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Manufacturing planning and control driven supply chain risk management: A dynamic capability perspective

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ABSTRACT

This paper builds on the dynamic capability view to theorize the role of manufacturing planning and control (MPC) activities and supply chain risk management (SCRM) capabilities towards the firm's operational performance. The study hypothesize that companies enhance MPC activities to respond to supply chain uncertainty (SCU) and enable SCRM that positively impacts operational performance. Data from 356 manufacturing companies in developing countries and regions, drawn from the sixth version of the International Manufacturing Strategy Survey is used to examine the hypothesized model empirically. The findings indicate that the MPC activities effectively respond to SCU and act as an enabler of preventive and reactive SCRM. Furthermore, the paper finds that MPC activities drive operational performance through effective SCRM. Also, the findings suggest that preventive risk management practices impact operational performance only through reactive risk management. Finally, the paper enriches the literature by identifying and discussing the theoretical and managerial significance of the role of MPC activities in the association between SCU, risk management practices, and firm performance.

1. Introduction

Uncertainty has become a permanent feature of today's supply chain management function (Chaudhuri et al., 2018; Wilson, 2007), resulting in a shorter product life cycle, short lead time, and increased risk exposure (Corallo et al., 2020; Dai et al., 2015). The start of the year 2020 has further witnessed significant supply chain challenges that have been aggravated by the uncertainty associated with the Covid-19 pandemic (Ivanov, 2021). With growing complexity and shift of manufacturing operations to developing countries, firms have become vulnerable to supply chain uncertainty (SCU) (Gao and Ren, 2020). SCU, explained as turbulences that may occur at any point within the supply chain network leading to positive or negative outcomes (Simangunsong et al., 2012, p. 4494; Wagner and Bode, 2008), has essential implications for manufacturing planning and control (MPC) activities. It is argued that when firms face uncertainty in their supply chain, they try to manage their internal manufacturing activities to cope with these uncertainties. (Cantor et al., 2014).

MPC refers to activities such as material planning and management, capacity planning, production floor control, order tracking, and shop/floor layout (Graves, 1999; Tenhiälä and Helkiö, 2015), just-in-time, master scheduling, sales, and operational planning,

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capacity requirement and inventory control (Darmawan et al., 2018; Chen and Shang, 2008; Olhager and Rudberg, 2002; Davies and Kochhar, 2000). MPC activities are seen as resource-driven capabilities (Wamba-Taguimdje et al., 2020) that firms develop by making use of superior tangible and intangible resources (Teece, 2007). Since the inception of information and computer technology and a widespread availability of industrial software tools, firms are making precise use of MPC activities such as material requirements planning, capacity planning, inventory management, lot-sizing, master production schedule and resource planning to improve their efficiency (Missbauer and Uzsoy, 2020). This resource-driven MPC capability can be used effectively to manage supply chain risk. Scholars have already examined certain supply chain-wide practices, such as agility, flexibility, and integration, that seek to reduce the impact of supply chain uncertainty and enable supply chain risk management (SCRM) (Wieland and Marcus Wallenburg, 2012; Sreedevi and Saranga, 2017; Kwak et al., 2018; Munir et al., 2020) (See Appendix B for details). Despite the significance of MPC in manufacturing firms, there is hardly any research that examines the role of MPC as a response to SCU and an enabler of SCRM. Based on this gap, the first research question this study aims to answer is:

Research question 1: Do firms adopt MPC as a response to SCU and an enabler for SCRM?

Further, SCRM can be classified into preventive and reactive SCRM as has been done by Gouda and Saranga (2018) for nuanced understanding of risk management capabilities. Where preventive SCRM allows the firm to develop strategies to minimize the exposure towards risk, reactive SCRM focuses on the needed mitigation strategies to minimize risk. The importance of SCRM can be witnessed through the development of certain practices at Ericsson over time. A major fire breakout at the plant of one of the critical suppliers halted production lines at Ericsson, and the firm suffered millions of dollars in losses (Norrman and Jansson, 2004). After 15 years of this incident, revisiting Ericsson revealed that the firm had developed preventive SCRM practices over time, focusing more on supplier development, logistics handling, improved infrastructural capabilities, and deployment of tools for SCRM (Norrman and Wieland, 2020). Similarly, taking the case of the German automotive industry, Thun and Hoenig (2011) discussed the importance of reactive SCRM such as multiple sourcing, backup suppliers, and IT systems towards the performance of firms. Extant literature has argued the significance of SCRM vis à vis firms' supply chain strategies and performance (Wiengarten et al., 2016; Kwak et al., 2018; Munir et al., 2020). However, the review of SCRM literature indicates that the significance of SCRM towards firm operational performance is not thoroughly examined and is inconsistent and inconclusive (Dellana et al., 2019). Also, the classification of SCRM as preventive and reactive approaches has received little attention (Sreedevi and Saranga, 2017) though it can help improve firm performance. Thus, the second research question this study aims to answer is:

Research question 2: Do preventive and reactive SCRM influence firms' operational performance?

We use Dynamic Capabilities View (DCV) to propose SCU as a trigger of MPC and MPC as an enabler of SCRM (Teece, 2007; Wernerfelt, 1984). DCV has been used in earlier studies to understand the relationship between SCU, supply chain risk and organizational actions and how firms react to SCU to develop a competitive advantage (Kauppi et al., 2016; Brusset and Teller, 2017; Jajja et al., 2018). DCV contends that organizations need to deploy superior resources to enhance their key manufacturing activities (resource-driven dynamic capabilities), such as the speed of production rescheduling, effectual forecasting, and maintenance of required inventory levels (Chen and Shang, 2008) to manage SCU (Teece, 2007). Further, inspired by DCV logic, we argue that firms facing SCU develop process-driven SCRM capabilities to enhance performance. Dynamic capabilities induce a transmission mechanism where one set of dynamic capability triggers another (Chen et. al., 2021). Grounded in DCV, we first posit that manufacturing firms that operate under SCU enhance their MPC activities. Next, underpinning the DCV, we contend that superior MPC activities enable SCRM and positively drives operational performance. Thus, we also argue for the mediation of SCRM between MPC activities and operational performance, leading to the third research question:

Research question 3: Does MPC affect operational performance through SCRM?

These relationships are studied using data of manufacturing firms from developing countries and regions in Asia, Europe, and South America. In contrast to developed countries, where advanced manufacturing technologies and facilities and supplier-manufacturing flexibilities support MPC practices (Sun, 2000; Avittathur and Swamidass, 2007), developing countries and regions struggle with implementing such practices. Rapidly changing competitive environments in developing countries force firms to change their manufacturing processes and implement MPC to stay competitive (Chen and Shang, 2008; Davies and Kochhar; 2000). The high degree of uncertainty in developing countries and regions warrants the need to empirically explore the reaction of manufacturing firms towards SCU and how these firms develop MPC activities to manage supply chain risks. Thus, in this paper, we empirically theorize and investigate how SCU impacts firms' internal MPC activities, enabling SCRM practices and operational performance, especially with developing countries and regions in the backdrop.

This paper enriches the literature presenting a novel explanation, backed by empirical examination, of whether SCU motivates a firm to enhance its MPC activities as means towards effective SCRM and performance. We argue that preventive and reactive SCRM mediate the role of MPC activities towards firm performance. Owing to the shift of manufacturing activities from developed to developing countries (such as India and China) over the past decade, it is argued that firms operating in these countries can develop core competences through MPC activities to cope with SCU. These MPC activities can help firms manage the supply chain risk effectively and lead to enhanced performance. Furthering the contribution towards practice, the extant research allows operations, logistics, and supply chain managers to clearly understand the alignment of internal manufacturing activities and SCRM practices.

2. Theory and hypotheses development

2.1. Dynamic capability view (DCV)

The extant research aims to understand whether MPC activities enhance firms' SCRM capabilities and drive operational performance. Considering the impact of MPC on SCRM capabilities, the conceptual model is developed based on DCV, an extension of the resource-based theory presented by Grant (1991). The resource-based view (RBV) contends that firms use superior resources to exploit opportunities and, as a result, acquire competitive advantage. These resources are unique in terms of imitability, rarity, substitutability, and value (Barney, 1991) and allow firms to achieve a competitive edge (Eisenhardt and Martin, 2000). Grant (1991) further argued that firms' resources are not limited to monetary, physical, or tangible resources. In fact, firms' resources also include knowledge, skills, and know-how of key processes that result in different types of dynamic capabilities (Wamba-Taguimdje et al., 2020; Votto et al., 2021), such as resource-driven and process-driven capabilities. DCV extends the concept of the RBV (Teece et al., 1997; Priem and Butler, 2001) as RBV has been criticized because it assumes that the firm's environment is stable and follows a gradual change pattern (D'Aveni, 1994). These assumptions do not hold in a turbulent and dynamic environment driven by changing customer demands, fast-paced technological advancements, product customization and modifications, and evolving market players (Kilubi, 2016; Eisenhardt and Martin, 2000; Jajja et al., 2018). DCV emphasizes building superior competencies that make firms better than their competitors (Eisenhardt and Martin, 2000). Firms build dynamic capabilities through configuration, reconfiguration, and integration of their resources that address environmental vigor (Teece et al., 1997).

