement a JIT environment when there are occasional small changes in supply or demand (Martha and Subbakrishna, 2002; Yu et al., 2024).

This study applies contingency theory and configuration theory to help develop insights into the use of JIT and JIC under different levels of SC shocks. For completeness, we consider both upstream and downstream shocks (Ali et al., 2022; Chen and Paulraj, 2004) caused by the COVID-19 pandemic. By doing so, this study makes significant contributions to theory and practice. From a theoretical perspective, we develop a configurational framework to clarify the impact of low/high levels of JIT and JIC on operational performance under varying magnitudes of SC shocks. The framework clarifies that supply chains can be divided into segments facing different volatilities and matched with suitable capacity and inventory buffers (Choi et al., 2023). We examine empirical evidence to show that the configurational tensions between JIT and JIC vary when SC shocks are small/large. From a practical perspective, this study provides insights to manufacturing managers on whether they should increase the use of JIT/JIC during SC shocks to improve operational performance and when they should vary the use of JIT/JIC. We also show that manufacturers from our samples failed to contain the negative interaction effects between JIT and JIC when SC shocks were large, while relying upon separating the resource configurations for hybrid JIT-JIC.

2. Theoretical constructs

2.1. JIT versus JIC SCs

JIT focuses on "increasing product quality, reducing lead times, and reducing inventory and manufacturing costs…complete elimination of waste, inconsistencies, and unreasonable requirements on the production line" (Choi et al., 2023, p. 2332). JIT reduces inventory by replenishing only the number of parts used. It is a pull-based system synchronizing production with demand. JIT systems have been identified by researchers and practitioners as a basis for world-class manufacturing. Extending JIT practices to suppliers and customers is thought to strengthen firm competitiveness because doing so reduces waste and inventory throughout the supply chain (Lamming, 1993; Shah and Ward, 2007). Manufacturers deploying JIT generally integrate, using pull based production, with customers and suppliers (Chavez et al., 2024; Furlan et al., 2011; Shah and Ward, 2007) and minimize system-level inventory (Dinu, 2014). For downstream customers to receive timely and quick delivery of products and services through JIT SCs, the manufacturer needs customer focus (involvement), continuous improvement, and process integration with customers (Huo et al., 2019; Shah and Ward, 2003, 2007; Yu et al., 2020). By sending consistent demand signals, the JIT manufacturer can ensure suppliers deliver the right quantity and right quality at the right time in the right location (Choi et al., 2023; Furlan et al., 2011; Shah and Ward, 2007).

However, recent events like the COVID-19 crisis and the Russo-Ukrainian war have shifted attention from JIT to JIC (Choi et al., 2023; Drakeley, 2022; Jiang et al., 2021). JIC relies on principles such as identifying critical items, anticipating stockouts, identifying sources and locations of shocks, and increasing inventory above traditional safety stock levels to cope with supply and demand variabilities. JIC systems emphasise responding to unexpected disruptions by implementing strategies like maintaining larger inventory buffers, supplier diversity, and component standardization. To continue production despite facing a SC shock, JIC manufacturers deploy strategies to maintain sufficient inventory and supply (Masters and Edgecliffe-Johnson, 2021; Koo, 2020; Suri and De Treville, 1986). Unlike JIT strategies, JIC emphasizes redundancies of materials, suppliers, and other resources to ensure material availability and product delivery (Martha and Subbakrishna, 2002).

JIC is considered effective for "idiosyncratic shocks with known distribution" eminating upstream (Jiang et al., 2022, p.143). However, shocks caused by COVID-19, wars and the like are more difficult to predict since the distribution is unknown. JIC SCs share inventory levels, demand forecasts, and supply/sales information through integrated information systems and through customer/supplier involvement (Shah and Ward, 2007; Yu et al., 2024). There is a difference in focus. While this is similar to JIT, JIC manufacturers use the information to update demand and supply information such that they can find alternatives (e.g., customers, suppliers, parts) and thereby adapt to changes in demand and supply (Yu et al., 2024) whereas JIT manufacturers use the information to adjust processes internally and in harmony with suppliers/customers.

The impacts of COVID-19 have increased debates about JIT versus JIC in the practitioner literature (e.g., Barrett, 2022; Drakeley, 2022; Koo, 2020). Koo (2020) highlights that JIC relies upon production approximation, anticipated demand, large lot-size, and high inventory levels; it has a greater potential for waste and the management of firefighting. Martha and Subbakrishna (2002) argue that it is foolish to completely reject tenets such as lean manufacturing and JIT delivery, but the benefits of these SCM concepts "must be weighted and balanced against risks" caused by "the world's political and military landscape but also the global environment". During the COVID-19 crisis, the literature argues JIT and JIC work best in tandem to deal with upstream and downstream SC shocks (Jenkins, 2021). A hybrid JIT-JIC system involves having some parts of the SC function as pull systems while others function as push systems (Jenkins, 2021). A hybrid JIT-JIC model that combines the benefits of JIC inventory and capacity buffers with JIT's judicious use of capital can arguably give firms the best of both worlds (Jenkins, 2021). By working together, these approaches enable firms to exploit market opportunities in a cost-effective manner (Inman et al., 2011).

2.2. SC shocks

Presently, more than ever, firms are facing escalating uncertainty (Kahiluoto et al., 2020; Yu et al., 2019). The pandemic led to widespread lockdowns, travel restrictions, and other measures that created demand shifts and elevated uncertainty resulting in SC disruptions (Ali et al., 2022; Alicke et al., 2021; Ivanov and Dolgui, 2020). The trade restrictions driven by tense geo-political conflicts and the spread of COVID-19 made supply shortages widespread, e.g., toilet rolls, fuel, microchips, and sunflower oil (Masters and Edgecliffe-Johnson, 2021). We use the term shocks to refer to abrupt changes, instability, variability, uncertainty, and disruption in SC processes. Our focus is on large-scale shocks rather than isolated small shocks. We consider supply shortages and demand uncertainties that might cause a domino effect and interrupt global SC operations. Since such shocks may alter the effectiveness of JIT and JIC at varying degrees, in this study, we divide SC shocks into upstream shocks and downstream shocks (Ali et al., 2022; Chen and Paulraj, 2004; Gurbuz et al., 2023).

Upstream shocks are defined as those emanating from suppliers (Ali et al., 2022). It includes indicators that represent SC disruptions and challenges coming from upstream suppliers, such as high rejection rates of incoming materials, unstable and inconsistent quality of materials from suppliers, a loss of key suppliers, suppliers' unreliable deliveries, and unstable quality of supplies (Ali et al., 2022; Brusset and Teller, 2017; Chen et al., 2013). Trade restrictions driven by geo-political conflicts have also led to supply shortages. The SC impacts include the cessation of trade even when supply was available. For example, during the COVID-19 pandemic, China required face masks and personal protective equipment (e.g., safety helmets, gloves, eye protection, hazmat suits, and respirators) and prioritized filling domestic domand.

Downstream shocks are defined as excessive fluctuations in demand (Ali et al., 2022; Chen et al., 2013; Gurbuz et al., 2023). Demand uncertainty may arise from various sources such as demand information distortion (bullwhip effect), order cancellation, and inaccurate demand forecasting (Ali et al., 2022; Gurbuz et al., 2023). The COVID-19 outbreak created high demand surges and fluctuations and significant disruptions to global SCs (Gurbuz et al., 2023; Ivanov and Dolgui, 2020). For example, the COVID-19 pandemic induced panic-buying and stockpiling (Sarma, 2020). Panic-buying of essentials (e.g., toilet rolls, canned foods, vegetables, and pasta) and critical health supplies (e.g., surgical face masks, hand sanitisers, and flu medicines) hit global SCs especially hard.

3. Research model and hypotheses

3.1. Theoretical background

Our argument that JIT or JIC becomes effective under certain conditions is grounded in contingency theory, which argues organizations are not closed systems, but rather are exposed to environmental pressure that shapes structures and strategy (Lawrence and Lorsch, 1967; Miller, 1987). Contingency theory suggests that the effectiveness of an organization's strategy depends on how well it fits with the environment. In this study, JIT and JIC are strategies manufacturers can choose, while up and downstream shocks are understood as environmental contingencies. When the chosen strategy fits with the environmental or contingency factors, performance and productivity should improve (Hofer, 1975). The literature broadly agrees JIT suits a lower level of SC shocks while increasing JIC is helpful when shocks increase. Applying the above contingency argument as a theoretical lens (Lawrence and Lorsch, 1967; Miller, 1987), we develop a framework (Figure 1) to examine the impacts of JIT and JIC on operational performance contingent upon upstream and downstream SC shocks (as moderators).

