Demand and Supply Disruptions During the Covid-19 Crisis on Firm Productivity

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Abstract

This paper explores the supply chain (SC) disruption impacts to the performance outcomes of a semiconductor company during the Covid-19 pandemic and proposes appropriate risk mitigation strategies to overcome the crisis. The research uses a single case study methodology and 24 SC employees from Belgium and Germany who take part in the survey. To measure the effect of SC disruptions to the firm's financial performance, some quarterly financial statement data are used from 2018 to 2021. The regression analysis results show that there is no significant impact of SC disruptions to the firm's productivity and non-financial performance. The paired samples t-test suggests that there is no significant change in the firm's financial performance before and during Covid-19 either due to the market's political and economic stability or the semiconductor company develops effective SC risk management strategies.

Keywords: Covid-19, Demand and supply disruptions risk, Firm productivity, Firm financial performance, Non-financial performance, Semiconductor company

Introduction

As the ongoing Covid-19 pandemic has created a new era, businesses continue to understand the pandemic's crippling effects on various aspects of their daily operations (Do et al., 2021). This virus reveals that events characterised by unprecedented uncertainty impinge on normal demand and supply patterns, causing a significant disruption in the supply chain (SC) system (Kumar & Abdin, 2021; Masudin et al., 2021; Parast & Subramanian, 2021; Sarker et al., 2021).

Over 1000 companies' more than 94% fortunes are impacted by SC disruptions due to Covid-19 pandemic (Butt, 2021a). A survey by the Institute for Supply Management (2021) finds that 97% of organisations encounter global disruptions in supply availability, production capacity, lead times and transportation of goods following Covid-19 till March 2020. As SCs embrace all activities related to the flow and processing of goods from raw materials to the ultimate finished goods to the customer (Chen, 2018), understanding of the companies can handle the disruptions and developing emergency plans has become a critical field of research in SC risk management (SCRM) (Azadegan et al., 2020; Skipper & Hanna, 2009; Tummala & Schoenherr, 2011).

Furthermore, the most significant Covid-19 global demand rise has been in the medical articles business, basic foodstuffs (like pasta) and other products (like toilet paper) (Hobbs, 2020; Paul & Chowdhury, 2020) as it exceeds the prevailing domestic production rate, thereby, generating higher demand and soaring prices (McKibbin & Fernando, 2021). For instance, a study by Sheth (2020) examines the impact of this pandemic on consumer behaviour. She finds that consumers engage in stockpiling behaviours due to the unpredictability of the future supply of commodities for basic needs while postponing unnecessary purchases and embracing digitalisation.

As the technology industry faces unprecedented challenges due to the lockdown measures, it stimulates the demand for telecommunications (Deloitte, 2020a). The semiconductor industry being a critical element of any technology has been greatly affected by the Coronavirus due to its globalised SC. With most of its production taking place abroad, semiconductor corporations have had to address and adjust to rising expenses, lead times and supply shortages while meeting customer demand (Accenture, 2020).

Supply chain risk management (SCRM) stems from two key elements: supply and demand (Blos et al., 2009). The literature on SCRM characterises panic buying as a demand risk and the supply plant shutdown which is called a classical supply risk. They both can negatively impact the business performance at numerous levels along with the customers and suppliers (Remko, 2020). Corporations have started addressing the need for investment in SCRM to minimise the consequences of disruptions (Dubey et al., 2019; Wallin et al., 2021) and the Covid-19 event has amplified this need. Although some studies address as to how disruption affects organisational and SC performance (Chen, 2018; Parast & Subramanian, 2021; Pérez Vergara et al., 2021; Wang, 2018), there is limited research examining the effects of SC risk on firm's productivity and performance within a semiconductor company, particularly in Covid-19 perspective.

This study has four aims.

Firstly, it aims to provide an SC risk sources' thorough conceptualisation. To achieve this objective, a range of relevant SC disruptions will be identified in the literature along with the Covid-19 context alignment.

Secondly, it aims to assess the SC risk impacts on firm productivity and performance following Covid-19, using the empirical evidence, surveys, and financial reports of the semiconductor company. Given that semiconductor manufacturers are highly exposed to SC risk (Vakil & Linton, 2021), it facilitates an appropriate arena for studying SC disruptions. According to Zsidisin (2003), this evaluation is critical since the first component of SCRM is to assess the impact of an event or malfunction in SC operations and financial performance.

Thirdly, it aims to contribute to SCRM literature with Covid-19 pandemic perspective.

Fourthly, this paper aims to provide disruption mitigation strategies as to how organisations can develop dynamic capabilities to make their SC resilient. As SC disruptions are assumed to have a detrimental impact on the organisational performance, it is essential to determine the severity of these effects and to develop organisational capabilities. As such, understanding of the SC risk in a SC network has significant practical implications (Parast & Subramanian, 2021).

This research is structured as follows: Sect. 2 is dedicated to the literature review and theory. In Sect. 3, we discuss the research methodology (survey development, data collection, measurements, and analysis). Section 4 discusses the obtained results. In the final section, we conclude this paper.

Literature Review and Hypothesis Development

Theoretical Background

Supply Chain Risks

In an era of increasing globalisation and dependence on suppliers, the likelihood of not achieving the expected SC performance is high which thus exposes organisations to SC risk. Wagner and Bode (2008) define SC risk as the possible deviation from the expected value of an SC performance measure. Tummala and Schoenherr (2011) view SC risk as an event that negatively impacts SC operations and desired performance metrics, such as service delivery levels and chain agility along with cost. They associate SC risk with undesired loss and uncertainty. This SC risk conception is principally grounded on the variance-based approach (Miller, 1983). In classical decision theory, risk is described as the fluctuation in the potential results spread, their expectations and subjective values (March & Shapira, 1987). Thus, wide variations make performance unforeseeable and raise the degree of risk.