Firms make use of their internal competences to develop capabilities that help them mitigate supply chain risk. Drawing on multiple cases of logistic service providers, Hohenstein (2022) has argued that reconfiguration of internal processes helps firms enhance their SCRM. Based on this logic, the notion of dynamic capabilities seems appropriate for evaluating how MPC activities can facilitate the development of SCRM capabilities in SCU. MPC addresses "the decisions on acquisition, utilization, and allocation of production resources to satisfy customer requirements most efficiently and effectively" (Graves, 1999, p. 2). It has also been discussed in the literature as a dimension of manufacturing strategy (Skinner, 1996; Kim and Arnold, 1996), a system that is developed at the planning level and execution level, and part of just-in-time and manufacturing resource planning (MRP) activities (Benton and Shin, 1998; Graves, 1999) (See Appendix B for details). Thus, we argue MPC activities as capabilities firms develop as a response to cope with SCU and enable SCRM. Singhry and Abd Rahman (2019) used DCV as a lens to study the effect of forecasting, collaborative planning, and replenishment activities on supply chain performance in Nigerian firms, all relating to the MPC activities.

Similarly, SCRM is also contended as a process-driven dynamic capability that helps firms improve their performance (Kilubi, 2016; Sabahi and Parast, 2019; Wang, 2018). SCU exerts a great deal of pressure on firms to manage their resources effectively for sustainable competitive advantage (Teece, 2007) (see Appendix B for details). The scholars have argued that firms operating under SCU develop dynamic capabilities such as SCRM (Gligor et al., 2015; Chaudhuri et al., 2018; Jajja et al., 2018). Supply chain management literature stresses the importance of key processes of preventing, detecting, mitigating and responding to supply chain risk as building blocks of dynamic capabilities that firm need to cope with rapidly changing environments (Teece, 2007) – all referring to the core elements of SCRM. DCV suggests that the firms develop dynamic capabilities based on resources deployed to enhance their processes (Teece, 2007; Eisenhardt and Martin, 2000) that help organizations strengthen their capabilities, such as SCRM.

2.2. Supply chain uncertainty and manufacturing planning and control

DCV contends that under uncertain environmental conditions, firms deploy superior resources to maintain their competitive advantage (Teece, 2007). The concept of uncertainty that roots back to the seminal works such as Thompson (1967) has been extensively studied in strategic management, organizational theory, and marketing management literature (Chen and Paulraj, 2004). SCU, which according to DCV, can be viewed as a turbulent environmental condition may ensue from within a firm's boundaries due to internal inconsistencies of manufacturing processes or various external factors concerning customers and suppliers (Flynn et al., 2016). SCU is referred to as a situation "where decision-maker lacks information about (or understanding of) the supply chain or its environment, lacks information processing capabilities, is unable to accurately predict the impact of possible control actions on supply chain behavior" (Van der Vorst and Beulens, 2002, p. 413). The complex and dynamic supply chain landscape is often linked to factors such as high level of customization, change in customer preferences, short lead times, and turbulence at part of suppliers. These complexities lead to a higher degree of uncertainty (Bhatnagar and Sohal, 2005), and product discrepancies and delays (Kwak et al., 2018).

Extant literature discusses SCU at the level of supply, demand, product, manufacturing, and technology uncertainties (Davis, 1993; Chen and Paulraj; 2004, Sreedevi and Saranga; 2017; Ho et al., 2005). Davis (1993) suggest that supply chains are affected by uncertainty in three different ways: supplier or supply uncertainty that includes inconsistencies of supplies, and delay or challenges of on-time performance; manufacturing uncertainty resulting from process performance, machine breakdowns, and product manufacturing requirements (volume, variety, technology, etc.); and demand uncertainty arising from demand fluctuations and an inability to anticipate these fluctuations. These supply chain uncertainties lead to increased supply and demand forecasting errors and manufacturing inefficiencies (Wiengarten and Longoni, 2018). The count of supply chain members and their interconnectedness enhances the degree of intricacy and uncertainty in supply chains (Wu and Pagell, 2011). There is a possibility that firms can wait for the uncertainties to settle at their own as these turbulences are uncontrollable, but an effort to manage internal operations through superior resources can help a firm overcome these challenges quickly.

Though extant literature has studied the moderating role of environmental and supply chain uncertainties towards dynamic capabilities and performance (Merschmann and Thonemann, 2011), motivated by DCV, we argue that SCU triggers the ability of firms to deploy superior resources that facilitate firms' operations. Shan et al. (2021) argued that SCU is a key environmental factor that triggers firms to develop sustainable production systems. DCV contends that firms must deploy their resources in the context of changing environments to create sustainable competitive advantage (Teece, 2007). These resources need a transmission mechanism to be deployed. We argue that MPC activities of firms lend this transmission mechanism to firms to use their resources dynamically in

SCU. The MPC activities, such as demand management, forecasting, material requirement planning, and capacity planning and utilization (Jacobs et al., 2011), help organizations sustain operations continuity and compete in SCU (Muckstadt et al., 2001). These activities can help organizations to cope with uncertainties such as demand fluctuations, suppliers' issues, and technological developments. Therefore, we hypothesize:

H_1: SCU significantly affects the firm's MPC activities.

2.3. Manufacturing planning and control and supply chain risk management

DCV argues that firms create and recreate capabilities through their resources to sustain their competitiveness in a rapidly changing environment (Barreto, 2010; Sabahi and Parast, 2019). In the presence of SCU, these resources are also used to develop MPC activities that relate to product-process alignment, information integration, and monitoring and restructuring of (Samaranayake, 2013). Chan and Burns (2002) argued that MPC leads to enhanced agility and a lean supply chain, that are discussed as SCRM strategies. Also, flexibility and customization in manufacturing capabilities and customization are much needed to cope with disruption and reduce supply chain risk (Doetzer and Pflaum, 2021; Dohale et al., 2021). Ho et al. (2015) identified SCRM strategies that include flexible supply base, maintaining strategic stock, dynamic pricing, postponement, make and buy strategies, flexible transportation, and product roll-over, which largely depend on careful planning of manufacturing processes.

Scholars have attempted to explain SCRM in multiple dimensions, e.g., "identification, assessment, treatment, and monitoring" of supply chain risks (Neiger et al., 2009). Jüttner et al. (2003) has suggested four elements of SCRM, i.e., "gauging risk sources, identifying risk concepts, tracking risk drivers, and mitigating risk." Similarly, Kleindorfer and Saad (2005) categorized SCRM in three stages of (1) specifying sources of risks, (2) assessment, and (3) risk mitigation. Broadly, SCRM includes activities of preventing (Tomlin, 2006; Norrman and Jansson, 2004), detecting (Zsidisin and Ritchie, 2009; Manuj and Mentzer, 2008), responding (Sheffi and Rice Jr, 2005), and recovering (Norrman and Jansson, 2004). These SCRM activities can be bifurcated into preventive and reactive SCRM (Thun and Hoenig, 2011; Gouda and Saranga, 2018). Preventive SCRM focuses on reducing risk exposure, whereas reactive SCRM enhances a firm's capability to mitigate risk effectively (Gouda and Saranga, 2018). Preventive risk management includes assessing risk sources, managing safety and planning for emergencies, flexible supply base, flexible transportation (Schenk et al., 2018; Ho et al., 2015). Reactive SCRM includes capabilities like capacity enhancements, contingency planning, and clarity in and responsibilities, strategic stock, and postponement (Gao et al., 2019; Ahmad, 2018; Gouda and Saranga, 2018). In an effort to establish various themes on SCRM based on a comprehensive review of literature, Pournader et al. (2020) argued preventive and reactive risk management strategies as separate clusters.

Using a logistics firm's case study that ships goods from China to Brazil, Blos et al. (2018) argued that a robust supply chain and logistics system and careful analysis and design of production systems are integral towards effective SCRM. Also, as mentioned earlier, the fire breakout incident at Ericsson pushed the firm to focus on "minimizing risk exposure" by enhancing its risk management processes (Norrman and Jansson, 2004), thus improving preventive SCRM. Reactive risk management focuses more on responding to and recovering from supply chain disruptions. These disruptions are difficult to foresee, as they can come from a wide range of sources like natural disasters, operational uncertainties, political or economic upheavals (Simchi-Levi et al., 2014; Norrman and Jansson, 2004). Realizing the intensity of impact when exposed to supply chain risk, firms need effective approaches that offer a systematic response to cope with risks and uncertainties (Williams et al., 2006). These approaches include risk tolerance, contingency planning, risk controlling, or risk transfer. Preventive SCRM, through the development and implementation of improved organizational processes, enhances the firm's ability to handle incidents and mitigating risks (Norrman and Jansson, 2004). Extant literature discusses preventive risk management, notably in medicine, environmental sciences, and computer sciences (Schenk et al., 2018; Baum and Bartram, 2018; Hijazi et al., 2014), but this topic needs to be addressed in supply chain management. Supply chain literature focuses more on reactive risk mitigation that helps firms respond to or recover from materialized supply chain risks (Gao et al., 2019; Murphy et al., 2019; Ahmad, 2018, Gouda and Saranga, 2018).