------------------------------ Insert Figure 1 ------------------------------

Next, we use configuration theory to theorize suitable configurations of JIT, JIC and SC shocks. Past studies argue organizations should structure resources differently to cope with changes in technology, competition, and customer behaviour (Porter, 1991). Long-term contracts are used to secure human and property-based resources under stable environments, while more flexible knowledge resources are useful in more uncertain environments (Miller and Shamsie, 1996). Incorporating these ideas, we argue JIT and JIC require different types or arrays of physical and knowledge resources. For example, JIC requires larger storage facilities for inventory, and knowledge about market changes and alternate supply routes (capacities) to cope with changing markets. Searching for alternate supplies such as semiconductors can be a daunting task for JIT manufacturers like Toyota. JIT uses Kanban systems that rely on high levels of supplier integration, supported by lean management expertise to reduce variability in the SC. Instead, JIC does not aim to reduce variability; it captures value from it (Yu et al., 2023a). When implementing a mix of JIT and JIC, an organization would need physical resources e.g., inventory and machinery, for both, adding operational and complexity costs, which are harder to compensate for or switch, as opposed to human resources that can "switch" between the two modes of operations. We believe this configuration lens could serve as a platform to develop a dynamic view of hybrid SC strategies.

Since there are two inter-related strategies (JIT and JIC) and one environmental variable (SC shocks), it is important to understand that the "congruence" of these different variables determines effective configurations (Ginsberg and Venkatraman, 1985; Hofer, 1975). We need to first recognize that JIT and JIC involve contradicting principles which may affect the effectiveness of the combined resource configurations. JIT operates under a pull principle that emphasizes reduction of waste whereas JIC produces independent of demand. When implementing JIT in parallel with JIC, organizations may face "configurational tensions" detrimental to performance. Hence, based on configuration theory, we argue that when SC shocks are low (as shown in Figure 2a), a lower level of JIC fits with a higher level of JIT (lower-right quartile). Conversely, when SC shocks increase (as shown in Figure 2b), organizations may "switch" to a low-JIT and high-JIC configuration (upper-left quartile). In addition, we argue that in the lower-left quartiles, low levels of JIT and JIC are least effective, whereas in the upper-right quartiles, configurational tensions between high levels of JIT and JIC reduce their individual effects on operational performance. Guided by the configurational framework in Figure 2, we formally motivate our hypotheses in the following sections.

------------------------------ Insert Figure 2 ------------------------------

3.2. Effect of SC shocks on operational performance

The COVID-19 pandemic has created significant upstream shocks in the form of supply shortages and uncertainties. These have negatively affected operational performance, e.g., cost and delivery (Ali et al., 2022; Gurbuz et al., 2023). Supply uncertainty caused by the pandemic decreased the availability of raw materials, component parts, and finished goods, making it difficult and more costly for firms to secure supplies (Ali et al., 2022; Ivanov and Dolgui, 2020). This results in increased cost and reduced product quality, as firms find alternative suppliers, use lower quality materials, pay higher prices for supplies, or find new ways to secure supplies from new supply sources without adequate due diligence. Upstream shocks might also cause delivery delays and a lack of flexibility. For example, during the pandemic, firms were forced to find alternative suppliers or modify their operations planning to respond to demand shifts, which resulted in longer lead times and delivery delays (Chen et al., 2013; Gurbuz et al., 2023). We therefore hypothesise:

H1a: Upstream shocks have a significant negative effect on operational performance.

The COVID-19 pandemic caused significant demand shocks across global SCs in the form of demand uncertainty. These shocks required firms to rapidly change product designs, components, production, suppliers, capacity, and inventory plans, which led to challenges in maintaining operational performance, e.g., product/service quality, new product/service development, delivery performance, and cost. During the pandemic, firms faced difficulties in maintaining the same quality level due to changes in production processes, workforce reduction, use of substitute parts, and increased pressure to lower costs. The sudden drop in demand for certain products and services made it more challenging for firms to quickly adjust their output in response to demand changes (Yu et al., 2019), and thereby ensure products and services were delivered on-time and quickly (Ali et al., 2022). Lockdown measures, shipping delays, restrictions on movement, and disruptions in production processes have all contributed to longer delivery times. The demand uncertainty caused by COVID-19 resulted in increased costs for businesses, e.g., increased production costs, higher shipping costs, and the cost of implementing new health and safety measures. Some firms had to pay expedite fees, others the financing costs for finished goods customers no longer wanted. We therefore posit:

H1b: Downstream shocks have a significant negative effect on operational performance.

3.3. Contingency effects of SC shocks (JIT)

The implementation of JIT practices upstream and downstream enables firms to achieve synchronized and lean manufacturing with suppliers and customers which leads to lower inventory and waste (Chavez et al., 2024). By focusing on pull based production, customer/supplier collaboration, and JIT links with customers and suppliers, firms can improve product quality, on-time delivery rates, new product development, and reduce operational costs (Shah and Ward, 2007; Huo et al., 2019). JIT depends on reliable supplies to ensure small lot-size deliveries, lead time reduction, lower work-in-progress and inventory, and removal of bottlenecks and delays from manufacturing and logistics processes (Yu et al., 2020; Shah and Ward, 2003). To improve operational performance, manufacturers can encourage suppliers to implement pull production systems (Chavez et al., 2013; Simpson and Power, 2005; So and Sun, 2010). With downstream customers, JIT principles enable manufacturers to meet market demands accurately, respond quickly to changing customer needs, and deliver the right quantity with the right quality at the right time and the right place to customers, which in turn leads to improved operational performance (Huo et al., 2019; Piercy and Rich, 2015; Shah and Ward, 2007).

The literature generally agrees the advantages of JIT inventory systems are impaired by upstream and downstream shocks. Smooth and stable demand allows JIT to deliver the best performance. As evidenced during the pandemic, a high level of supply uncertainty, e.g., unstable quality and delivery from suppliers and unpredictability and variability of raw materials and component parts, can make it difficult for JIT systems to synchronize production processes. When demand uncertainty rises, pull principles struggle to effectively cope with abrupt and significant changes in demand (Chen and Paulraj, 2004; Gurbuz et al., 2023).

Even though large SC shocks may compromise the effectiveness of JIT systems, we posit that applying JIT principles may attenuate some negative effects of SC shocks. That means increasing the use of JIT may contribute to operational performance gains even when SC shocks are present. When downstream shocks arise, manufacturers maintain JIT deliveries to customers may improve operational performance and gain customer loyalty. This is achieved by collaborating with suppliers to apply variation reduction methods. However, we argue these counter effects are more difficult to achieve when SC shocks are large. Thus, consistent with performance rising with fit, we conclude that increasing JIT will become more effective in improving operational performance when SC shocks are small.

H2a: When upstream shocks are low, operational performance will increase as the level of JIT increases.

H2b: When downstream shocks are low, operational performance will increase as the level of JIT increases.

3.4. Contingency effects of SC shocks (JIC)

When facing SC shocks, firms should adapt inventory and capacity planning practices to mitigate unpredictable demand and adjust for supply disruptions (Ali et al., 2022). To cope with these challenges, firms can embrace JIC approaches such as diversifying suppliers and increase inventory levels in anticipation of disruptions. A sudden demand surge often causes inventory shortages. JIC relies on increased safety stock and/or extra capacity to reduce the risk of having insufficient materials for production (Drakeley, 2022; Koo, 2020). JIC keeps extra buffer stock/capacity that allows production to continue running (Yu et al., 2024), which in turn helps firms maintain high levels of product/service quality and delivery performance. Extra safety stock can help respond to spikes in customer demand while extra capacity can increase speed to respond. Researchers suggest that the JIC system is more costly than JIT because it leads to waste when not all the inventory is sold and/or not all extra capacity is used (Masters and Edgecliffe-Johnson, 2021; Koo, 2020). However, firms need these buffers to mitigate SC risks such as supplier delays, unexpected increases in demand, or spikes in the cost of materials. Investment in buffers reduces other costs caused by shocks, e.g., additional operating costs, logistics and transport cost, and labour overtime cost. Thus, JIC will have a significant positive effect on operational performance when shocks are high to the extent the benefit outweighs the extra inventory costs.