The literature highlights two main categories of SC risk, i.e. operational risk and disruption risk (Chen et al., 2013; Knemeyer et al., 2009; Tang, 2006). Manuj and Mentzer (2008) define operational risk as the spread of outcomes which is associated with the unfavorable occurrences within the company. It impacts the company's production capacity, quality and speed, and/or profitability. Operational risk is mostly related to the coordination of supply & demand and arises from flawed or defective processes, systems and people. In contrast, disruption risks are usually natural disasters (e.g. tsunami, floods) and man-made risks (e.g. war or economic crisis). In principle, disruption risks are uncontrollable and have a far more negative impact on businesses in relation to operational risks (Chen et al., 2013; Ho et al., 2015).

Supply Chain Operation Risks

The SC variation encompasses all disruptions that impair performance at the SC and company level. It impacts the flow of information, materials, services and the demand-supply alignment (Jüttner, 2005). In an SC, variations come primarily from three points: upstream, i.e. suppliers' performance; downstream, i.e. customer demands and inward, i.e. company's manufacturing operations (Davis, 1993; Germain et al., 2008). Accordingly, Chen et al. (2013) define the SC operational risk is involved with three types of risks, namely-supply risk, demand risk and process risk.

In addition, the Theory of Swift and Even Flow are the techniques to analyse the SC risk impact on the organisational performance. According to this theory, the faster and smoother materials flow through the process makes the process more efficient (Schmenner &

Swink, 1998). Swift, and Even Flow theory have two elements: (1) 'the reduction of variation' which can be measured in terms of standard, quantities and timing (2) 'the reduction of processing time', which is the time taken to manufacture a product or to provide a service (Schmenner, 2014). Based on this theory, variance-based SC risk (supply, demand or process risk) will shape the SC performance.

Risk Sources

To distinguish SC risks from other business risks, Christopher and Peck (2004) present a 'conceptual approach of disruption' from an SC perspective. In their model, there are five SC disruption risks classified into three classes: disruption risks within the company (process and control); disruption risks beyond the company's control but internal to the SC (demand and supply) and disruption risks outside the SC (environmental). Given the impact of the latest disruptions (i.e. Covid-19) on SCs (illustrated in Fig. 1), this research focuses on supply and demand disruptions of the COVID-19 reality of the SC.

Fig. 1

Supply chain disruption risk drivers.

Source: Christopher and Peck (2004)

Supply Disruption

Organisations face various disruptions related to the upstream part of their SCs (Wagner & Bode, 2008). Supply disruption is the possible deviation of incoming supply regarding time, quality and quantity which may lead to unfilled orders (Aldrighetti et al., 2019; Kumar et al., 2010). Lack of consistency in suppliers' practices will affect their performance and increase supply disruptions (Chen et al., 2013). They are triggered by many forces including supply market production capacity constraints, delivery delays, changes in product technology and design, poor supplier service, lack of supplier involvement or supplier bankruptcy etc. (Wagner & Bode, 2008; Zsidisin et al., 2000). These are likely to have immediate or delayed adverse impacts on the performance of the purchasing company in the short and/or long-run, depending on the magnitude of the disruption and the purchasing company's ability to recover (Sheffi & Rice, 2005).

In addition to the above-mentioned supply risks, empirical studies demonstrate that improving supplier quality leads to superior customer service, firm's performance and long-term competitive advantage (Hartley et al., 2002; Shin et al., 2000). As Giunipero and Eltantawy (2004) consider the likelihood of the suppliers' products quality enhancement and uncertainties reduction, businesses tend to minimise supply risk. Tse and Tan (2012) demonstrate that product and service quality significantly reduces supply disruptions especially in the complex or multi-layered SC. Furthermore, suppliers should possess the competence to cope with the changing market demands (e.g. customer preferences) and should sustain their competitiveness through innovative product development (He et al., 2020; Zsidisin & Ellram, 2003). Similarly, suppliers' inability to provide the requested product will adversely affect the SC effectiveness in its core purpose (Chen et al., 2013). According to Porter's (1985) value chain model, success is based on the unbroken links between various activities in the chain, namely inbound and outbound logistics, which will eventually affect firms' productivity and performance.

Demand Disruption

SC demand disruption is associated with the product demand (Diabat et al., 2012). Demand disruption arises from the failures emerging from downstream of SC operations (Jüttner, 2005). It could be caused by the product's distribution disruptions due to transportation constraints (McKinnon, 2006) and by the volatility and unpredictability of the customer demand (Nagurney et al., 2005). Fluctuating demand can be driven by inbound shocks like economic downturn, customers' high bargaining power, seasonality, fashion volatility, new product introductions, or short product life-cycles (Diabat, et al., 2012; Johnson, 2001). They can also be 'vendor-induced', i.e. some marketing activities like sales promotion and order bundling which will enhance demand fluctuations (Paul & Chowdhury, 2021; Taylor & Fearne, 2006).

Moreover, one of the SC primary objectives is to match the supply to demand (Cohen & Kunreuther, 2007). Unanticipated changes in demand reduce the accuracy of supply estimates and also make it challenging for manufacturers to meet this objective. The potential gap between projected and actual demand, along with poor SC coordination, will harm SC performance and its reliability. If the projection is above the actual demand, it can lead to overstocking, obsolescence, inefficient capacity utilisation or lower prices. If the projection is below the current demand, it can create costly shortages and an inability to meet customer needs (Chen et al., 2013; Wagner & Bode, 2008).

Demand amplification or the bullwhip effect is not a recent phenomenon in SC dynamics (Geary et al., 2006). It was first presented by Forrester (1958, 1961) which is the operations and SC management discipline basis. It is directly associated with the demand risks and how they are likely to disrupt the entire SC (Butt, 2021b). The bullwhip effect occurs due to the increasing order variability as one moves upstream in the SC from retailer to manufacturer (Sucky, 2009). Although consumer sales indicate a relatively constant demand, the demand/order placed by the retailer to a wholesaler is greater than the actual demand seen by that retailer. The order placed by the wholesaler to the manufacturer and the order from the manufacturer to the supplier vary even more (Meiryani et al., 2022; Paik & Bagchi, 2007).