DCV lends a reasonable argument to developing preventive and reactive risk management as firms need resources to prepare for and react to the exposed risks. These resources are deployed in developing MPC activities that help firms develop their risk management capabilities. For instance, if firms engage in product/part tracking activities through bar codes and/or RFID technologies, it may impact their risk preparedness in terms of supplier handling, product inspection, and tracking. Thus, we hypothesize:

H_2: MPC activities positively affect preventive SCRM.
H_3: MPC activities positively affect reactive SCRM.

2.4. Preventive and reactive supply chain risk management

The fabric of the supply chain is exposed to higher level risks over the past few decades. DCV argues that firms need to improve their performance by countering the uncertainties in the environment. SCRM provides a decent mechanism to achieve this (Jajja et al., 2018). Risk management in the supply chain can be preventive and reactive (Gouda and Saranga, 2018; Thun and Hoenig, 2011); while some firms put more effort into preventive risk management strategies, other firms develop abilities to react to risk events. Firms that continuously engage in proactive activities in risk management such as development and implementation of improved organizational processes, preventive maintenance, reliable supplier selection, and adoption of safety procedures (Norrman and Jansson, 2004; Sodhi et al., 2012) may reduce the exposure and consequences of risks and can mitigate and respond to risks in a better way. For instance, firms that deploy resources to enhance preventive SCRM, such as selecting more reliable suppliers, total preventive maintenance, supplier monitoring, etc., will be better prepared to react to any supply chain or environmental anomaly. These reactions may include switching to backup suppliers in case of supply failures, respond to fluctuating demands by deploying extra production capacity, etc. The recent outbreak of Covid-19 has tested the strengths of firms to counter risks in their supply chain (Lin et al., 2021, Ivanov, 2021; Spieske and Birkel, 2021). Firms have borne a great deal of pressure due to supply shortages, price fluctuations, and restricted commutation (Ivanov, 2020). By the mid of the first quarter of 2020, the Covid-19 has made 9% of the shipment fleet inactive, and manufacturing indices of Chinese companies have reached the lowest level since The Great Recession (Retaildive, 2020). The firms that were well prepared for such uncertainties were able to react to these conditions in a better way. It is argued that when firms invest in being prepared to prevent and detect supply chain risk, their ability to mitigate risk enhances for such an event if at all it occurs (Kern et al., 2012; Gouda and Saranga, 2018). Thus, we hypothesize:

H_4: Preventive SCRM positively affects reactive SCRM.

2.5. Manufacturing planning and control and operational performance

The overall aim of a manufacturing firm is to satisfy market requirements and customer demand efficiently and effectively through the management of manufacturing activities (Hong and Leffakis, 2017). Firms make use of superior resources and key manufacturing processes to improve performance. DCV lends an understanding to this phenomenon. The manufacturing process improvements stem from uncertainties in supply chains such as time variability, supplier unreliability, and process output variations (Mapes et al., 2000). These uncertainties allow the firm to build such capabilities that will make them attain and retain a competitive advantage (Ngamsirijit, 2011) and improve performance. The key dimensions of MPC include product flexibility, order tracking, demand management, material requirement planning, and capacity planning (Sheu and Wacker, 2001), affecting manufacturing performance. These dimensions are in line with DCV that argues that firms develop superior competencies in uncertain environments to enhance performance (Teece, 2007). These competencies are argued as the abilities developed by firms to plan and control their manufacturing activities driven from the resources (Nurcahyo et al., 2019), leading to improved operational performance. Tenhiälä and Helkiö (2015) argued that key determinants of operational performance like cost, speed, delivery, flexibility, and reliability are affected by MPC processes. The operational performance of firms is an integral measure of the efficiency and effectiveness of manufacturing practices (Sancha et al., 2019) that make firms perform better (Porter, 1985), i.e., cost and differentiation. Differentiation can further be categorized in terms of delivery, quality, and flexibility (Demeter et al., 2017). Under uncertain environmental conditions, MPC can be used as a dynamic capability to drive superior performance in all dimensions. Thus, we hypothesize:

H_5: MPC activities positively affect operational performance.

2.6. Supply chain risk management and operational performance

Supply chain risks and risk management affect firm operational performance. Exposure of firms to supply risk, attributed to supply chain complexity, lead to negative performance (Wagner and Bode, 2008). Whilst SCRM practices have shown a positive impact on operational performance (Kauppi et al., 2016; Manuj et al., 2014), the firms with a lower focus on SCRM have yielded lower performance (Thun and Hoenig, 2011). Using transaction cost theory, Hoffmann et al. (2013) argued that SCRM moderates the role of environmental uncertainty towards SCRM performance. We use DCV logic here to contend that SCRM is a process-driven capability that firms develop to mitigate the impact of SCU through MPC, thus resulting in enhanced performance. Operational effectiveness is a basis of competitive advantage and helps the firm achieve a superior position (Porter, 1985). It is also a qualifying criterion for operational performance established as flexibility, quality, and delivery (Kauppi et al., 2016; Golini et al., 2016). Improved SCRM practices (e.g., control mechanisms, backup suppliers, and alternate transportation modes) can amplify performance (Lummus et al., 2005; Williams et al., 2013). As discussed above, SCRM can be preventive and reactive. Preventive SCRM includes proactive measures and detection of risk sources in the supply chain, whereas reactive SCRM helps firms reduce and recover from the risk quickly (Pournader et al., 2020). Therefore, we hypothesize:

H_6: Preventive SCRM positively affects operational performance.
H_7: Reactive SCRM positively affects operational performance.

2.7. Mediation effects

DCV and supply chain literature argues that an uncertain environment enhances firms' ability to use their resources in a way that helps them achieve competitive advantage (Teece, 1994; Davis, 1993; Muckstadt et al., 2001). MPC activities are viewed as a transmission mechanism to deploy exceptional resources that help firms reduce supply chain risks. In hypotheses H_2 and H_3, we have sought to explain MPC as an antecedent of preventive and reactive SCRM. Where there is extant literature supporting a positive relationship between SCRM practices and the firms' operational performance (Manuj et al., 2014; Kauppi et al., 2016; Williams et al., 2013), there are other empirical studies that do not support this notion of significance between SCRM practices and performance (Colicchia and Strozzi; 2012, Shou et al., 2018). Risk mitigation strategies such as reduced waste loss, contingency plans, and clear responsibilities (Narasimhan and Talluri, 2009) help firms improve performance; however, some risk management practices negatively affect firm operational performance, such as extra capabilities, excessive inventories, and preventive maintenance (Shou et al., 2018). Thus, it is imperative to understand the role of right MPC activity to trigger preventive SCRM for enhanced performance. For instance, drawing from the impact of the covid-19 pandemic, Ivanov (2021) suggests that the firms' unawareness regarding their capacity and inventory control had a grave impact on performance and risk preparedness. Thus, here we suggest that the preventive SCRM process mediates the relationship between MPC activities and operational performance. Therefore, we hypothesize:

H_8: Preventive SCRM mediates the relationship between MPC activities and operational performance.

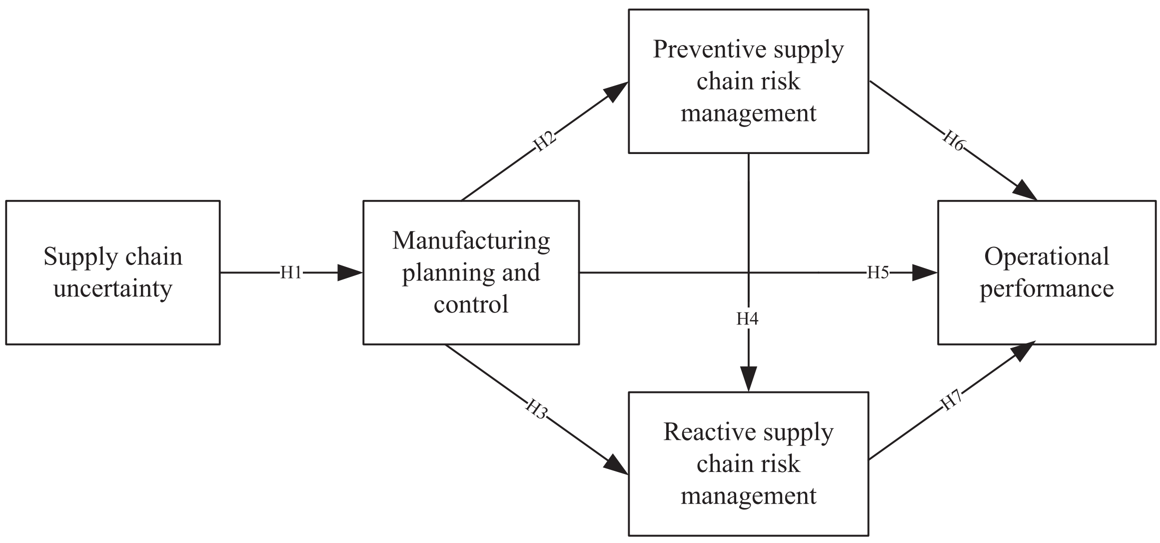
Finally, DCV warrants that a rapidly changing environment encourages firms to develop capabilities through resources that help them become capable of operating efficiently and effectively (Teece et al., 1997; Eisenhardt and Martin, 2000). MPC activities, seen as capabilities developed through superior resources that firms build to cope with environmental uncertainties, enhance reactive risk management capabilities. These risk management capabilities include some make-shift arrangements to counter the negative impact on performance such as switching to backup suppliers, altering production plans, and deploying risk management procedures (Gao et al., 2019; Gouda & Saranga, 2018). Drawing on the logic of process-driven and resource-driven capabilities (Wamba-Taguimdje et al., 2020; Votto et al., 2021), it is suggested that MPC affects operational performance through reactive SCRM. Thus, we hypothesize:

H_9: Reactive SCRM mediates the relationship between MPC activities and operational performance.