From a contingency perspective, JIC fits with uncertain business environments caused by SC shocks (Lawrence and Lorsch, 1967; Miller, 1987). Deploying JIC when SC shocks are large an/or frequent will result in a better performance. As upstream uncertainty increases, the need for alternate supplies and extra inventory/capacity increases. There is a strategic fit between JIC and SC shocks. Theory suggests that greater alignment will result in better performance (Galeazzo et al., 2021). High levels of supply uncertainty may come from inconsistent quality or late supplier deliveries, and losses of key suppliers. JIC leverages extra inventory and alternate suppliers to facilitate delivery performance (speed and dependability) and production flexibility performance (Wong et al., 2011). When demand uncertainty rises, firms may adapt a variety of JIC strategies such as increasing inventory/capacity, diversifying suppliers, and improving demand forecasting to inform supply planning (e.g., Chaturvedi and Martinez-de-Albeniz, 2016; Drakeley, 2022). Drawing upon our CT argument, under high levels of upstream and downstream shocks, firms benefit from keeping extra stocks/capacities, larger order sizes, and diversification of suppliers (Ali et al., 2022; Chen et al., 2013; Gurbuz et al., 2023), which strengthens the effects of JIC on operational performance.

H3a: When upstream shocks are large, operational performance will increase as the level of JIC increases.

H3b: When downstream shocks are large, operational performance will increase as the level of JIC increases.

3.5. Configurational effects of JIT and JIC

To determine effective configurations, we need to consider the fit between JIC/JIT and the environment (SC shocks) as well as between JIT and JIC. JIC is an appropriate strategy for relatively unstable and unpredictable environments through an emphasis on adding alternate suppliers and extra inventory. However, the main disadvantages of the JIC system include higher additional storage and obsolescence costs (Ware2Go, 2022). In contrast, JIT emphasizes process quality, elimination of waste, lead time reduction, and reducing inventory costs (Shah and Ward, 2007; Huo et al., 2019). JIT relies on the timeliness and reliability of suppliers and limited fluctuations in demand (Jenkins, 2021). These contradicting principles mean resource configurations for JIT will become less effective when applied to JIC, and vice versa.

So, there is an inherent configuration tension between JIT and JIC. When a firm employs a hybrid push-pull inventory system it leverages decoupling points to separate the push and pull parts of the system. Decoupling avoids separate resources and processes for the two strategies. A JIT manufacturer may keep extra buffer stock, especially in front of bottleneck steps or processes. While the supply-side decoupling point adds cost, inventory buffers reduce disruption risk and enable continued operation of JIT systems. When a manufacturer deploys extra stock and capacity to achieve JIC, the efficiencies of pull principles will be impaired. Some JIT setups e.g., Kanban systems and level schedules, may also make it harder to use JIC. When JIT and JIC interact and reduce each other’s effectiveness, configurational tension occurs. This is particularly the case when a JIT manufacturer attempts to simultaneously apply JIC since it must invest in extra inventory and manage additional suppliers that may not supply according to JIT principles. The benefit of low inventory and waste will be eliminated from deploying JIC inventory principles and the additional suppliers may lead to inconsistency in supplier capability and performance.

We further argue the configurational tensions between JIT and JIC vary depending on level, as shown in Figure 2. The tension becomes more serious when a manufacturer tries to implement both JIT and JIC at a high level (a high level of mismatch). Instead, when JIC is low, it is beneficial to increase the level of JIT, because this configuration produces less tension between JIT and JIC. However, when JIC is already high, increasing use of JIT simultaneously will significantly increase the tensions between them and decrease operational effectiveness.

H4: When the level of JIC is low, operational performance will increase with an increase in the level of JIT.

The above hypotheses do not consider the magnitude of SC shocks. We argue that at different magnitudes, the configurational tensions between JIT and JIC and the roles of JIT and JIC (independently) will vary. When SC shocks are small, the tensions between JIT and JIC will be less profound since as manufactures can switch to the appropriate levels of JIT and JIC using existing flexibility strategies. Alternatively, when SC shocks are large, the existing flexibility approaches cannot cope so manufacturers must separately manage new flexibility strategies such as alternate suppliers, infrastructures (e.g., warehouses), and processes which could reduce the efficacies of JIT and JIC. Some manufactures may completely switch to JIC or use less of JIT; they may also need to separate the processes for JIT and JIC to minimize negative effects created by the inherent tension.

We use the above arguments to further distinguish the effectiveness of the four quartiles in Figure 2 for small and large SC shocks. Configurational tensions are further amplified by the misfit between JIT and large SC shocks (Figure 2b, upper-right quartile) and between JIC and small SC shocks (Figure 2a, upper-right quartile). At a low magnitude of SC shocks, a higher JIT and a lower JIC (lower-right quartile) is the most effective configuration. Instead, at a high magnitude of SC shock, JIT will play a much smaller role in generating operational performance, so a higher JIC and a lower JIT becomes the most effective configuration. Thus, we posit:

H5: When upstream SC shocks are of high magnitude, the interaction effect between JIT and JIC on operational performance will increase.

H6: When downstream SC shocks are of high magnitude, the interaction effect between JIT and JIC on operational performance will increase.

4. Methodology

4.1. Survey data collection

Due to China's zero-COVID policy aimed at combating the spread of the virus, we collaborated with a professional survey organization to conduct an online questionnaire survey from July to November 2022. Our goal was to enhance the response rate and obtain high-quality survey data from various regions in China. The survey firm provided a list of manufacturers from different regions in China, which we used to randomly select a sample of 800 companies. With the help of the survey organisation, we identified a key informant from each chosen manufacturer, and sent the questionnaire and survey link to them through email and WeChat. We received 207 completed questionnaires after two waves of data collection, suggesting a response rate of 25.88%.

----------------------------- Insert Table 1 ------------------------------

Table 1 summarizes the profiles of the sample companies, which were diverse and encompassing a wide range of manufacturing industries, various firm ownership structures, and different geographic regions of China. To ensure that survey respondents possessed the requisite knowledge and experience to complete the questionnaires effectively, we requested that the various sections of the questionnaire be completed by knowledgeable executives, such as CEOs, directors, and managers. For example, we recommended that logistics or supply chain managers, who are responsible for developing and implementing inventory management practices in response to the shocks caused by the COVID-19 pandemic, complete the JIT and JIC sections. Additionally, if necessary, we advised seeking input from other senior members of the management team, particularly from relevant functional units such as operations and marketing departments. Furthermore, most of our respondents were senior executives and managers who had been with their companies for about 10 years. Therefore, we believe that these respondents had the necessary knowledge to complete the questionnaires.

4.2. Bias assessment

In this study, we assessed non-response bias by comparing early and late responses in terms of number of employees and annual sales (Hair et al., 2010). The results reveal that there is no significant difference between these two groups, which suggest that non-response bias is not a significant concern in this study.

We endeavoured to reduce the likelihood of common method bias (CMB) and performed several tests to assure it was not an issue. First, we performed examined the results of a confirmatory factor analysis (CFA)-based Harman's single-factor model. The results suggest undesirable fit indices (χ^2/df = 5.602, CFI = .534, IFI = .538, RMSEA = .149, and SRMR = .137) (Hair et al., 2010). Second, we employed a marker variable technique to further examine CMB. Respondents' job tenure was used as a method variance marker because it is theoretically unrelated to at least one scale used in this study (Lindell and Whitney, 2001), and has been commonly used in previous research (e.g., Wong et al., 2013; Yu et al., 2023b). The lowest positive correlation between respondents' job tenure and other variables (r = .019, see Table 4) was used to adjust the inter-construct correlations and statistical significance (Lindell and Whitney, 2001). As shown in Table 4, after this adjustment, no significant correlations became insignificant. Thus, the results presented above suggest that CMB is not a serious concern in this survey research.

4.3. Measures and controls

The measurement items JIT, JIC, and SC shocks were measured using a seven-point Likert scale, 1 “strongly disagree” to 7 “strongly agree”. We employed measures from the SC literature, except the newly developed scale for JIC. To strengthen content validity and reliability of the measurement scales, we carried out a pilot test with researchers who had expertise in lean and inventory management and practitioners who were senior executives at manufacturing firms in China. The pilot test enabled us to obtain useful feedback on the questionnaire survey, especially for the newly developed scale.

We adapted items from the work of Furlan et al. (2010) to measure JIT SCs, which focused on assessing how companies implemented JIT inventory management practices with upstream suppliers and downstream customers during the COVID-19 pandemic. We developed new measurement items for JIC SCs as there are no existing measures for this construct. The new measure development was based on the interviews with senior executives at manufacturing companies in China, annual reports of international manufactures (e.g., BYD, Toyota, Reckitt, GSK, Honda, etc), and strategic reports by consulting firms (e.g., McKinsey and KPMG). The scale evaluated how manufacturing firms adopted JIC inventory management practices during the COVID-19 crisis. Our results presented below (see section 5.1) confirm the reliability and validity of the newly developed scale.