According to Sucky (2009), the bullwhip effect usually results in excessive inventory investments throughout the SC which causes significant inefficiencies as the participants involved must hedge against demand variations.

Figure 2 demonstrates the variation in orders at each phase of the SC.

Fig. 2

The bullwhip effect.

Source: Paik and Bagchi (2007)

Conceptual Framework

Covid-19 and Supply Chain Disruption

Epidemics represent a particular phenomenon of SC risks due to their long-term nature, high risk and ripple effects propagation (Ivanov & Dolgui, 2020). Over time, the likelihood of supply disruptions leads to a growing interest in researching the impact of epidemics on SCs, highlighting the magnitude of their threats to business continuity (Baz & Ruel, 2021; Guan et al., 2020; Natarajarathinam et al. 2009; Udofia et al., 2021).

Recently, the Covid-19 outbreak has disrupted the availability of many global SCs, affected the world economy and crippled many industries (Araz et al., 2020). It is apparent that this pandemic is an unseen event compared to other types of SC disruptions, and therefore, its impact on SC is considerably greater than anything witnessed in the past (Butt, 2021a). According to Walmart, several sectors and categories, such as disinfectant, toilet paper, and hair-colorant have experienced massive panic buying due to the coronavirus (Wallace, 2020). World’s 1,000 biggest corporations had more than 12,000 facilities, stores and operations in quarantine zones as of early March 2020 (Remko, 2020). Many UK retailers’ websites have collapsed due to the overflow of online shopping (Shaw, 2020). On eBay, a bundle of 20 facemasks was sold for more than $100 (Lufkin, 2020).

As for the production and services, Covid-19 impacts have prompted drastic measures such as the trade barriers enforcement and export restrictions which harmed worldwide merchandise trade (UNs, 2020; WTO, 2020). Containment measures taken and enforced by numerous governments worldwide as part of a health strategy to curb the spread of the virus have disrupted the production plants' operations (Butt, 2021b; Ivanov, 2020). Some industries such as tourism and aviation were the most affected ones due to lockdowns and reduced public movements (Moosavi et al., 2022; Obayelu et al., 2021).

According to Handfield et al., (2020), Covid-19 impacted the SC materials flow both upstream and downstream. They also added that this pandemic has caused a bullwhip effect in the manufacturing industry on an unseen magnitude. Ivanov (2020) considers this disaster to be the worst in the last decade as it has dismantled global SCs. Furthermore, research has revealed that Covid-19 is a catalyst for companies to have short-term initiatives to address or lessen upcoming challenges and to reevaluate their existing SC strategies (Handfield et al., 2020; Mollenkopf et al., 2021).

Supply and Demand Disruptions During Covid-19

On the supply side, Covid-19 impact is primarily mirrored in economic terms of tradeable sections, people and workforce (Butt, 2021b; Handfield et al., 2020). For example, Rio-Chanona et al., (2020) argued that the amount of labor that is withdrawn due to social distancing, travel restrictions, self-isolation measures, illness or mortality are likely to be the main challenges impacting on countries' supply capacity. Similarly, Lemieux et al., (2020) examined the early effects of Covid-19 on the Canadian labor market. Their analyses found that Covid-19 caused a 32% decline in total weekly working hours along with a 15% rise in unemployment—the majority of which are public facing-jobs.

On the demand side, the most significant Covid-19 impact was the sharp increase in global demand and stockpiling of medical supplies, causing unexpected demand shocks and stockouts (Friday et al., 2021; Hasan & Shahbaz, 2021). Additionally, increased export restrictions imposed by some countries experiencing shortages have also led to higher prices. Butt (2021b) highlighted that the pandemic may impact through numerous transmission channels on the demand-side, for instance reduced household expenditure with rising business uncertainty about future demand. McKibbin and Fernando (2020) observed a decline in aggregate consumer demand, especially a consumption pattern distortion and consequent market anomalies due to panic buying and customers' preferences shift. Coibion et al., (2020) investigated the determinant effects of lockdowns on consumer spending and employment. They found that they have an adverse impact. Finally, Chronopoulos et al. (2020) explored the evolution of household spending in the UK. They found that discretionary consumption has fallen. Based on the above argument, we develop the following hypothesis:

H1

Manufacturers make optimal SCRM decisions to handle demand and supply disruptions caused by the Covid-19 outbreak.

The Semiconductor Industry and Its Supply Chains

The demand for semiconductors has grown rapidly over the last twenty years due to the ongoing development of new applications for integrated circuits (ICs) (Mönch et al., 2018). Semiconductors allow the functioning of most electronic devices. They are an integral part of all computers, video game consoles, smartphones and associated processors etc. (Kempf et al., 2021). Moreover, big data analytics, technological developments such as 5G, the Fourth Industrial Revolution and artificial intelligence are generating a growing demand for semiconductors (Chang & Wu, 2021). According to the Semiconductor Industry Associate

(SIA) (2021), chip sales are expanding dynamically and are forecast to increase by 8.8% in 2022 globally.

The semiconductor SCs are directly influenced by their products and manufacturing processes (Mönch et al., 2018). Firstly, it demands high-quality capabilities from its suppliers to meet the international industry standards (ISO 9000 certification) (Briscoe et al., 2004). Secondly, semiconductor firms are particularly exposed to the bullwhip effect as they are located well upstream in the overall SC (de Kok et al., 2005; Hasan et al., 2022; Mönch et al., 2018). Thirdly, the industry has undergone substantial value chain challenges with the requirement for technical specialisation, skilled engineers, heavy capital expenditures and a rapid pace of development (Hickey & Kozlovski, 2020). Fourthly, many semiconductor organisations nowadays operate globally seeking low-cost production sites, government support and tax benefits etc., which increase their SCs complexity (Mönch et al., 2018). Fifthly, semiconductor SC is threatened by geopolitical factors between the US and China due to the struggle for technological dominance which limits the flow of materials (Crawford et al., 2020; Hasan et al., 2021). Finally, their demand cycles are relatively volatile due to the misconception about the industry regularly delivering original, advanced and cheaper microchips. This has led to a shortening product life cycle and increased fragmentation of the SC (Macher et al., 2002). Therefore, this can already result in delays and disruptions for upstream producers.