Fig. 1 proposes the model of hypothesized direct and mediation relationships in the study.

3. Research methodology

We used the data collected in a large-scale global project by International Manufacturing Strategy Survey (IMSS-VI) to test the hypothesized model. Participants from 23 countries responded the survey that belongs to International Standard Industrial Classification (ISIC) code ranging from 25 to 30. The total of 931 firms responded from the pool of 7167 companies who consented to participate in the survey. In the current research, we used data from developing countries and regions only that included India, China, Taiwan, Hungary, Malaysia, and Brazil (IMF, 2015; Kang et al., 2019). After filtering, a total of 356 usable responses were screened, as shown in Table 1. Researchers at the national level translated the original questionnaire where the native language is not English. The active involvement of the managers ensured the relevance of the instrument and its content validity. Data was collected from all countries by deploying a standard methodology. In all countries, the respondents mainly worked in operations management, such as



H_8: MPC → PSCRM → OP	H_9: MPC → RSCRM → OP

SCU: Supply chain uncertainty, MPC: Manufacturing planning and control, PSCRM: Preventive supply chain risk management, RSCRM: Reactive supply chain risk management, OP: Operational performance

Fig. 1. Hypothesized model.

operations managers, supply chain managers, plant managers, etc. Potential respondents were contacted through the local research team of the country, and questionnaires were sent to the organizations through fax, email, or ordinary mail.

3.1. Common method bias

IMSS questionnaire is a self-reported and self-respondent survey that may lead to the possible risk of common method bias (Podsakoff et al., 2003). Some procedural measures were taken before moving towards hypothesis testing. First, the IMSS questionnaire has a built-in feature to minimize common method bias (Hu et al., 2019); the items of different constructs were clubbed in various segments of the questionnaire. Further, varying numbers of items in the constructs used in this study (ranging from 2 to 6) had different scales of comparisons and levels of implementations (Zhao et al., 2011; MacKenzie and Podsakoff, 2012).

Second, the IMSS VI data collection process helped to control for common method bias. The respondent's anonymity was ensured in data collection that encouraged the respondent to complete the questionnaire objectively rather than in a biased manner (Demeter et al., 2017). Third, we used the respondent's tenure as a method variance marker variable, measured on a single item scale (Shou et al., 2018; Hu et al., 2019). Tenure of the respondent as a measure of experience and work length has no theoretical relation with any other construct used in the study. The insignificance of the correlations between marker variables and other constructs shows that common method bias is not an issue of concern (Hu et al., 2019; Podsakoff et al., 2003).

3.2. Measurement scale

This study used constructs measured through multiple items from the IMSS VI survey (see Appendix A). Each latent construct is measured through items adapted from existing literature. SCU is operationalized in terms of supply, manufacturing, product, and demand uncertainties (Chen and Paulraj, 2004; Ho et al., 2005). Demand uncertainty includes measures representing demand fluctuations, whereas manufacturing uncertainties include volume fluctuations and changes in the mix of product range over time (Davis, 1993; Sreedevi and Saranga, 2017). Product uncertainty is gauged in terms of the degree of technical modifications in the products. In contrast, supply uncertainty is measured as variations due to alterations in parts and components supplied and a degree of change in supply requirements and (Chen and Paulraj, 2004). A 5-point Likert scale was used to measure the degree of uncertainty on stated items (1 = None to 5 = to a great extent).

Planning and control are theorized at a higher level in supply chains that encapsulate managerial activities like forecasting, planning, controlling, and performance evaluation (Zhang et al., 2015). MPC activities are seen as a part of the MPC system at the planning and execution level and an aspect of manufacturing strategy (Skinner, 1996). Indicators of MPC include production planning, stock planning, demand and supply forecast, and information integration (Jabbour et al., 2011; Fogarty et al., 1991; Berry and Hill, 1992). We measured MPC activities in terms of collaborative forecasting and planning, information integration, information exchange capability with supply chain partners through usable formats such as barcodes, RFID, etc. (Su and Yang, 2010), and the ability to transform production process such as restructuring manufacturing process or initiating pull productions (Demeter and Matyusz, 2011). MPC of the plant's dominant activity was measured on a 5-point Likert scale measuring the current implementation level of the stated items (1 = None to 5 = High).

Table 1
Demographic characteristics of the sample.

IMSS VI sample		No.	%age
Firm Size (Number of employees)			
1.	Small companies (Up to 250)	130	36.51
2.	Medium companies (251–500)	75	21.06
3.	Large companies (>500)	150	42.13
4.	Missing	1	0.28
Total	**Valid responses**	**356**	**100**
Industrial Sector			
1.	ISIC 25 Manufacturer fabricated metal products,	76	21.34
2.	ISIC 26 Manufacturer of the electronic computer and optical products	77	21.62
3.	ISIC 27 Manufacturer of electrical equipment	62	17.41
4.	ISIC 28 Manufacturer of equipment and machinery not elsewhere classified	72	20.22
5.	ISIC 29 Manufacturer of trailers, motor vehicles, and semi-trailers	51	14.32
6.	ISIC 30 Manufacturer of other transport equipment	18	5.05
Total	**Valid responses**	**356**	**100**
Countries and Regions			
1.	India	91	25.56
2.	China	135	37.92
3.	Taiwan	28	7.86
4.	Hungary	57	16.01
5.	Malaysia	14	3.93
6.	Brazil	31	8.70
Total	**Valid responses**	**356**	**100**

The total sample size is 356. ISIC: The International Standard Industrial Classification

SCRM has been measured from a process (Fan and Stevenson, 2018) and a strategy perspective (Kwak et al., 2018). Raj Sinha et al. (2004) established a process to mitigate supply chain risk through *"risk identification, risk assessment, planning, and control."* Similarly, Kleindorfer and Saad (2005) focused on SCRM as a combination of risk assessment and mitigation. Generally, the SCRM process includes *"preventing, detecting, responding and recovering from risks"* (Gouda and Saranga, 2018). We measured SCRM as two different constructs of preventive risk management and reactive risk management. Preventive risk management includes activities that occur before a risk materializes (Sreedevi and Saranga, 2017), such as risk prevention and risk detection. Reactive risk management includes risk response and risk recovery. SCRM process for the current level of implementation of each of four stages is measured through a 5-point scale.

We gauged operational performance as operational efficiency and operational effectiveness (second-order constructs) through indicators of quality, cost, flexibility, and delivery (Shin et al., 2000; Rosenzweig and Roth, 2004; Wagner and Bode, 2008; Rodrigues et al., 2004; Chen and Paulraj, 2004; Demeter et al., 2017) using Likert scale (1 = lower performance than competitors to 5 = higher performance than competitors). For items where a lower value represents better performance (cost), the scale was reversed (Demeter et al., 2017).

3.3. Control variables

We employed some control variables in this study that would have otherwise affected the robustness of the analysis. Environmental uncertainty is operationalized by the degree of complexity and dynamism in the environment in terms of competition, market/demand fluctuation, and change in the technology landscape (Droge et al., 2008; Phromket and Ussahawanitchakit, 2009; Uzkurt et al., 2012). We measured these three dimensions as market concentration measured as the number of competitors and competitive rivalry within the industry, market size, market span, and rate of technological change. A 5-point Likert scale was used to measure the degree of strength of each of the environmental forces.

Firm size and industry types were also controlled to ensure contextual validity (Jajja et al., 2018). The logarithmic value of the total human resource in the business unit was used to operationalize the firm size. Industry type was operationalized as a dichotomous variable using ISIC code classification (Wiengarten et al., 2014; Jajja et al., 2018).