We adopted items from Chen and Paulraj (2004) and Ali et al. (2022) to measure upstream shocks and downstream shocks, which focused on the shocks within the upstream (pandemic-related supply uncertain) and downstream (pandemic-related demand uncertainty) SC network. Consistent with previous studies (e.g., Wong et al., 2011), we measured operational performance in terms of quality, flexibility, cost, and delivery performance by asking respondents to evaluate their recent performance relative to their leading competitors during the COVID-19 pandemic, using a seven-point scale (1 = much worse than your major competitors; 7 = much better than your major competitors).

We employed four controls in the research model, including firm age (number of years since the firm’s establishment), firm size (number of employees), manufacturing industries, and firm ownership (Yu et al., 2019; 2023a; 2023b). A dummy variable was used for both industry type and firm ownership.

5. Analysis and results

5.1. Unidimensionality, reliability and validity assessment

We developed a new JIC scale and adopted measurement items from previous research into the context of COVID-19 pandemic, so we carried out both exploratory and confirmatory factor analyses (EFA and CFA respectively) to assess the unidimensionality, reliability and validity (discriminant and convergent validity) of the theoretical constructs (Hair et al., 2010). For the EFA, we conducted a principal components analysis with varimax rotation to examine the underlying dimensions of the constructs. The EFA generated five factors with eigenvalues greater than one and strong loadings (ranged from .590 to .870). Table 2 reports the full EFA results.

------------------------------ Insert Table 2 ------------------------------

In addition, the CFA results presented in Table 3 also indicate that the measurement model has good fit indices (χ^2 / df = 2.007, CFI = .902, IFI = .903, RMSEA = .070, and SRMR = .074) (Hair et al., 2010). Thus, both EFA and CFA results provide evidence of the unidimensionality of the constructs. We calculated Cronbach's alpha and composite reliability (CR) to assess construct reliability. Table 3 shows that the Cronbach alpha ranged from .810 to .880 for the constructs and the CR values ranged from .817 to .885. All values are well above the recommended level of 0.70 (Hair et al., 2010). As such, the results provide evidence of reliability.

------------------------------ Insert Table 3 ------------------------------

As noted above, the CFA results suggest that the model fit indices are acceptable and all items' factor loadings exceed the recommended level of 0.50 (Hair et al., 2010). As indicted in Table 3, average variance extracted (AVE) of all five constructs exceeded the minimum value of 0.50 (Fornell and Larcker, 1981). These results provide evidence of convergent validity. Table 4 reveals that the square root of AVE of all five constructs is greater than the correlation between any pair of them, which provides evidence of discriminant validity (Fornell and Larcker, 1981).

------------------------------ Insert Table 4 ------------------------------

5.2. Hypotheses tests

Table 5 shows results from multiple regression anlyses. To test for multicollinearity, we examined the variance inflation factors (VIF). The results show that all VIF values in each model are less than 10, suggesting multicollinearity is not a significant problem (Hair et al., 2010). Model 1 shows we controlled for firm age, size, ownership, and industry type, but no significant positive effects were found on operational performance at a .05 level of significance.

------------------------------ Insert Table 5 ------------------------------

As shown in Model 2 (Table 5), we find that upstream shocks are negatively ($\beta = -.138$, $p < .05$) related to operational performance, while there is no significant association between downstream shocks and operational performance ($\beta = .032$, *n.s.*). Thus, H1a is supported, but H1b is rejected. We also find that JIT ($\beta = .246$, $p < .001$) and JIC ($\beta = .513$, $p < .001$) have a significant positive association with operational performance, as expected. The Beta coefficient for JIC is higher than for JIT, suggesting JIC increases operational performance at a higher rate than JIT.

Model 3 includes two-way interaction effects (Table 5). The adjusted R^2 in Model 3 increased from .455 (Model 2) to .545 (Model 3). The beta coefficients for JIT and upstream/downstream shocks in Model 2 remain significant and constant in sign. That means the additional explanatory powers come from certain interactions among JIT, JIC, and SC shocks. Since the interactions between upstream/downstream shocks and JIT are not significant, neither type of shock combines with JIT to create negative effect on operational performance, thus providing evidence to reject H2a and H2b. Next, we found that upstream shocks ($\beta = .182$, $p < .05$) and downstream shocks ($\beta = .145$, $p < .05$) significantly and positively moderated the JIC–operational performance relationship, providing indications of support for H3a and H3b.

We then performed two simple slope tests (Hair et al., 2010). Figure 3 shows, at low JIC, a better operational performance is achieved under low upstream shocks. At high JIC, there is no difference in operational performance based on the level of upstream shocks. While increasing from low to high JIC increases operational performance, and the degree of increase is higher (a steeper slope) for a high level of upstream shocks, thus providing support for H3a. Moreover, Figure 4 shows JIC has a (marginally) higher impact on operational performance when downstream shocks are large. Both figures show the JIC-operational performance (upward) slopes are steeper when upstream/downstream shocks are large. This suggest that increasing JIC when SC shocks are large could improve operational performance, thus supporting H3a and H3b.

------------------------------ Insert Figure 3 ------------------------------

------------------------------ Insert Figure 4 ------------------------------

Model 3 in Table 5 shows the interaction of JIT and JIC is negatively associated with operational performance (β = -.298, *p* < .001), providing evidence for the existence of configurational tension between JIT and JIC. That means the positive effect of JIT [JIC] on operational performance is reduced by an increase in JIC [JIT], confirming tensions between them. To understand the ways in which JIT and JIC decrease each other's effects on operational performance, we performed another simple slope test. Figure 5 shows that at a low level of JIT, a lower level of JIC produced the lowest operational performance. At a high level of JIT, operational performance is still lower when JIC is low. Overall, a high level of JIC produced the highest level of operational performance, regardless of the level of JIT. The degree of improvement in operational performance is steeper when increasing JIT from low to high under a low level of JIC, thus supporting H4. This is related to a match between low/high level of JIT/JIC (see Figure 2). The slope is less significant (almost flat) at a high level of JIC, which suggests that increasing JIT when JIC is already high results in high tension between them that cancels their positive effects on operational performance (see Figure 2).

------------------------------ Insert Figure 5 ------------------------------

The above leads us to revisit the results together. Table 5 suggests downstream shocks do not affect operational performance but the interactions between both upstream and downstream shocks and JIC significantly affect operational performance. JIC seems to play a larger role than JIT when SC shocks are large. This suggests the effectiveness of JIT, JIC, and their configurational tensions may vary under low and high magnitude shocks as per H5 and H6. To confirm this, we divided the samples into low and high magnitude upstream shocks (Table 6a) and downstream shocks (Table 6b) based on the median of their composite scores (Hair et al., 2008; Wong et al., 2011). Under low levels of upstream and downstream shocks, both JIT and JIC are the main explanatory variables for operational performance. At a low level of upstream shocks, the negative interaction effect between JIT and JIC increases the R^2 a small amount (from .557 to .575). And, at a low level of downstream shocks, the interaction effect (negative sign) between JIT and JIC is insignificant. This suggests that when SC shocks are low, the manufacturers in our sample could better leverage the benefits of both JIT and JIC without experiencing significant configurational tension. In fact, manufacturers can even benefit from high levels of both JIT and JIC (see Figure 5).

------------------------------ Insert Tables 6a and 6b ------------------------------

The situations change quite a bit when SC shocks are high. First, the significant relationships between JIT and operational performance disappear (see Model 2 in Tables 6a and 6b). Only when the JIT x JIC interaction terms are added do we find the positive effects of JIT and JIC again. At high magnitude upstream and downstream shocks, the Beta coefficients for JIC become higher (than for JIT), suggesting operational performance relies more on JIC. The increases in R^2 to .660 (Table 6a) and .608 (Table 6b) suggest operational performance was more affected by the interaction between JIT and JIC (than when the shocks were low). More importantly, the JIT × JIC interaction terms significantly reduce operational performance when upstream shocks ($\beta = -.532$, $p < .001$) and downstream shocks ($\beta = -.578$, $p < .001$) are high. There are also noticeable increases in the Beta coefficients for JIT and more so for JIC. This shows when SC shocks are large, the manufacturers in our samples relied more on JIC (without giving up JIT), but they faced more negative effects produced by the configurational tensions between JIT and JIC.