The Semiconductor Industry and Covid-19

KPMG (2020) study demonstrated that many global semiconductor firms have been experiencing SC bottlenecks which impact their sales and financial performance. Likewise, the Financial Times (2021) reported that due to strict lockdowns and increase in Coronavirus cases, numerous Asian semiconductor factories and their SCs have been affected, resulting in global chip shortages. That said, the world's semiconductor producers are largely dependent on the Asian producers (specifically Japan, Taiwan and China) for their cheap materials (Deloitte, 2020b). Therefore, whenever the Asian production is disrupted, global manufacturing SCs are severely affected.

Despite the impact on the SC, global semiconductor revenue reached USD 442 billion in 2020, up 5.4% from 2019 (International Data Corporation, 2021). The pandemic has driven the demand for healthcare items such as ventilators to treat critically ill-patients (SIA). Afterwards, the second burst occurred when people rushed to buy PCs, monitors and other devices to work or study remotely. This trend was followed by an increased demand for consumer electronics such as gaming devices, TVs and smartphones etc. Another notable fact is the significant change in demand for key semiconductor components which continue to outstrip supply. For example, Samsung indicated that there is actually a severe imbalance between demand and supply which affects the TV and home-appliances productions (Shed, 2021). Volkswagen stated that they are facing microchip shortages due to the chip-suppliers reserving their supplies for tech-companies producing tablets, smartphones and gaming devices (Keohane, 2021). In fact, production is higher than demand to match supply and demand (Sparkes, 2021).

Organisational Productivity

Organisational productivity represents the efficiency with which resources are transformed into finished goods (Kopelman et al., 1990) and without which organisational objectives are not feasible to achieve (Ali et al., 2011). The manufacturing assembly of products is an essential component of the SC, and it must be closely monitored and continuously improved. Slack et al., (1995) stated that among the various characteristics of production performance, capacity utilisation primarily affects the speed of response to customer demand such as its impact on flexibility, lead time and delivery capability. According to Gunasekaran et al. (2004), scheduling is critical to production performance. It represents the time/date at which operations are to be conducted. This alignment defines how resources flow through an operating system and how its efficiency has a major impact on SC performance. Since scheduling is highly dependent on customer demands, scheduling techniques must be considered within this context. Rushton and Oxley (1989) asserted that the focal point of an SC has an immediate effect on the delivery of the products & services to the customers. It is a key factor in customer satisfaction. Delivery, by its nature, occurs in a dynamic environment. This makes it difficult to predict as to how changes in any key element of the distribution structure will impact the overall system. Based on the above argument, we develop the following hypothesis:

H2

Demand and supply disruptions have a negative impact on Excelsior's productivity during Covid-19.

Organisational Performance

With the advancement of SC management (SCM) and the increased demand for quality, timely delivery, measuring organisational performance has become a necessary concern (Beamon, 1999). Organisational performance relates to the way in which a company achieves its market and financial objectives (Yamin et al., 1999). The short-term goal of SCM is mainly to enhance productivity, diminish inventory and cycle-time while the long-term goal is to have a strong cash-flow, gain market share and revenues (Simon et al., 2015; Tan et al., 1998). Financial metrics are used to evaluate and compare organisations in terms of profitability, financial stability, growth and organisation's behaviour over time (Holmberg, 2000). Hence, any organisational approach including SCM aims to improve organisation's performance.

Some previous studies have used a mixture of financial and non-financial indicators to measure organisational performance and to assess SC performance. For example, some studies have considered ROI and ROE as financial indicators (Galankashi & Rafiei, 2021). Wu et al. (2006) used ROI and cash-flow from profitability and operations to measure SC performance. Li et al. (2006) assessed companies' performance and SC by four types of achievements, i.e. ROI, profit margin, sales and growth of market share. On the other hand, a range of non-financial indicators have been identified in SCM research such as customer satisfaction/retention, product/service quality, lead-time, accuracy, flexibility, responsiveness, innovation, partnership and quality etc. (Gawankar et al., 2020; Gunasekaran et al., 2004; Tangen, 2004). In view of the above literature, Table Table11 illustrates the financial and non-financial measures used in this study. Based on the above argument, we develop the following hypothesis:

Table 1

Financial and non-financial measures on organisational performance

Financial indicators	**Non-financial indicators**
Profit margin (PM)	Product quality
Return on assets (ROA)	Customer satisfaction

Financial indicators	Non-financial indicators
Return on equity (ROE)	Market share

H3

Demand and supply disruptions have a negative impact on Excelsior's (a pseudonym) of non-financial and financial performance during Covid-19.

Methodology

Sample and Data Collection

In this research, as the Excelsior SC department is selected, it yields a homogenous sample. Access is given to two sites in Belgium and Germany. The sample participants are assumed to have experience in SCM and the research problem knowledge. As here we use two different countries' data, it makes this research more comparable.

As this research is designed to collect information related to the experience and perceptions of SC risk over the Covid-19 course, a survey is the best method for data collection. Houser (2008) describes surveys to be among the most effective and commonly used techniques for capturing primary data. A survey questionnaire via Google form is chosen not to interfere with employees' work; to avoid any physical contact and to increase the data accuracy amid the limited research conduct time.

To administer the survey, all names are provided by the HR department. An email is sent to 26 participants at their office email address with complete information about the purpose and objectives of the study. The mailings and two reminders generated 24 responses with the response rate of about 92.3%.

Regarding the length of service at the company, a period of service of > 10 years constitutes 12.5% of all employees surveyed, followed by 6–10 years (20.8%), 3–5 years (41.7%) and 2–5 years comprising the remaining 25%.

In terms of job position, most respondents are in operations management (45.8%), with the next positions including logistic/SCM (29.2%), sales/distribution/service (8.3%), senior positions (12.5%) and not reported (4.2%). A detailed breakdown is shown in Fig. 3.