4. Findings

4.1. Measurement model

We employed principal component exploratory factor analysis (EFA) to examine the factor loadings of each item of the survey under specific constructs (Table 2). Factor loadings of all items of their respective constructs had values between 0.727 and 0.930 which are higher than the suggested coefficient of 0.70 (Hair et al., 2010). Internal consistency, reliabilities, and validities were tested before the structural model. The reliability of the data was measured using Cronbach's alpha value (Nunnally, 1994). Table 3 reveals that all constructs have Cronbach alpha value between 0.812 and 0.903 above the desired value of 0.70 (Hair et al., 2010). Composite reliabilities of all constructs fall between 0.890 and 0.926 (higher than the desired value of 0.60) (Bagozzi and Yi, 1988). The average Variance Extracted (AVE) of each construct was used to test for convergent validity which is above 0.50 (Chau, 1997; Fornell and Larcker, 1981). We checked for discriminant validity by comparing the square roots of AVE for each construct and off-diagonal correlation measures in Table 4. The greater value of the square roots of AVE from off-diagonal correlation measures supports discriminant validity (Fornell and Larcker, 1981; Adebanjo et al., 2018). Variance inflation factors (VIF) was used to address the issue of multicollinearity. As presented in Table 3, all values of VIF are between 1.061 and 2.303, which are less than the threshold value of 3.00 (Hair et al., 2010), thereby confirming that multicollinearity is not a grave concern in our study.

Due to the spread of respondents across geographical regions, measurement invariance of constructs was tested through Confirmatory factor analysis (Steenkamp and Baumgartner, 1998) by separating the sample into two factions: (1) Asia and (2) Europe and South America. The rationale behind combining Europe and South America into a single group was that we only have one developing country from each of these regions. To balance the number of respondents from different regions, we converged Brazil and Hungary into one group. We ran the unconstrained CFA model with sub-groups in AMOS corresponding to two samples from different geographical locations. The fit indices ($\chi^2_{(774)}$ = 1054.596, CMIN/df = 1.363, GFI = 0.896, AGFI = 0.870, CFI = 0.944, RMSEA = 0.032,

Table 2
Results of factor analysis.

Constructs		items	KMO	BTS	EV	Factor Loadings					
						Item1	Item 2	Item 3	Item 4	Item 5	Item 6
Supply chain uncertainty		6	0.858	1434.575***	4.069	0.830	0.863	0.838	0.888	0.754	0.761
Manufacturing planning and control		5	0.796	770.252***	3.097	0.727	0.824	0.820	0.822	0.735	–
Preventive supply chain risk management		2	0.500	223.762***	1.685	0.918	0.920	–	–	–	–
Reactive supply chain risk management		2	0.500	268.931***	1.730	0.930	0.928	–	–	–	–
Operational performance	Efficiency	2	0.741	257.834***	1.607	0.921	0.875	–	–	–	–
	Effectiveness	6	0.798	1058.482***	3.594	0.815	0.789	0.779	0.744	0.745	0.769

BTS: Barlett's test of sphericity, KMO: Kaiser – Meyer – Olkin; EV: Eigenvalue, *** $p < 0.001$.

Table 3
Results of descriptive, validity, and reliability analysis.

	Mean	Standard deviation	Cronbach's alpha	Composite reliability	AVE	VIF
Supply chain uncertainty	2.558	0.945	0.903	0.926	0.678	1.061
Manufacturing planning and control	3.471	0.830	0.842	0.890	0.619	1.403
Preventive supply chain risk management	3.720	0.844	0.812	0.916	0.845	2.154
Reactive supply chain risk management	3.587	0.913	0.840	0.926	0.863	2.303
Operational performance	3.649	0.629	0.866	0.900	0.599	1.287

Table 4
Results of correlation analysis.

	1	2	3	4	5
(1) Supply chain uncertainty	**0.823**				
(2) Manufacturing planning and control	0.220**	**0.786**			
(3) Preventive supply chain risk management	0.160**	0.456**	**0.919**		
(4) Reactive supply chain risk management	0.192**	0.506**	0.725**	**0.928**	
(5) Operational performance	0.055	0.347**	0.357**	0.334**	**0.773**

Bold values are the square root of AVE. significance established at *p*-value < 0.001 (two-tailed).

SRMR = 0.049) showed satisfactory fit. All factor loadings were above 0.60 with significance level (p < 0.01) except for only one item of cost performance (factor loading: 0.546) but still significant at (p < 0.01). It is thus fair enough to conclude that all constructs show satisfactory invariance across groups. Also, we tested for the statistical significance of the difference of χ^2 between constrained and unconstrained models. Regression weights for all items between groups were fixed. That yielded ($\chi^2_{(806)} = 1099.665$ with $\Delta\ \chi^2_{(\Delta d.f.\ 31)} = 45.069$ (p = 0.491) and the values of other fit indices remained satisfactory (GFI = 0.886, AGFI = 0.868, CFI = 0.942, RMSEA = 0.032, SRMR = 0.048). The test statistics supported measurement invariance between constrained and unconstrained models across different sub-groups of the sample.

4.2. Structural model

A good fitting model was produced by deploying structural equation modelling with $\chi^2_{(332)} = 559.079$, CMIN/df = 1.672, CFI = 0.952, GFI = 0.902, AGFI = 0.880, RMSEA = 0.044, SRMR = 0.051. As shown in Table 5, there is a positive relationship between SCU and MPC activities. Higher the level of uncertainty, higher would be the plant's focus on implementation of MPC activities ($\beta = 0.213$, *p*-value < 0.01). MPC activities also affect preventive SCRM ($\beta = 0.545$, *p*-value < 0.001) and reactive SCRM positively ($\beta = 0.182$, *p*-value < 0.01). Preventive SCRM is positively associated with reactive SCRM ($\beta = 0.771$, *p*-value < 0.001). Further, preventive SCRM has no relationship with operational performance whereas reactive SCRM shows significant positive relationship with operational performance ($\beta = 0.260$, *p*-value < 0.001). An interesting insight is revealed that preventive risk management in supply chain has no direct impact on operational performance. MPC activities also show a direct positive impact on operational performance ($\beta = 0.249$, *p*-value < 0.01). The results provided support for H_1, H_2, H_3, H_4, H_5 and H_7.

4.3. Mediation analysis

As suggested by Preacher and Hayes (2008), the bootstrap approach was employed to check the impact of MPC on operational performance through SCRM. "Bootstrapping is a non-parametric statistical procedure in which the data set is repeatedly sampled, and indirect effects are calculated. These indirect effects are then tested for significance using confidence intervals. If indirect effects are significant, mediation is inferred in the model" (Ambulkar et al., 2015). Bootstrapping is preferred over the Sobel Test or other methods of mediating testing because of its robustness and multiple iterations executed on the sample (Selig and Preacher, 2008). Bias

Table 5
Results of structural equation modelling analysis.

Hypotheses	Hypothesized direct effect	Standard path coefficient	Standard errors	Critical ratios	*p*-value
H_1	SCU → MPC	0.213	0.056	3.179	0.001**
H_2	MPC → PSCRM	0.545	0.067	8.177	0.000***
H_3	MPC → RSCRM	0.182	0.060	3.294	0.000***
H_4	PSCRM → RSCRM	0.771	0.069	11.718	0.000***
H_5	MPC → OP	0.249	0.061	2.758	0.006**
H_6	PSCRM → OP	0.061	0.052	1.251	0.181
H_7	RSCRM → OP	0.260	0.055	3.402	0.000***

**p* < 0.05; ***p* < 0.01; ****p* < 0.001.
SCU: supply chain uncertainty, MPC: manufacturing planning and control, PSCRM: preventive supply chain risk management, RSCRM: reactive supply chain risk management, OP: operational performance.

corrected bootstrapping procedure was used with 5000 resamples to assess the effect size and significance of indirect effects. Apart from *p-value* < 0.05, a non-zero value of upper and lower confidence intervals indicates the significance of indirect effects. Table 6a and 6b shows the results of mediation effects.

We found evidence of partial mediation of reactive SCRM between the relationship of MPC and operational performance, but preventive SCRM does not mediate the relationship between MPC and operational performance.

4.4. Post-hoc analysis

Based on the significance of H_4 and insignificance of H_6, we explored the interplay of MPC, PSCRM, and RSCRM, and operational performance. We conducted a post hoc analysis to study the mediation effect of PSCRM on the relationship of MPC and RSCRM. Further, we tested for mediation effects of RSCRM on the relationship of PSCRM and operational performance. Preventive SCRM mediates the relationship between MPC and reactive SCRM. Further, there is evidence of full mediation of reactive SCRM between the relationship of preventive SCRM and operational performance. Based on insignificance of H_8, double mediation analysis was also tested to measure the impact of MPC on operational performance through preventive and reactive SCRM. Bias-corrected confidence interval revealed that MPC activities lead to preventive SCRM that enhances the firm's ability to mitigate and control risk (reactive risk management), leading towards higher operational performance. Table 6b and 6c shows the results of post-hoc analysis.

Table 6d summarizes the results of all direct and indirect effects.