6. Discussion and conclusion

6.1. Contributions to theory

This study answers the crucial question: what configuration of JIT and JIC is best for improving operational performance under different levels of SC shock? The literature has some straightforward answers: use JIT when SC shocks are small and switch to JIC when SC shocks are large or use hybrid JIT and JIC (Koo, 2020). However, the literature has not fully considered that the configurational tensions between JIT and JIC vary when SC shocks vary, and JIT and JIC can complement one another in different ways when SC shocks vary. Theoretically, while the literature acknowledges JIT and JIC fit with small and large shocks, respectively, this study reveals the degree of such fit varies when the magnitude of SC shock increases. A contribution here is the integration of contingency theory and configuration theory to unpack the changing relationships between JIT, JIC and SC shocks when the level of shock varies.

The key theoretical and empirical contributions follow. The results indicate downstream shocks did not negatively affect the operational performance of manufacturers in China. The main problem was upstream shocks, which reflects the strict lockdown measures in China while demand from overseas had recovered. Having said that, the manufacturers in our sample managed to use both JIT and JIC to improve operational performance. They did not abandon JIT and switch to JIC altogether. The results suggest they may have used JIC to capture new market opportunities caused by the downstream shocks and to neutralise the negative effects of upstream shocks, perhaps using stock piling to satisfy customers facing shortages. The manufacturers did not use JIT to reduce the negative effects of upstream and downstream shocks, but to achieve operational performance, more so when shocks were high. The increase in performance could be from attenuation effects that stem from the better fit between environment and production strategy. While this possibility is not formally tested in this study, the remainder of the results confirm the use of hybrid JIT-JIC.

The literature assumes JIT works best under small SC shocks (Mackelprang and Nair, 2010), and it might not fit with high magnitude shock environments (Drakeley, 2022). Thus, we hypothesized under low magnitude shocks, increasing JIT should increases operational performance more than when the shocks are large. Instead, we found, under small or large shocks, operational performance increased at a similar degree as the level of JIT increased. That means the effects of JIT on operational performance were not reduced by shocks; they also depend on JIC use. Notably, when shocks were low in magnitude, both JIT and JIC were major contributors of operational performance, and the simultaneous implementation of both JIT and JIC did not reduce operational performance as much as when the shocks were large. JIT and JIC seem to be less conflicting when SC shocks are small. However, when shocks were large, JIC contributed more than JIT to operational performance, but the interactions between JIT and JIC significantly reduced that performance.

The literature assumes JIC works best under high magnitude SC shocks. We found that increasing JIC improves operational performance at different degrees when the levels of upstream and downstream shocks vary. The degree in improvement was greater when SC shocks were large. When SC shocks were large, operational performance was explained more by JIC, when JIT remained deployed. When SC shocks grow, rapidly increasing JIC can improve operational performance. Thus, our findings are consistent with the literature on the increasing use of JIC when shocks are large, but our results suggest JIT and JIC could reduce each other’s effects on operational performance due to configurational tensions. Negative interaction effects were magnified when up and downstream shocks are high. The manufacturers in our samples also had higher operational performance when they had high levels of JIC, regardless of JIT level. This suggests a better configuration when SC shocks are elevated is to maintain JIT and increase JIC.

The empirical evidence also clarifies a very important effect, i.e., the configurational tension between JIT and JIC, especially when SC shocks are large. Our framework in Figure 2 further explains the effects of the tension under low/high magnitude SC shocks and the interactions with JIT and JIC. Using the ideas of contingency, fit, and configurational tension, the framework can be used to explain operational performance of manufacturers when they increase JIT (or JIC) under low or high SC shocks. Due to the decrease in fit with current shocks, our analysis shows increasing JIT (from left to right quartiles) during COVID-19 pandemic did not matter regardless of the shock level. Instead, increasing JIC caused an increase in fit with shocks (from lower to upper quartiles) and thus improved operational performance. To avoid configurational tension, the ideal configurations are either low JIT high JIC for high magnitude SC shocks or high JIT low JIC for low magnitude SC shocks. It is easier to reconfigure resources for changing the levels of JIT and JIC when SC shocks are low, as manufacturers experience less tension between JIT and JIC. However, high JIC levels matter. Even though the configurational tensions that reduce operational performance increase when both JIT and JIC are high, additional operational performance is gained when increased shocks allow JIC to be an appropriate strategy.

The framework opens a new avenue for developing new theories about the effective configurations of JIT and JIC. The question here is not just about fit. We need knowledge about how to configure resources and processes for JIT and JIC, so that they can independently deal with SC shocks as well as not reduce each other's effectiveness. Our analysis shows that in the case of upstream shocks, the interaction of JIT and JIC negatively impacts operational performance which suggests avoiding the increase of JIT when JIC is already high because operational performance is not improved from the investments. This suggests the 'hybrid' version of JIT/JIC is more effective when they are implemented through a hybrid operating model, i.e., separating resources and processes for JIT and JIC. This suggests it is fine for JIT manufacturers to hold excess inventory, diversify suppliers, and order larger quantities in the presence of upstream and downstream shocks (Drakeley, 2022; Koo, 2020). Also, our data suggest the hybrid model relied more on JIC when manufacturers face unprecedented shocks caused by the COVID-19 pandemic.

Our hypotheses and results suggest the question of JIT/JIC configurations depends on the 'match' or 'fit' between JIT/JIC and the environment (SC shocks), but also 'congruence' or 'tensions' between JIT and JIC. As pointed out by Ginsberg and Venkatraman (1985), we need to recognize and capture the interrelations between multiple strategies or organizational processes because one mode of operation is often ill-suited for a changing environment. We need a more comprehensive understanding of JIT/JIC configurations that considers how to reduce tension between them, and how to quickly switch levels of JIT and JIC from one mode to another to reach the right configuration quickly. We suggest that JIC can be thought of as a reserved adaptive capacity, like a water tap that can be adjusted, to cope with increasing SC shocks. Further research along this line will have a great potential to produce useful knowledge.

6.2. Contributions to practice

The empirical findings offer several managerial implications. First, a recent report by SAP indicates that most firms (approximately 84%) in the UK planned to abandon JIT inventory methods and adopt JIC instead during the COVID-19 pandemic. Our results show this to be a suboptimal strategy being that it is important to keep JIT while increasing the use of JIC. Even though our study shows JIC becomes more important during events such as a pandemic, the results show it is not wise to abandon JIT altogether. It is more beneficial for operations managers to implement a hybrid JIT-JIC system to enhance performance during times of uncertainty. However, our results also show a hybrid pull-push inventory system can negatively impact operational performance. One way to reduce such negative effects is to operate at a low-tension configuration when SC shocks increase.

Our data show Chinese manufactures were mainly affected by upstream shocks during the pandemic. Our results suggest operations managers increase the use of JIC as such shocks increase. Even though downstream shocks did not create a negative effect on operations, JIC should be given priority, as it can help managers capture new market opportunities and dampen the negative effects of SC shocks. The implementation of the JIC inventory and capacity system e.g., diversifying suppliers, holding safety inventory, and developing alternative sourcing options, allows firms to enhance operational performance in the face of high levels of supply- and demand-side uncertainty.

Our configuration framework (Figure 2) offers manufacturers a map for understanding fit between JIT, JIC and SC shocks. It informs managers on how to maintain JIT while adjusting the use of JIC system, depending on the combined levels of JIT and JIC and the level of SC shocks. Logically, the levels of JIT and JIC should be opposite, too few or too much of both is less than desirable. In the presence of high levels of demand shocks e.g., fluctuating demand and unpredictability and variability of customer demand, it becomes crucial for firms to utilize both JIT and JIC in a hybrid manner. This enables firms to maximally improve operational performance. More importantly, this study provides a framework for developing resources and processes for increasing JIC and dealing with tensions between JIT and JIC. The framework guides managers to be cautious when implementing a hybrid push-pull inventory system in high supply uncertainty environments e.g., instability in supplier quality and delivery, unpredictability and variability in the availability of raw materials and component parts, as it may result in a weaker effect on operational performance.