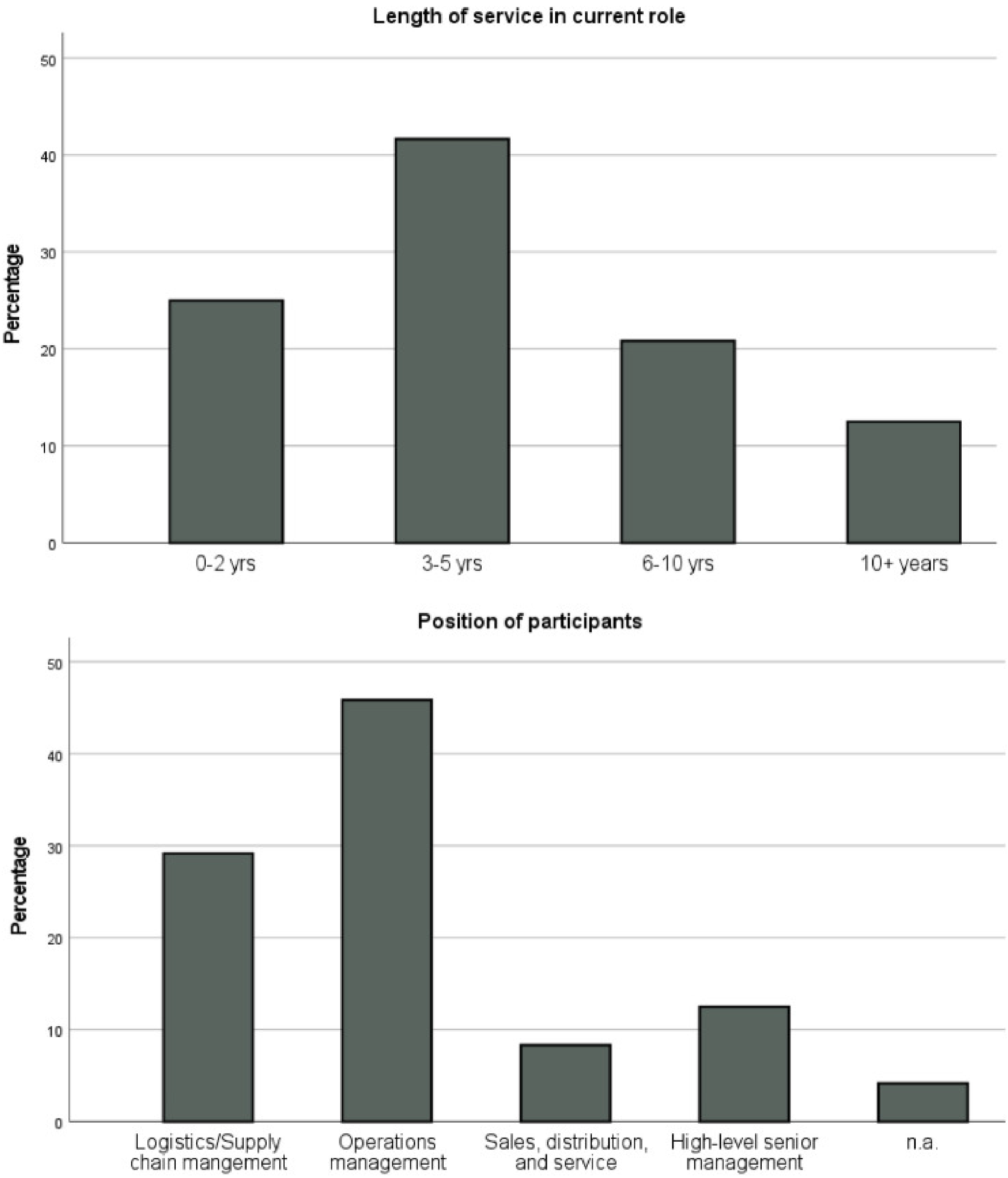

Fig. 3

Descriptive statistics of the participants.

Source: Primary data

As for the second part of the first RQ, quarterly figures (i.e. [Q3, Q4 year 2018, Q1–Q4 year 2019—pre-Covid-19] and [Q1–Q4 year 2020, Q1, Q2 year 2021—during Covid-19] of Excelsior's balance sheets and income statements are collected from their website to calculate financial ratios which are used to compare the company's performance before and during Covid-19 pandemic.

Survey Questionnaire Development & Structure

A multi-stage process is undertaken to develop and validate the questionnaire. Initially, an in-depth examination of operations and SCRM literature is conducted to determine relevant concepts, operation definitions, and survey measurement metrics. Approved measures from previous surveys are adjusted to match our investigation for demand and supply disruption during the pandemic.

The demand risk measure captures the risk arising from changes in customer demand and market volatility during Covid-19 (Chen et al., 2013; Ho et al., 2015; Parast & Subramanian, 2021; Wagner & Bode, 2008). Similarly, SC risk encompasses risk from Covid-19 and its upstream SC actors such as the suppliers' performance (Chen et al., 2013; Ho et al., 2015; Parast & Subramanian, 2021; Wagner & Bode, 2008). Organisational productivity measures are taken from Udofia et al. (2020). Finally, organisational non-financial and financial performance measures are taken from (Chen, 2018; Simon et al., 2014). Table Table22 lists the constructs, their details, and sources.

Table 2

Constructs, details and sources

Construct	Details	Sources
Supply disruption	Measured on four elements based on the upstream side of the company's SC, including activities such as purchasing and supplier quality	Wagner and Bode (2008) Chen et al. (2013) Ho et al. (2015) Parast and Subramanian (2021)
Demand disruption	Measured on four elements that assess internal risks associated with changing demand, market uncertainty, mismatch between actual and projected demand and bullwhip effect	Wagner and Bode (2008) Chen et al. (2013) Ho et al. (2015) Parast and Subramanian (2021)
Firm productivity	Assessed by production delays, change in technology employed and production capacity	Udofia et al. (2021)

Construct	Details	Sources
Firm performance	Measured by product quality, overall competitive position, customer satisfaction, PM, ROA, ROE (non-financial and financial performance)	Simon et al. (2014) Chen (2018)

As illustrated in appendices 2–3, the questionnaire comprises a consent form and multiple-choice questions. According to Vinten (1995), this type of interrogation requires participants' minimum time and effort. The initial questionnaire is in English and is translated into German for Germany. It is felt that respondents are more likely to respond if it was written in their own language. A five-point Likert scale, ranging from strongly disagree (represented by value '1') to strongly agree (represented by value '5') is found suitable as it is a common format for evaluating respondents' opinions in terms of degree of agreement with positive and negative items (Wang et al., 2015).