4.5. Robustness check

Using contextual analysis, we also tested for the robustness of our findings (Yang et al., 2011; Gillani et al., 2020; Munir et al., 2020). Diverse and large samples may not hold the results across regional differences and varying sizes of organizations. To confirm that our results hold firm across the regional differences and size of firms, we segregated the model into two groups, namely Asian versus European/South American firms and small firms (No. of employees up to 250) and large firms (No. of employees > 250). All relationships of key constructs sustained their significance across different regions and different sample sizes, except H_3 in the European and South American regions. The details are illustrated in Table 7.

Endogeneity: Based on the fact that the current study is non-experimental in nature, endogeneity may be a potential problem. Endogeneity occurs when an explanatory variable has strong correlation with error-terms in a regression model. Although we have presented strong theoretical arguments to support the hypothesized relationships, an empirical analysis was also considered appropriate to test the absence of reverse causalities and validity of the proposed paths analysis. To check for this issue of reverse causality, we conducted Durbin-Wu-Hausman augmented regression suggested by Davidson and Mackinnon (2004) and deployed by various studies (Narayanan et al., 2015; Dong et al., 2016; Munir et al., 2020). We used environmental context as an instrumental variable as it is correlated with SCU (Paulraj and Chen, 2007) but not with MPC. Environmental context was measured as a composite variable of four items focusing on rate of technological change, competitive rivalry, threat of substitute products and bargaining power of customers (Gillani et al., 2020). We conducted a stage 1 regression analysis with SCU as a dependent variable and predicted the residual of stage 1 model. In stage 2 model, we include the residual with MPC as dependent variable. The beta-coefficients of the residual in the second stage were insignificant for MPC ($\beta = 0.0231$, $p > 0.05$). This indicated that in the hypothesized model of the extant study, the bias of reverse causality was not a significant issue.

5. Discussion

Grounded in DCV, this study conceptualizes MPC and SCRM as key capabilities that firms develop under SCU to improve performance. Uncertainty is an issue of importance towards supply chain effectiveness because business environment in today's era is highly affected by unforeseen events. Taking into account, the influence of SCU on firms ability to compete effectively, dynamic capability view argues that firms develop MPC activities on superior resources (Teece, 2007; Teece, 1994). The use of stat-of-the-art tools and techniques in MPC activities has made the firms more efficient in their production mechanisms (Missbauer and Uzsoy, 2020). Thus MPC activities can be seen as resource-driven dynamic capabilities (Nurcahyo et al., 2019) that lead to SCRM capabilities (Kilubi, 2016) and enhance performance. Scholars have classified dynamic capabilities as process-driven and resource-driven capabilities (Wamba-Taguimdje et al., 2020; Votto et al., 2021). This study positions MPC as resource-driven and SCRM as process-driven dynamic capabilities as manufacturing activities are driven by provision of tangible and intangible resources whereas managing supply chain

Table 6a
Bootstrap results for direct, indirect, and total effects.

Hypo–theses	IV	MV	DV	IV → MV (a)	MV → DV (b)	IV → DV (c')	IV → MV → DV (a*b)	Total Effect (a*b) + c'	95% confidence interval
H_8	MPC	PSCRM	OP	0.545***	0.061	0.249***	0.033	0.282	−0.048 – 0.386
H_9	MPC	RSCRM	OP	0.182***	0.260***	0.249***	0.047**	0.296**	0.007 – 0.082

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.
SCU: supply chain uncertainty, MPC: manufacturing planning and control, PSCRM: preventive supply chain risk management, RSCRM: reactive supply chain risk management, OP: operational performance.

Table 6b
Bootstrap results for post-hoc analysis.

IV	MV	DV	IV → MV (a)	MV → DV (b)	IV → DV (c')	IV → MV → DV (a*b)	Total Effect (a*b) + c'	95% confidence interval
MPC	PSCRM	RSCRM	0.545***	0.771***	0.182***	0.420**	0.602***	0.297 – 0.644
PSCRM	RSCRM	OP	0.771***	0.260***	0.061	0.200**	0.261**	0.245 – 0.589

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.
SCU: supply chain uncertainty, MPC: manufacturing planning and control, PSCRM: preventive supply chain risk management, RSCRM: reactive supply chain risk management, OP: operational performance.

risk is a process of identifying, assessing, mitigating, and controlling risk (Neiger et al., 2009; Manuj and Mentzer, 2008).

SCU can also be witnessed due to the recent outbreak of Covid-19 that has significantly affected the supply chains, especially those that extend to developing countries (van Barneveld et al., 2020). It has led academics to draw their attention towards vulnerable supply chains in developing countries. For example, production of Apple iphone was halted, and the launch of new model was delayed because of the Covid-19 outbreak. (Feiner, 2020). This indicates that SCU can suddenly emerge from any unexpected source (Simangunsong et al., 2012), and firms should be prepared for such events to minimize its impact on their performance and MPC activities provide effective means for this purpose. In the past as well various events causing supply chain disruptions have been reported, such as the hazardous chemicals explosion at Beijing's Maritime Gateway in 2015, building collapse at Rana Plaza in Bangladesh in 2013, and fire accident at the plant of one of the suppliers of Ericsson (Norrman and Jansson, 2004; Jacobs and Singhal, 2017). Such incidents have pushed firms to focus more on managing SCU and develop strategies to manage supply chain risks (Heidary and Aghaie, 2019; Qi et al., 2017; Shou et al., 2021). Based on DCV environmental uncertainty impacts the manufacturing planning of a firm – a key driving factor of SCRM (Simangunsong et al., 2012).

Gualandris and Kalchschmidt (2014) discussed various manufacturing planning and control activities that help firms minimize their exposure to supply chain risk. These activities include modular design, process reengineering, team-based working, and inventory management. Similarly, Sigala et al., (2022) have suggested production changeovers as a specific risk mitigation strategy. Transportation risk is also managed through preventive SCRM. Based on empirical examination of shipper's abilities to implement preventive SCRM, Bendul et al. (2016) argued that product vulnerability and production processes affect the implementation of preventive measures in the transportation field. Prior literature has argued that SCRM is enabled by supply chain flexibility, supply chain integration, supply chain responsiveness and agility (Wieland and Marcus Wallenburg, 2012; Riley et al., 2016; Munir et al., 2020). Thus we discuss the role of MPC activities as a resource-driven dynamic capability and an enabler of SCRM.

Using the DCV lens, SCRM is identified as a process-driven dynamic capability that drives firm performance positively (Kilubi, 2016; Sabahi and Parast, 2019). Extant literature has discussed the relationship between SCRM and firm performance (Hoffmann et al., 2013; Kwak et al., 2018; Riley et al., 2016; Wieland and Marcus Wallenburg, 2012). We maintain that SCRM drives the operational performance of firms positively (Ritchie and Brindley, 2007; Kilubi and Haasis, 2015); however, risk management in supply chains is seen as a process of preventive and reactive risk management (Gouda and Saranga, 2018). This allows the firm to gather additional information on the events that have caused SCU and proactively take measures to minimize risk exposure. It will also enable firms to prepare themselves effectively to react to the exposed supply chain risk. Reactive SCRM helps firms mitigate risk by maintaining excess capacities, excess inventories, and flexible transportation modes. Our findings reveal exciting insights into this phenomenon. Preventive SCRM alone is non-significant towards improving the operational performance dimensions such as quality, cost, flexibility, and delivery. Reactive SCRM fully mediates the link between preventive SCRM and performance. Therefore, it is argued in this study that preventive SCRM acts as a precursor of reactive SCRM leading to improved operational performance. It does not mean that firms with preventive SCRM will invest more in reactive SCRM; the dynamic capabilities of preventive SCRM will enhance the dynamic capabilities of reactive SCRM. Thus, preventive SCRM practices act as a foundation for reactive SCRM for improved operational performance.

The business environment in developing countries and regions is more vulnerable and exposed to supply chain risks (Moradeyo, 2018; Tarei et al., 2020; Wang, 2018). Data from developing countries, mainly from India and China, reveal that resource-driven dynamic capabilities such as technology adoption, infrastructural developments and state-of-the-art manufacturing systems (Accenture, 2013) are key contributors towards firm performance. Further, MPC, positioned as resource-driven capabilities enable SCRM, a process-driven capability, that has a positive impact on performance. Theoretically, this study informs the literature on transfusion of dynamic capabilities in terms of MPC and SCRM capabilities that allow firms to respond to SCU and enhance performance.

5.1. Managerial implications

Logistics, production, and supply chain Managers may draw valuable insights from the extant study. First, the research suggests that managers should adequately plan and control manufacturing activities for effective logistics and supply chain risk management. MPC helps managers to identify the key activities that contribute towards firms' success through reducing transportation risk and enhance SCRM. These activities include JIT, enhanced product characteristics, production scheduling, lot sizing, demand forecasting, and shop floor scheduling (Chan and Burns, 2002; Olhager and Rudberg, 2002; Nurcahyo et al., 2019). Further, using technological advancements in MPC activities as summarized by Missbauer and Uzsoy (2020), astute managers can take an edge on using these capabilities as a source to manage supply chain risk. The study also brings out the fact that production and supply chain managers must

Table 6c
Bootstrap results for post-hoc analysis (double-mediation).