6.3. Limitations and future research directions

The results obtained from this study should be evaluated considering their limitations. Firstly, in today's digital age, advanced digital technologies such as big data analytics, artificial intelligence, and internet of things facilitate synchronisation and collaboration across SCs (Núñez-Merino et al., 2020; Yu et al., 2023a; 2023b). Thus, future research is encouraged to examine how digital transformation improves the implementation of JIT and JIC inventory practices. Secondly, in this study we focused on examining the moderation of business environments i.e., SC shocks. The lean manufacturing literature suggests that other factors, such as the geographic distance between buyers and suppliers (Choi et al., 2023) and organizational culture and human resources e.g., employee training and motivation (Cullinane et al., 2014), are important contingency variables that might strengthen the competitiveness of JIT/JIC inventory practices. Thus, future research might examine the moderating effect of these factors on the relationship between JIT/JIC and performance. Thirdly, in this study, survey data were collected from manufacturing firms in China that may have implemented both JIT and JIC practices during the COVID-19 pandemic. Choi et al. (2023) assert that, in general, global SCs do not adhere to the JIT principle. Geographically dispersed SCs inherently necessitate additional inventory, even when employing JIT inventory systems. Therefore, we encourage future research to collect data from other research settings (different industries in various regions and countries) to confirm the empirical findings generated from this study. Fourthly, another significant limitation is that this study solely investigates the impact of JIT/JIC practices on operational performance, without considering their effects on financial performance. It is conceivable that the elevated level of JIC, which enhances operational performance, might incur costs significant enough to adversely affect financial performance. Lastly, although we carefully addressed potential CMB and endogeneity problems, we recognize that eliminating endogeneity completely is unlikely, which we acknowledge as a limitation of this study employing a cross-sectional research design.

7. Conclusions

In this study, a framework is proposed and empirically tested, based on contingency theory and configuration theory, that differentiates configurations of JIT/JIC under low and high magnitude SC shocks. Overall, the results show that JIC's impact on operational performance is enhanced by both upstream and downstream shocks, whereas JIT does not demonstrate the same effect. Specifically, when shocks are large, increasing JIC is effective only when JIT levels are low. The empirical findings offer timely and comprehensive guidance for managers who are uncertain about whether and when to increase or adjust their use of JIT/JIC in response to disruptions like COVID-19 and the Ukraine war.

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Table 1: Sample characteristics

	%		%
Industry type		**Firm location**	
Automobile	8.7	Pearl River Delta	14.0
Building materials	5.3	Yangtze River Delta	18.8
Chemicals and petrochemicals	6.8	Bohai Sea Economic Area	16.4
Electronics and electrical	19.3	Northeast China	4.8
Fabricated metal products	14.0	Central China	30.4
Food, beverage and alcohol	8.2	Southwest China	7.2
Industrial machinery and equipment	14.0	Northwest China	8.2
Pharmaceutical and medical	6.3	**Firm ownership**	
Publishing and printing	1.4	State-owned manufacturer	22.2
Rubber and plastics	5.8	Private Chinese manufacturer	69.6
Textiles and apparel	3.4	Wholly foreign-owned manufacturer	4.8
Wood and furniture	.5	Joint venture manufacturer	3.4
Others	6.3	**Job title**	
Number of employees		President / Chief executive officer (CEO)	5.8
≤ 100	13.0	Vice president	.5
101 – 500	43.0	Director	6.3
501 – 1000	21.7	Manager	70.0
> 1000	22.2	Other senior executive	17.4
Firm age (years)		**Job tenure**	
≤ 20	51.2	≤ 10	62.3
21 – 40	42.0	11-20	34.3
41 – 60	5.8	> 20	3.4
> 60	1.0		

Table 2: EFA results: factor loadings

Measurement items	F1	F2	F3	F4	F5
1. Upstream shocks					
UP1: The suppliers produce materials with inconsistent quality during COVID-19	-.056	.009	.163	.241	**.734**
UP2: We have a high rejection rate of incoming critical materials from suppliers during COVID-19	-.113	.111	.135	.076	**.845**
UP3: We lost our key suppliers during COVID-19	.246	-.063	-.075	.355	**.665**
UP4: We receive unstable quality of product supplies during COVID-19	-.022	.090	.139	.092	**.838**
2. Downstream shocks					
DOWN1: Our supply requirements vary drastically from week to week during COVID-19	.162	.100	.116	**.728**	.176
DOWN2: The volume and/or composition of demand is difficult to predict during COVID-19	.071	.212	.051	**.716**	.057
DOWN3: We have inaccurate demand forecasting during COVID-19	.029	.260	-.057	**.741**	.238
DOWN4: We have insufficient or distorted demand information during COVID-19	.130	.244	-.032	**.727**	.311
3. Just-in-time supply chain					
JIT1: Our suppliers deliver to us on a JIT basis	.408	.269	**.624**	.051	.015
JIT2: Our suppliers deliver to us in Kanban containers, without the use of separate packaging	.222	-.013	**.771**	.133	.188
JIT3: Our suppliers are linked with us by a pull system	.088	.181	**.870**	-.055	.127
JIT4: Our customers are linked with us via JIT systems	.129	.176	**.855**	.005	.073
4. Just-in-case supply chain					
JIC1: We reorder stock before it reaches the minimum level to continue to sell inventory while our suppliers are supplying the goods during COVID-19	.322	**.603**	-.094	.157	.279
JIC2: We seek to find diverse suppliers closer to home to stock up on our inventories during COVID-19	.088	**.752**	.202	.153	.019
JIC3: We work closely with our existing suppliers while diversifying the supply base during COVID-19	.143	**.798**	.144	.050	.081
JIC4: We emphasize accurate demand forecasting during COVID-19	.248	**.663**	.175	.298	.094
JIC5: We hold sufficient safety stock during COVID-19	.259	**.590**	.092	.388	-.067
JIC6: We anticipate stock outs, especially of essential stock items during COVID-19	.403	**.652**	.035	.192	-.015
JIC7: We track excess stock to prevent obsolescence during COVID-19	.323	**.625**	.224	.261	.002
5. Operational performance					
OP1: Quickly modify products to meet our major customer's requirements	**.700**	.274	.277	.075	-.078
OP2: Quickly respond to changes in market demand	**.805**	.177	.149	.175	.012
OP3: An outstanding on-time delivery record to our major customer	**.829**	.237	.037	.151	.043
OP4: Provide a high level of customer service to our major customer	**.780**	.274	.099	.196	-.057
OP5: Produce high quality products that meet our customer needs	**.620**	.438	.058	-.068	-.067
OP6: Produce products with low costs	**.621**	.066	.270	.006	.092
Eigenvalues	8.262	3.220	2.431	1.527	1.119
Total variance explained			66.236		

Table 3: CFA results: reliability and validity assessment

Measurement Items	Factor loadings	Cronbach's alpha	Composite reliability	AVE
1. Upstream shocks		.819	.826	.546
UP1	.739			
UP2	.795			
UP3	.596			
UP4	.807			
2. Downstream shocks		.810	.817	.534
DOWN1	.612			
DOWN2	.574			
DOWN3	.827			
DOWN4	.866			
3. Just-in-time supply chain		.858	.864	.617
JIT1	.672			
JIT2	.720			
JIT3	.877			
JIT4	.854			
4. Just-in-case supply chain		.879	.881	.516
JIC1	.640			
JIC2	.697			
JIC3	.703			
JIC4	.766			
JIC5	.707			
JIC6	.752			
JIC7	.755			
5. Operational performance		.880	.885	.566
OP1	.765			
OP2	.798			
OP3	.835			
OP4	.835			
OP5	.686			
OP6	.555			

Goodness-of-fit indices: $\chi^2 = 531.821$; df = 265; χ^2 / df = 2.007; CFI = .902; IFI = .903; RMSEA = .070; SRMR = .074

Table 4: Construct-level correlation matrix

Variables	Mean	S.D.	UP	DOWN	JIT	JIC	OP
Upstream shocks (UP)	3.661	1.277	**.739**	.453**	.224**	.190**	.054
Downstream shocks (DOWN)	5.069	1.085	.463**	**.731**	.150**	.514**	.298**
Just-in-time supply chain (JIT)	4.965	1.109	.239**	.166*	**.786**	.381**	.437**
Just-in-case supply chain (JIC)	5.645	.885	.205**	.523**	.393**	**.718**	.614**
Operational performance (OP)	5.803	.856	.072	.311**	.448**	.621**	**.752**
Job tenure (marker variable)	1.411	.558	-.086	.027	-.165*	-.129	-.019

Note: Square root of AVE appears on the diagonal; unadjusted correlations appear below the diagonal; adjusted correlations for potential CMV appear above the diagonal; ** $p < .01$; * $p < .05$.