The questionnaire is divided into three parts with definitions to guide participants. Part 1 explores the sources of disruption during Covid-19. Part 2 investigates the relationship between disruption sources and performance outcomes whereas part 3 profiles the overall SC employees.

Measurements

Non-financial Performance

Respondents' answers to SC disruptions are used as the unit of analysis. Eight measurement items, along with demand and supply disruptions are treated as independent variables. Six measurement items, firm productivity and performance are addressed as dependent variables.

Financial Performance

The profit margin (PM), ROA, ROE are used to evaluate Excelsior's financial performance. The grounds are simple: PM reflects the entire operational performance of a company (Salancik & Pfeffer, 1980), ROA measures how effectively a company's management produces revenue from its assets/resources (Mahajan & Singh, 2013) and lastly ROE indicates the efficiency with which businesses generate income from shareholders' capital (Lau & Sholihin, 2005). The following formulas are used to calculate PM, ROA, ROE:

Profitmargin=NetIncomeSales

1

Returnonassets=NetIncomeTotalAssets

2

Returnonequity=NetIncomeShareholders'equity

3

Findings and Discussions

Non-financial Performance

Scale Reliability and Validity

Prior to data analysis, the questionnaire is tested for its reliability and validity. Reliability is an estimate of the level of consistency between various measures of a variable. Validity is a major characteristic that reflects the degree of reliability of measurements (Wang et al., 2015). Content, convergent and discriminant validity are also examined.

With respect to content validity, it is assumed that each of the concepts is precisely articulated and has a clear meaning (Yan et al., 2014). Convergent validity determines the level of correlation between two measures of the same construct. A correlation of > 0.7 is required for convergent validity. Conversely, discriminant validity is the level at which two similar concepts are different (Hair, 2010).

The measurement model is presented in Table Table3.3. It includes the factor loadings, average variance extracted (AVE) and composite reliabilities (CRs) of each construct (Appendix 5 describes the calculations). One factor loading ($Fper_3$) is < 0.5 and therefore, it is removed. All AVE values are above the minimum, i.e. 0.40 (Namagembe et al., 2019), with values ranging from 0.4703 to 0.6879 which support the discriminant validity (Parast & Subramanian, 2021). The CRs range between 0.6353 and 0.8686 which supports convergent validity (Parast & Subramanian, 2021). Therefore, based on these results, there is a strong level of reliability. So, we can tell that our first hypothesis is true.

Table 3

Constructs in the SCR non-financial model

Variables	**Indicators**	**Factor loading**	**Composite reliability**	**Average variance extracted**
Demand disruption	DR_1	0.7232	0.8269	0.5472
	DR_2	0.6157		
	DR_3	0.8414		

Variables	Indicators	Factor loading	Composite reliability	Average variance extracted
Supply disruption	DR_4	0.7607	0.8268	0.5518
	SR_1	0.6431		
	SR_2	0.5676		
	SR_3	0.8788		
	SR_4	0.8362		
Firm productivity	$Fpro_1$	0.8229	0.8686	0.6879
	$Fpro_2$	0.8525		
	$Fpro_3$	0.8123		
Firm performance	$Fper_1$	0.5843	0.6353	0.4703
	$Fper_2$	0.7741		
	$Fper_3$	–		

Source: Primary data

Descriptive Statistics

The means, standard deviations, skewness and kurtosis are presented in Table Table44.

Table 4

Descriptive statistics (non-financial performance)

Variables	**Min. statistic**	**Max. statistic**	**Mean**	**SD**	**Skewness statistic**	**SE**	**Kurtosis statistic**	**SE**
Demand risk	3.75	5.00	4.4792	0.4418	− 0.275	0.472	− 1.430	0.918
Supply risk	2.75	5.00	4.2188	0.6355	− 0.679	0.472	− 0.199	0.918
Firm productivity	2.33	4.33	3.2639	0.6058	0.148	0.472	− 0.822	0.918
Firm performance	1.00	3.00	1.9583	0.6064	0.491	0.472	− 0.545	0.918

Source: Primary data (SPSS version 27)

With a mean of 4.4792 and a low standard deviation of 0.4418, it is indicated that Excelsior experiences a very high demand disruption. Similarly, Excelsior experiences a very high supply disruption with a mean of 4.2188 and a low standard deviation of 0.6355. With a mean of 3.2639, Excelsior faces a moderate impact on its productivity with respect to demand and supply disruption. Finally, there is a low impact on the company's non-financial performance with a mean of 1.9583 and standard deviation of 0.6064.

The data are normally distributed with skewness values < 2, ranging from − 0.679 to 0.491, and kurtosis values < 7, ranging from − 0.199 to − 1.430. According to Namagembe and et al., (2019), the absolute value of univariate skewness must be < 2 and that of univariate kurtosis be < 7, to denote the existence of a normal distribution.

Pearson's Correlation Analysis

Correlation analysis is essentially applied to measure the strength of relationships between variables (Lin, 2021). Presented in Table Table5,5, the Pearson's correlation coefficient is used to assess whether the correlation between the variables was statistically significant using the *p*-value. If its value is small (i.e. $p < 0.01$), it indicates that there is a statistically significant relationship between the variables presented (Kaawaase et al., 2021). Results indicate a significant and positive relationship between demand and supply disruptions ($r=0.520, p<0.01$). However, both demand and supply disruptions are not significantly associated with firm productivity ($r=0.238, p>0.01$ and $r=0.201, p>0.01$). Furthermore, there is a non-significant negative correlation between demand risk and firm's non-financial performance ($r=-0.227, p>0.01$) whereas supply disruptions are insignificantly associated with the firm's non-financial performance ($r=0.067, p>0.01$).