Hypo–theses	Path	IV → MV (a)	MV1 → MV2(b)	MV2 → DV (c)	IV → DV (d)	IV → MV1 → MV2 → DV (a*b*c)	Total Effect (a*b*c) + d	95% confidence interval
Double mediation	MPC → PSCRM → RSCRM → OP	0.545***	0.771***	0.260***	0.249***	0.11**	0.359***	0.027 – 0.159

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.
SCU: supply chain uncertainty, MPC: manufacturing planning and control, PSCRM: preventive supply chain risk management, RSCRM: reactive supply chain risk management, OP: operational performance.

Table 6d
Hypotheses and post-hoc test results.

Hypotheses	Result	Hypotheses	Result
H_1: SCU → MPC	Supported	H_7: RSCRM → OP	Supported
H_2: MPC → PSCRM	Supported	H_8: MPC → PSCRM → OP	Not Supported
H_3: MPC → RSCRM	Supported	H_9: MPC → RSCRM → OP	Supported
H_4: PSCRM → RSCRM	Supported	PSCRM → RSCRM → OP	Supported
H_5: MPC → OP	Supported	MPC → PSCRM → RSCRM	Supported
H_6: PSCRM → OP	Not supported	MPC → PSCRM → RSCRM → OP	Supported

$*p < 0.05$; $**p < 0.01$; $***p < 0.001$.
SCU: supply chain uncertainty, MPC: manufacturing planning and control, PSCRM: preventive supply chain risk management, RSCRM: reactive supply chain risk management, OP: operational performance.

Table 7
Contextual analysis of the hypothesized model.

Hypotheses	Hypothesized direct effect	Effects	Firm Size		Regions	
			Small (n = 130)	Large (n = 225)	Asia (n = 268)	Europe and South America (n = 88)
H_1	SCU → MPC	0.213**	0.224**	0.211**	0.248**	0.148*
H_2	MPC → PSCRM	0.545***	0.580***	0.535***	0606***	0.495**
H_3	MPC → RSCRM	0.182***	0.212***	0.180***	0.259***	0.003
H_4	PSCRM → RSCRM	0.771***	0.778***	0.770***	0.680***	0.979***
H_5	MPC → OP	0.249**	0.250**	0.248**	0.213**	0.371**
H_6	PSCRM → OP	0.061	0.070	0.060	0.060	0.066
H_7	RSCRM → OP	0.260***	0.261***	0.259***	0.221**	0.403**
H_8	MPC → PSCRM → OP	0.110	0.121	0.108	0.124	0.120
H_9	MPC → RSCRM → OP	0.037*	0.040*	0.033*	0.148**	0.194**

$*p < 0.05$; $**p < 0.01$; $***p < 0.001$.
SCU: supply chain uncertainty, MPC: manufacturing planning and control, PSCRM: preventive supply chain risk management, RSCRM: reactive supply chain risk management, OP: operational performance.

operate closely to see the impact of MPC on SCRM. MPC activities are primarily concerned with production managers whereas, SCRM is an issue to be dealt by supply chain managers. It will also help bring a culture of open communication and collective decision making in the organization.

Logistics and supply chain managers can make use of preventive and reactive SCRM and should consider reactive SCRM after taking preventive measures towards supply chain risks. Additionally, SCRM is not only a matter of managing key supply chain partners alone. Instead, there is a requirement to create core manufacturing capabilities to see through the risk in the supply chain. Astute managers should take insights from using this two-edged sword of SCRM and MPC to achieve a competitive advantage in their logistics operations.

MPC activities such as improving process focus, reducing batch size, using kanban systems, and developing product tracking programs are critical competencies that managers should develop to enhance SCRM. Firms' ability to prevent supply chain risk increases significantly when they improve these activities. For managers, SCRM serves a dual purpose: addressing external stakeholders to streamline and foresee critical risks in the supply chain and managing internal manufacturing activities to develop competence to cope with SCU.

6. Conclusion and future research directions

We aimed to empirically examine the role of MPC activities towards firms' effort to cope with supply chain risk and, as a result, improve operational performance. This is among the first studies as there is no empirical research that has systematically examined the mentioned relationships in the literature except for some conceptual work (Simangunsong et al., 2012). Previous studies on risk management (Kern et al., 2012; Thun and Hoenig, 2011) attribute that higher SCRM results in better performance. However, our analyses imply that realization of preventive risk management practices drives the efficacy of risk mitigation in terms of reactive risk management strategies. We report that preventive risk management practices are only effective towards performance when they become sources to enhance reactive risk management. Theoretically, our study lends the DCV lens to MPC activities as a means to enhance SCRM capabilities. Earlier, MPC activities have been seen as functional capabilities that improve performance. We argue that in uncertain environments, firms deploy superior resources to build dynamic capabilities in manufacturing and control activities. These capabilities further enhance firms' ability to manage supply chain risk effectively, thus enhancing performance.

This theoretical argument is backed by the significance of key hypotheses in the study. The result provides evidence of SCRM through MPC activities in uncertain supply chains. It is revealed that MPC, along with reactive SCRM, has a substantial effect on firms' improved operational performance. Previously, MPC activities were mainly linked with superior firm performance, innovation, and a source of competitive advantage; however, our study identifies MPC as a source of SCRM, especially reactive SCRM towards enhancing operational performance. Therefore, this study highlights how manufacturing companies can face external uncertainties (SCU) through managing internal operations (MPC activities) for mitigating external risks (supply chain risk) for improved operational performance.

This study used a sizeable number of data points from manufacturing firms belonging to ISIC code 25 to 30 from six different developing countries and regions. Though measurement and structural models were ensured to be rigorous, we do acknowledge a few limitations. We draw the sample from the IMSS VI survey that restricts the data under a limited number of industries, so our results can only be generalized to those industries. The study opens future research directions towards studying the impact of MPC activities on SCRM and firm performance in sub-segments of these and other sectors. The data collected through the IMSS VI survey is cross-sectional. However, preventive SCRM strategies may take time to develop and affect firm performance. A longitudinal study can unearth the significant effect of preventive risk management on firms' operational performance. Also, the moderating role of demograhic charactersitics, such as type of industry, firm size and environmental factors, can be studied to see the variations amongst different relationships between SCU, MPC, and SCRM.

CRediT authorship contribution statement

Attique ur Rehman: Conceptualization, Methodology, Formal analysis, Writing – original draft. **Muhammad Shakeel Sadiq Jajja:** Data curation, Writing – review & editing, Supervision. **Sami Farooq:** Resources, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Supply chain uncertainty

To what extent do you agree with the following statements?	Not at all	To a greatextent			
Your demand fluctuates drastically from week to week.	1	2	3	4	5
Your total manufacturing volume fluctuates drastically from week to week.	1	2	3	4	5
The mix of products you produce changes considerably from week to week.	1	2	3	4	5
Your supply requirements (volume and mix) vary drastically from week to week.	1	2	3	4	5
Your products are characterized by a lot of technical modifications.	1	2	3	4	5
Your suppliers frequently need to carry out modifications to the parts/components they deliver to your plant.	1	2	3	4	5

Manufacturing planning and control

Indicate the current level of implementation of, action programs related to:	Current level of implementation				
	None				High
Restructuring manufacturing processes and layout to obtain process focus and streamlining (e.g. reorganize plant-within-a-plant; cellular layout)	1	2	3	4	5
Undertaking actions to implement pull production (e.g. reducing batches, setup time, using kanban systems)	1	2	3	4	5
Improving forecasting and planning accuracy (methods, software, frequency…)	1	2	3	4	5
Increasing information integration (monitoring and control the processes in real time by a dedicated information system)	1	2	3	4	5
Engaging in product/part tracking and tracing programs (bar codes, RFID)	1	2	3	4	5

Preventive SCRM

Indicate the current level of implementation of, action programs related to:	Current level of implementation				
	None				High
Preventing operations risks (e.g. select a more reliable supplier, use clear safety procedures, preventive maintenance)	1	2	3	4	5
Detecting operations risks (e.g. internal or supplier monitoring, inspection, tracking)	1	2	3	4	5

Reactive SCRM

Indicate the current level of implementation of, action programs related to:	Current level of implementation				
	None				High
Responding to operations risks (e.g. backup suppliers, extra capacity, alternative transportation modes)	1	2	3	4	5
Recovering from operations risks (e.g. task forces, contingency plans, clear responsibility)	1	2	3	4	5

Operational performance

How does your current performance compare with that of your main competitor(s)?	Relative to our main competitors, our performance is				
	Much lower		equal		Much Higher
Unit manufacturing cost	1	2	3	4	5
Ordering costs	1	2	3	4	5
Conformance quality	1	2	3	4	5
Product quality and reliability	1	2	3	4	5
Volume flexibility	1	2	3	4	5
Mix flexibility	1	2	3	4	5
Delivery speed	1	2	3	4	5
Delivery reliability	1	2	3	4	5

Appendix B

Table I: Supply chain uncertainty, supply chain risk management, and firm performance