Table 5: Results of hypothesis testing

	Model 1	**Model 2**	**Model 3**
Control variables			
Firm age	-.013 (-.142)	.016 (.234)	.047 (.740)
Firm size	.149 (1.765)	.027 (.415)	.049 (.819)
Industry1 (Electronics and electrical)	-.102 (-1.343)	-.042 (-.716)	-.019 (-.353)
Industry2 (Fabricated metal products)	-.018 (-.243)	-.064 (-1.156)	-.054 (-1.053)
Industry3 (Industrial machinery and equipment)	.073 (.994)	.026 (.459)	.036 (.695)
Industry4 (Automobile)	.066 (.926)	.011 (.198)	.000 (.005)
Firm ownership1 (Private manufacturer)	.168 (.948)	.191 (1.408)	.179 (1.445)
Firm ownership2 (State-owned manufacturer)	.289 (1.747)	.283 (2.238)*	.205 (1.751)
Firm ownership3 (Wholly foreign-owned manufacturer)	-.080 (-.753)	-.024 (-.291)	-.057 (-.737)
Independent variables			
Just-in-time supply chain (JIT)		.246 (4.117)***	.254 (4.614)***
Just-in-case supply chain (JIC)		.513 (7.697)***	.502 (7.787)***
Upstream shocks (UP)		-.138 (-2.271)*	-.139 (-2.491)*
Downstream shocks (DOWN)		.032 (.462)	.042 (.656)
Interaction effect			
JIT × JIC			-.298 (-4.123)***
JIT × UP			.091 (1.250)
JIC × UP			.182 (2.120)*
JIT × DOWN			-.066 (-.728)
JIC × DOWN			.145 (1.981)*
R^2	.103	.490	.585
Adjust R^2	.062	.455	.545
F-value	2.510**	14.240***	14.720***

Note: Standardized coefficients and t-values are reported; Dependent variable is operational performance; *** *p* < .001; ** *p* < .01; * *p* < .05.

Table 6(a): Results of multiple-group analysis across low and high upstream shocks

	Low Upstream Shocks			High Upstream Shocks		
	Model 1	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**
Control variables						
Firm age	.073 (.568)	.097 (1.029)	.091 (.973)	-.116 (-.923)	-.039 (-.411)	-.082 (-1.008)
Firm size	.082 (.660)	-.115 (-1.219)	-.101 (-1.083)	.215 (1.861)	.175 (2.010)*	.115 (1.544)
Industry1 (Electronics and electrical)	-.097 (-.950)	-.062 (-.813)	-.060 (-.795)	-.157 (-1.341)	.006 (.063)	.074 (.950)
Industry2 (Fabricated metal products)	.038 (.382)	-.006 (-.087)	-.009 (-.126)	-.092 (-.878)	-.165 (-2.064)*	-.086 (-1.242)
Industry3 (Industrial machinery and equipment)	.113 (1.114)	.070 (.921)	.072 (.963)	.029 (.271)	.005 (.058)	.023 (.335)
Industry4 (Automobile)	.042 (.439)	.034 (.467)	.029 (.414)	.109 (1.030)	.012 (.142)	.112 (1.549)
Firm ownership1 (Private manufacturer)	-.230 (-.715)	-.076 (-.317)	-.113 (-.478)	.353 (1.596)	.378 (2.268)*	.403 (2.864)**
Firm ownership2 (State-owned manufacturer)	-.011 (-.038)	.136 (.640)	.094 (.446)	.408 (1.890)	.328 (2.013)*	.400 (2.890)**
Firm ownership3 (Wholly foreign-owned manufacturer)	-.415 (-2.027)*	-.181 (-1.176)	-.189 (-1.247)	.220 (1.777)	.082 (.861)	.198 (2.397)*
Independent variables						
Just-in-time supply chain (JIT)		.253 (3.224)**	.237 (3.054)**		.143 (1.699)	.288 (3.842)***
Just-in-case supply chain (JIC)		.506 (6.477)***	.486 (6.260)***		.617 (7.407)***	.845 (10.564)***
Interaction effect						
JIT × JIC			-.140 (-2.007)*			-.532 (-5.992)***
R^2	.172	.557	.575	.129	.517	.660
Adjust R^2	.096	.506	.521	.041	.456	.612
F-value	2.261*	10.976***	10.714***	1.470	8.482***	13.887***

Note: Standardized coefficients and t-values are reported; Dependent variable is operational performance; *** $p < .001$; ** $p < .01$; * $p < .05$.

Table 6(b): Results of multiple-group analysis across low and high downstream shocks

	Low Downstream Shocks			High Downstream Shocks		
	Model 1	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**
Control variables						
Firm age	.242 (1.881)	.095 (.931)	.104 (1.011)	-.226 (-1.746)	.026 (.234)	.005 (.050)
Firm size	.034 (.286)	-.076 (-.821)	-.075 (-.810)	.223 (1.756)	.119 (1.162)	.032 (.364)
Industry1 (Electronics and electrical)	-.156 (-1.564)	-.081 (-1.031)	-.082 (-1.045)	-.065 (-.531)	.021 (.211)	.080 (.952)
Industry2 (Fabricated metal products)	-.021 (-.219)	-.093 (-1.212)	-.090 (-1.166)	-.108 (-.958)	-.104 (-1.139)	-.006 (-.080)
Industry3 (Industrial machinery and equipment)	.151 (1.552)	.060 (.788)	.063 (.817)	.040 (.337)	.050 (.534)	.085 (1.057)
Industry4 (Automobile)	.061 (.636)	.073 (.947)	.066 (.855)	.002 (.015)	-.035 (-.388)	.074 (.918)
Firm ownership1 (Private manufacturer)	.086 (.392)	.118 (.686)	.120 (.697)	.409 (1.360)	.363 (1.505)	.345 (1.674)
Firm ownership2 (State-owned manufacturer)	.144 (.727)	.269 (1.716)	.257 (1.623)	.553 (1.893)	.302 (1.276)	.358 (1.767)
Firm ownership3 (Wholly foreign-owned manufacturer)	-.290 (-1.953)	-.043 (-.359)	-.040 (-.334)	.156 (.940)	.017 (.131)	.082 (.722)
Independent variables						
Just-in-time supply chain (JIT)		.310 (3.779)***	.290 (3.395)***		.119 (1.257)	.439 (4.446)***
Just-in-case supply chain (JIC)		.437 (5.178)***	.428 (5.022)***		.604 (6.576)***	.723 (8.896)***
Interaction effect						
JIT × JIC			-.066 (-.823)			-.578 (-5.633)***
R^2	.156	.499	.503	.109	.456	.608
Adjust R^2	.082	.444	.442	.015	.384	.550
F-value	2.101*	9.067***	8.341***	1.160	6.325***	10.589***

Note: Standardized coefficients and t-values are reported; Dependent variable is operational performance; $^{***}p < .001$; $^{**}p < .01$; $^{*}p < .05$.