Table 5

Pearson's correlation analysis (primary data)

Variables	**Demand disruptions**	**Supply disruptions**	**Firm productivity**	**Firm performance**
Demand disruptions	1.000			

Variables	Demand disruptions	Supply disruptions	Firm productivity	Firm performance
Supply disruptions	0.520[a]	1.000		
Firm productivity	0.238	0.201	1.000	
Firm performance	− 0.227	0.067	0.406[b]	1.000

[a]Correlation is significant at the 0.01 level (2-tailed)

[b]Correlation is significant at the 0.05 level (2-tailed). (SPSS version 27)

Regression Analysis

Regression analysis is an effective statistical technique for examining the relationship between variables (Gray, 2002). This research uses a simple linear regression analysis. The formula below is utilised to demonstrate the linear relationship between the variables:

$$y=\propto+\beta*x+\mu$$

4

where *y* and *x* represent the values of dependent and independent variables, respectively, *α* represents the intercept, *β* denotes the slope of the regression line and *μ* is the residual error term (Ambrosius, 2007).

Table Table66 summarises the results of the linear regression analysis. The beta coefficient between demand disruption and firm productivity is equal to 0.238 (a moderate positive correlation) and firm performance is equal to − 0.227 (a negative correlation). The low R^2 values of 0.057 and 0.051 state that demand disruptions account for 5.7% and 5.1%, respectively, of total variance in firm's productivity and non-financial performance. The *F*-statistic is an assessment of how well the regression has optimised the prediction of the outcome relative to the accuracy level of the model (Field, 2005). With values of 1.321 and 1.190, it indicates that the findings are not robust. The *p*-values are equal to 0.263 and 0.287 which are greater than all significant levels i.e. 1%, 5% and 10%. Therefore, demand disruptions have no significant impact on Excelsior's productivity and non-financial performance.

Table 6

Regression analysis (primary data)

Regression weights	**Beta coefficient**	R^2	**Adjusted** R^2	*F*	***p*-value**
DR → Firm pro	0.238	0.057	0.014	1.321	0.263
DR → Firm per	− 0.227	0.051	0.008	1.190	0.287
SR → Firm pro	0.201	0.040	− 0.003	0.928	0.346
SR → Firm per	0.067	0.004	− 0.041	0.099	0.756

Source: Primary data (SPSS version 27)

According to Table Table7,7, there is a low beta coefficient of 0.201 between supply disruptions and firm productivity. The beta coefficient of 0.067 between supply disruptions and non-financial performance indicates a weak relationship. The low R^2 values of 0.040 and 0.004 explain that supply disruptions account for 4% and 0.4% of the total variance in firm productivity and non-financial performance. Finally, the *F*-statistic is equal to 0.928 and 0.099. The *p*-values are equal to 0.346 and 0.756 which are greater than all significant levels. It demonstrates that there is a statistically insignificant relationship between supply disruptions and Excelsior's productivity and non-financial performance. Based on these results we can accept our hypothesis three (H3).

Table 7

Descriptive statistics (financial performance)

	N	**Mean**	**SD**	**% increase**
PM_before Covid-19	6	15.02	4.1109	
PM_during Covid-19	6	15.35	4.0489	2.12
ROA_before Covid-19	6	4.57	1.7261	
ROA_during Covid-19	6	4.81	1.8379	5.00
ROE_before Covid-19	6	6.00	2.0946	
ROE_during Covid-19	6	6.30	2.2645	4.83

Source: Secondary data (Figures extracted from Excelsior's financial reports. Quarterly figures 2018–2021)

Financial Performance

Descriptive Statistics

The descriptive analysis results in Table Table88 indicate that there is an increase-trend in average PM, ROA and ROE at Excelsior during Covid-19 opposed to pre-pandemic time. The average percentage increase is 2.12%, 5.00%, 4.83%, respectively, which indicates that Excelsior experiences an amelioration in its financial performance. Based on these results, we can accept our second hypothesis (H2).

Table 8

The paired samples *T*-test of PM, ROA and ROE samples

Paired samples test								
	Paired differences							
	Mean	**SD**	**SE mean**	**95% confidence interval of the difference**		***t***	***df***	**Sig. (2-tailed)**
				Lower	**Upper**			
PM_before Covid- 19 PM_during Covid-19	− 0.32667	7.20291	2.94057	− 7.88565	7.23232	− 0.111	5	0.916
ROA_before Covid-19	− 0.24167	3.09042	1.26166	− 3.48486	3.00153	− 0.192	5	0.856

Paired samples test

	Paired differences							
	Mean	**SD**	**SE mean**	**95% confidence interval of the difference**		***t***	***df***	**Sig. (2-tailed)**
				Lower	**Upper**			
ROA_during Covid-19								
ROE_before Covid-19 ROE_during Covid-19	− 0.30333	3.69970	1.51039	− 4.18593	3.57926	− 0.201	5	0.849

Source: Secondary data (Figures extracted from Excelsior financial reports. Quarterly figures 2018–2021). (SPSS version 27)

Paired Samples t-Test

A normality test is first performed before running the test. As shown in Appendix 6, the scores show that all constructs meet the requirements of normality. The results from the paired samples *t*-test in Table Table88 show that there is no significant difference in the overall financial performance of Excelsior between pre-Covid-19 and during-Covid-19 as all *p*-values are equal to 0.916, 0.856, 0.849 ($p > 0.05$).

Theoretical Contributions

This study analyses the impact of SC disruptions on firm productivity, non-financial and financial performance caused by Covid-19. This research contributes to literature in three essential aspects.