Author	Year	Journal	Method	Empirical context (Country/ Industry)	Theory	Key pertinent findings
Hohenstein	2022	IJLM	Empirical qualitative	Germany	–	• Environmental uncertainty (Covid-19) →SCRM
Ivanov	2020	TRE	Empirical quantitative	China	–	• Lead time and speed of uncertainty (caused by epidemic outbreak) affects supply chain performance
Gouda and Saranga	2018	IJPR	Empirical quantitative	Countries: India Industries: ISIC code 25-30 including manufacturers of machinery, metal products, and equipment, computers, TV, radio and communication devices etc.	–	• Risk assessment →preventive SCRM →Actual SCR • Risk assessment →reactive SCRM →Actual SCR
Shou et al.	2018	Industrial management and data systems	Empirical quantitative	Countries: 21 countries in Europe, Asia, and North America Industries: ISIC code 25-30 including manufacturers of machinery, metal products, and equipment, computers, TV, radio and communication devices etc.	Information processing theory	• SCRM →operational efficiency →Business performance • SCRM →operational flexibility →Business performance
Chaudhuri et al.	2018	IJOPM	Empirical quantitative	Countries: China, India, Japan, Malaysia, and Taiwan Industries: ISIC code 25-30 including manufacturers of machinery, metal products, and equipment, computers, TV, radio and communication devices etc.	Agency theory	• SCRM moderate relationship between SCI →Manufacturing flexibility
H. L. Chen	2018	IJOPM	Empirical quantitative	Country: Taiwan Industries: ISIC code 1-30 including food, rubber, textile, electric machinery, electronics information services, etc.	–	• Industry-specific uncertainties →SCR →Financial performance
H. L. Chen	2018	IJOPM	Empirical quantitative	Country: Taiwan Industries: ISIC code 1-30 including food, rubber, textile, electric machinery, electronics information services, etc.	–	• Industry-specific uncertainties →SCR →Financial performance
Kwak et al.	2018	IJOPM	Empirical quantitative	Country: South Korea Industries: manufacturers and Logistics intermediaries	RBV	• SC innovation →SCRM capabilities →Competitive advantage

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Author	Year	Journal	Method	Empirical context (Country/ Industry)	Theory	Key pertinent findings
Sreedevi and Saranga	2017	IJPE	Empirical quantitative	Countries: India Industries: ISIC code 25-30 including manufacturers of machinery, metal products, and equipment, computers, TV, radio and communication devices, motor vehicles, etc.	–	• Environmental uncertainty →Supply risk • Environmental uncertainty →manufacturing risk • Environmental uncertainty →Demand risk • Significant moderation of supply flexibility on EU →Supply risk
Riley et al.	2016	IJPDLM	Empirical quantitative	Country: USA Industry: Healthcare (Hospitals)	–	• The study tests the mediating impact of SCRM capabilities on internal integration, training, operational performance, and information sharing • II →warning capabilities →OP • II →warning capabilities →recovery capabilities • Information sharing →warning capabilities • Training → recovery capabilities • Warning capabilities →recovery capabilities →OP
Wiengarten et al.	2016	IJPE	Empirical quantitative	Countries: 19 countries in Asia, Europe, and North America Industries: ISIC code 25-30 including manufacturers of machinery, metal products, and equipment, computers, TV, radio and communication devices, motor vehicles, etc.	–	• SCRM moderates the relationship SCI →cost performance • SCRM moderates the relationship SCI →innovation performance
Hoffmann et al.	2013	JPSM	Empirical quantitative	Countries: Germany, Austria, Luxembourg, and Switzerland Industries: manufacturing	Transaction cost theory	• SCRM moderate relationship between Environmental uncertainty →SCRM performance • SCRM moderate relationship between Behavioral uncertainty →SCRM performance
Wieland and Marcus Wallenburg	2012	IJPDLM	Empirical quantitative	Country: Germany, Austria, and Switzerland Industries: ISIC code 20-39 including food, textile, apparel, lumber and wood products, paper, chemical, leather, primary metal, etc.	–	• SCRM →Agility →Business performance • SCRM →Robustness →Business performance

Table II: Manufacturing planning and control dimensions and its significance towards performance

Author	Year	Journal	Method	Empirical context (Country/ Industry)	Theory	Key pertinent findings
Singhry and Abd Rahman	2019	BPMJ	Empirical quantitative	Nigeria	DCV, Social exchange theory	• Collaborative forecasting and replenishment →supply chain performance • SCRM →supply chain performance
Nurcahyo et al.	2019	International Journal of Technology	Empirical quantitative	Country: Indonesia Industry: Automotive	RBV DCV	• Manufacturing/production/ operations planning is an attribute of functional capabilities • Manufacturing planning includes firm abilities to use updated technology on the plant, improve facilities' layout, work line and work management and improve production processes • Manufacturing/operations planning →Flexibility performance • Manufacturing/operations planning →Delivery performance • Manufacturing/operations planning →Quality performance

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Author	Year	Journal	Method	Empirical context (Country/ Industry)	Theory	Key pertinent findings
Z. Chen and Shang	2008	IJMTM	Empirical quantitative	Country: China Industries: manufacturing including automobile, electronics, chemical and machine	System theory RBV	• Manufacturing operations planning →Cost performance • MPC activities are associated with Just-in-Time (JIT) and MRPII. Key dimensions include demand forecasting, master production scheduling, shop floor scheduling, inventory management, basic data management, small lot sizing, KANBAN systems • MPC →production planning and control performance
Olhager and Rudberg	2002	IJPR	Conceptual	Not applicable	–	• MPC is linked with the manufacturing strategy • Market requirements determine the process choice between *"assemble-to-order, make-to-order or make-to-stock"* • Dimensions of MPC include operations planning, long term planning, master scheduling, and product characteristics
Chan and Burns	2002	Benchmarking	Empirical quantitative	Country: Hongkong Industries: light manufacturing i.e., electronic products, electrical appliances, plastic products, fabricated metal products, toys and, watches and clocks	–	• Manufacturing planning and control (MPC) dimensions include master production scheduling, inventory control, forecasting and inventory control • MPC →Organization performance • MPC →lean and agile supply chain
Sheu and Wacker	2001	IJPR	Empirical quantitative	Countries: Japan and the United States of America Industries: Non-fashion textile production and Machine tool industry	–	• Manufacturing planning and control (MPC) dimensions include forecasting, production planning, demand management, capacity requirement planning, and material requirement planning (MRP-I) • MPC →manufacturing goals performance
Graves	1999	EJOR	Quantitative model	Not applicable	–	• Key dimensions of manufacturing planning and control are product flexibility, order tracking, schedule flexibility, shop/floor layout and production batch size • These dimensions vary across MRP II, Just-in-time (JIT) and Optimum Production Technologies
Benton and Shin	1998	EJOR	Review	Not applicable	–	• MPC is associated with Manufacturing Resource Planning (MRPII) and Just-in-Time (JIT).

Table III: Supply chain uncertainty dimensions and its significance towards manufacturing planning and control and firm performance

Author	Year	Journal	Method	Empirical context (Country/ Industry)	Theory	Key pertinent findings
Chankov et al.	2016	IJPR	Quantitative model		–	• Logistic synchronization in manufacturing systems is negatively correlated with performance
Flynn et al.	2016	JSCM	Empirical quantitative	Countries: Sweden, Finland, Germany, Spain, Austria, Japan, Italy, South Korea, US, Brazil, China Industries: Electronics, Machinery. Transportation components	Contingency theory Organization theory Information processing theory	• Two levels of supply chain uncertainty: micro-level and macro-level uncertainties • Micro-level uncertainties include demand and manufacturing uncertainties • Macro-level uncertainties include competitive pressure and needs of the customer • Micro-level SCU →SCI • Macro-level SCU →SCI
Merschmann and Thonemann	2011	IJPE	Empirical quantitative	Country: Germany Industry: Manufacturing	Contingency theory	• SCU moderates the relationship between SCF →Firm performance

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Author	Year	Journal	Method	Empirical context (Country/ Industry)	Theory	Key pertinent findings
Simangunsong et al.	2012	IJPR	Review		Contingency theory Alignment theory	• Dimensions of supply chain uncertainty include product characteristics, manufacturing process, decision complexity, customer demand, supplier, order forecast and disasters
Paulraj and Chen	2007	JSCM	Empirical quantitative	Country: US Industries: ISIC codes 34-39 including commercial and industrial machinery, computer equipment, fabricated metal, transportation equipment, etc.	RDT	• Supply uncertainty →Strategic SCM • Manufacturing uncertainty →Strategic SCM • Strategic SCM →Firm performance • SCU →Strategic SCM →Firm performance
Olhager and Selldin	2007	IJPR	Empirical quantitative	Country: Sweden Industries: consumer goods manufacturing and industrial goods manufacturing	–	• Market uncertainty →(-) Operational performance • Market uncertainty →MPC • Market uncertainty →MPC →Operational performance
Van der Vorst and Beulens	2002	IJPDLM	Qualitative		–	• Key causes of supply chain uncertainty include supply, demand and product characteristics, decision complexity and information availability

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