Figure 1: Research model

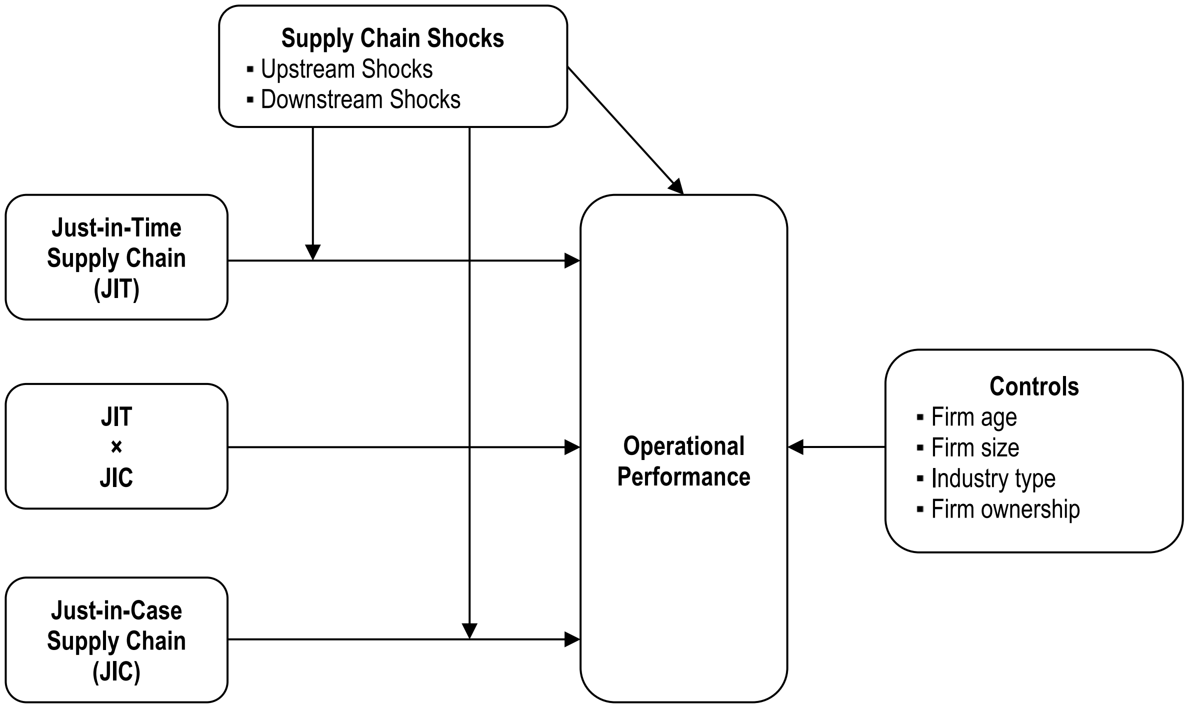

Figure 2: Configurations of JIT-JIC under low and high SC shocks

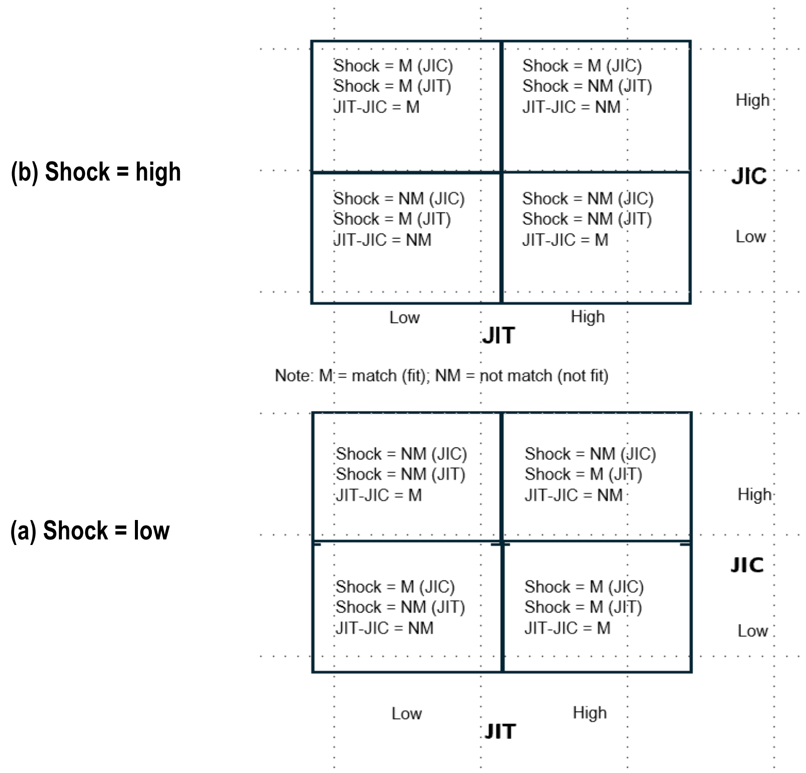

Figure 3: Interaction effect of JIC and upstream shocks on operational performance

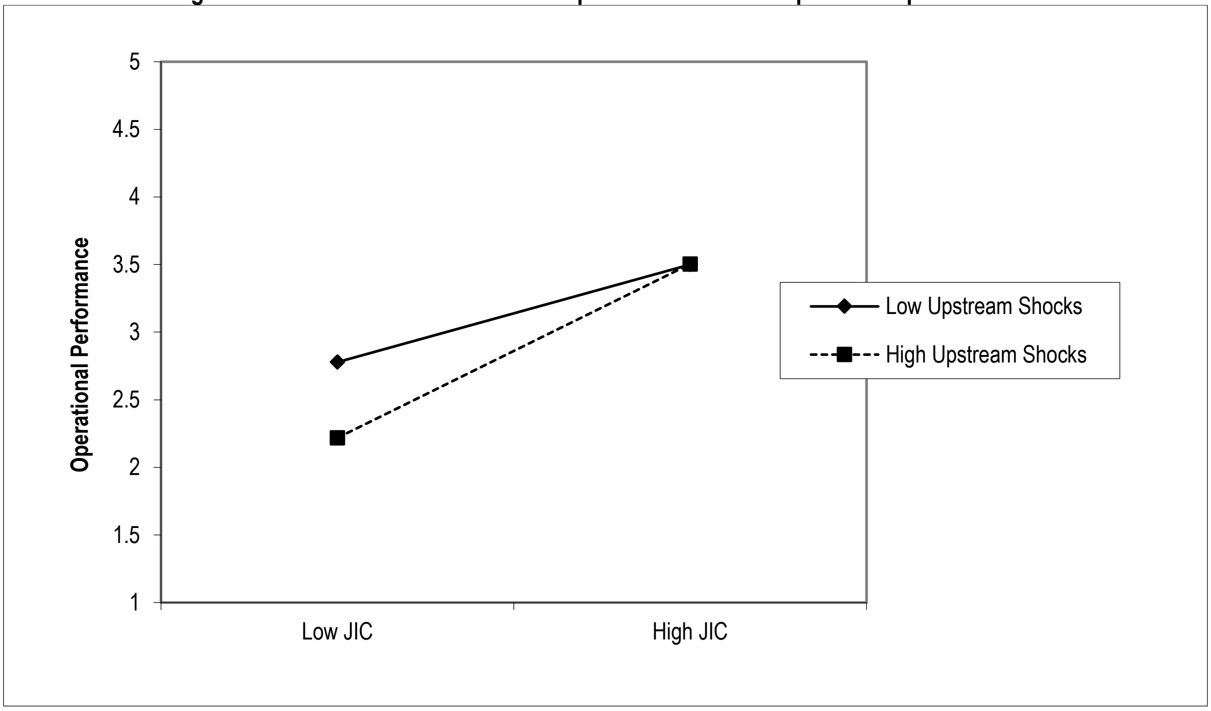

Figure 4: Interaction effect of JIC and downstream shocks on operational performance

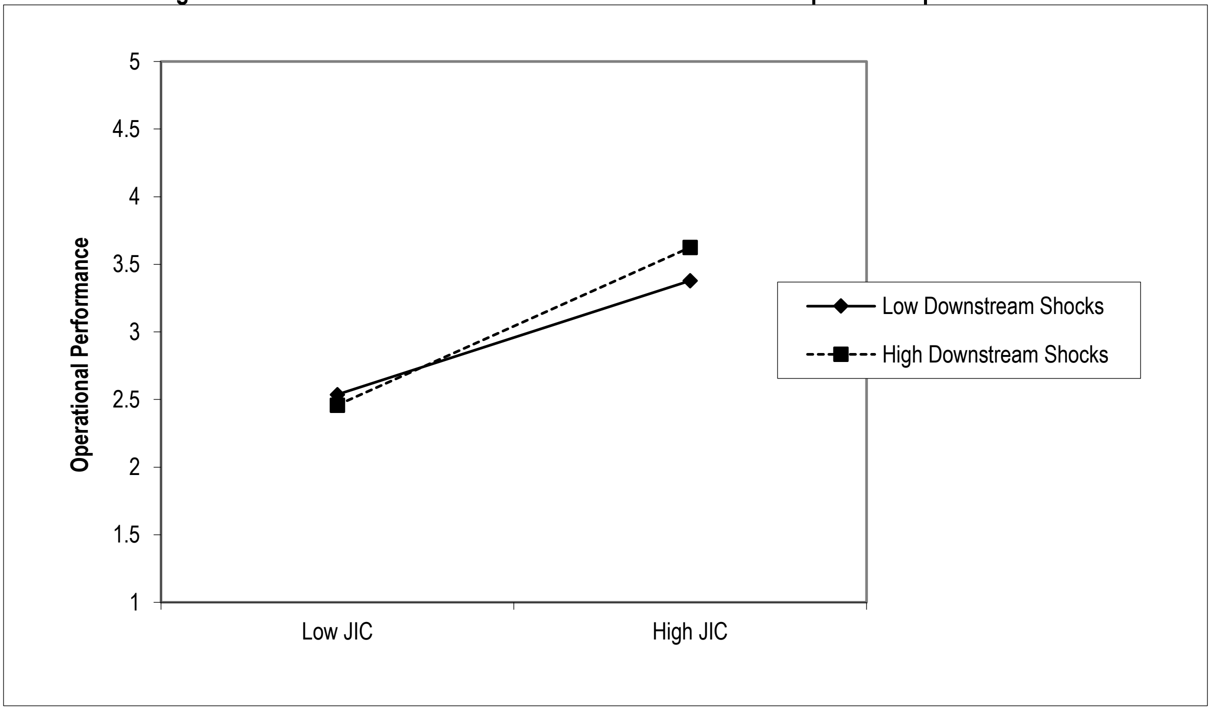

Figure 5: Interaction effect of JIT and JIC on operational performance