Firstly, by mapping different types of disruptions in the literature review, the 24 participants from Excelsior's SC department provide evidence of the multiple forces' presence during the pandemic. This in-depth examination validates the typical retrospective descriptions of disruptions such as the bullwhip effect (Forrester, 1958). This paper empirically also tests the conceptual model of SC disruptions developed by Christopher and Peck (2004). So as far as disruptions are concerned, Excelsior's operating environment is uncertain and evolving.

Secondly in answering to the H1, this research provides empirical evidence that there is no profound/significant impact between SC disruptions and firm non-financial performance. These results are contrary to our expectations for two reasons– the general insight in the reviewed literature and worldwide scale of SC disruptions due to the pandemic. As it was presumed that the majority of the global semiconductor industry's SC did not withstand Covid-19, many existing suppliers are unable to respond to the high demand (Accenture, 2020). Our findings need to be contrasted with the conclusions of Parast and Subramanian (2021). They showed that both demand and supply risks have an extreme impact on firm performance. However, this contradiction may appear due to the different sample, distinct country, and the number of respondents.

Thirdly in answering to the H2, the results provide empirical evidence that there is no impact of SC disruptions on Excelsior productivity. These conclusions are conflicting with the extant literature (Butt, 2021b; Udofia et al., 2020). However, four explanations are possible (1) there is a perception gap between how academics and practitioners think SCR affects firm productivity vs how SCR variables really affect firm productivity. The constructs retained for firm productivity are expected to be experienced by Excelsior during Covid-19. Therefore, this judgment may have resulted in an insignificant impact on the company's productivity.

(2) Excelsior is engaged in agile production. Studies have shown that organisations during this pandemic crisis have dealt with these disruptions by adopting agile manufacturing. For instance, Butt (2021b) demonstrated that companies have prioritised some production when they expected a shortage of direct materials and inventories. (3) Excelsior may have focused on tier 1 supplier risk and get visibility on their inventory, production process and fulfillment status. Prior studies confirmed that businesses have identified their first-tier suppliers to battle Covid-19 (Butt, 2021b).

(4) the impacts of Covid-19 on production and value chains have differed greatly across products and countries. The contextual settings in developed countries such as Germany and Belgium may not fully affect production. Production is highly automated, with inherent social distancing and institutional stability which may not require changes in some production practices (Swinnen & Vos, 2021). These benefits could have had little impact on Excelsior's productivity.

Nevertheless, additional research needs to be conducted to shed light on the unexpected results regarding SC disruptions risk on firm productivity, non-financial and financial performance.

Practical Implications for Managers

Results from the present study show that demand and supply disruptions are highly prevalent in times of crisis. Therefore, it is critical that SC managers prepare themselves and implement key strategies for a prosperous post-Covid-19 world. To answer RQ3, some insights for manufacturing companies are proposed in a bid to address SC disruption risks.

Firstly, SC managers can foster agility by accumulating resources that act as 'shock buffers', i.e. inflating inventory, having flexible production methods, locating secondary suppliers and having a product design (Bode et al., 2011). Accordingly, Butt (2021b) shows that during Covid-19, managers of buying companies closely monitor their suppliers' functions i.e. their production schedules, inventory positions and shipment status in order to forecast any sudden supplier shortfalls. However, taking such proactive measures require high upfront investments.

Secondly, SC collaboration with internal and external partners reduces SC risk (Chen et al., 2013). Collaboration and information sharing across the SC enables SC partners to share knowledge about plans, needs and progress, thereby, improving SC performance and minimising uncertainty. Milliken (1987) argues that uncertainty arises from a lack of adequate information to predict precisely. Consequently, with accurate visibility into upstream and downstream movements, SC managers would be confident about order cycle times, demand forecasts, suppliers' ability to deliver etc. Thus, investing in visibility are sound agility strategies that avoid double guessing and provide businesses with resources to respond to SC disruptions (Gunessee & Subramanian, 2020).

Thirdly, for unforeseen turbulence, leveraging technology and extensive data mining, such as artificial intelligence, internet of things, blockchains, machine learning, control system, automated production, 3D printing etc. are significant in this pandemic (Sharma et al., 2020).

Studies show that enterprises with more advanced digital capabilities are quicker to overcome SC disruptions during Covid-19 (Sajjad, 2021). Moreover, Cai and Luo (2020) demonstrate that these technologies assist in the production of high-demand products, speed up the delivery system and recalibrate and optimise SC planning during the pandemic. Thus, SC managers can better capture high-quality data along the value chain, increase SC visibility and take necessary corrective actions based on early warning signals.

Covid-19 has undoubtedly brought attention to the circular economy which leads to resilience (Khan et al., 2021; Nandi et al., 2021). It focuses on the efficient use of resources and reduction of waste throughout the entire value chain. In times of high uncertainty, resources are precious and need to be used efficiently by integrating the 'reduce-redesign-reuse' approach.

Fourthly, to get through a crisis, a more effective strategy is required to leverage existing relationships to stabilise the effect of the shock (Runfola et al., 2021). Companies need to know the production recovery status of other SC partners and assist them as it can be costly and difficult to replace them. Therefore, offering financial and non-financial incentives can contribute to a smooth SC recovery (Cai & Luo, 2020).

Fifthly, firms need to have a transition from their traditional linear SC approach by adopting a more modern and holistic system such as the digital supply network (DSN) (Kilpatrick & Barter, 2020). DSN offers suppliers, producers and customers to work collaboratively through a dynamic data-sharing platform powered by real-time data (Sajjad, 2021). This empowers businesses to optimally align and connect with their SC network partners which subsequently enhance a firm's agility and overall competitiveness.

Conclusion

SC disruptions caused by Covid-19 crisis highlight that pandemics have destructive effects on both demand and supply. This research presents an analysis of the impact of SC disruptions on firm productivity, financial and non-financial performance during Covid-19, in a semiconductor company. The results indicate that SC disruption risk does not necessarily have a significant impact on business performance outcomes. Moreover, the results have fueled the growth of SCRM literature. The 'Triple-A' mitigation measures are proposed namely, Agility, Adaptability and Alignment. They cover the importance of flexibility, collaboration with all SC partners, SCs digitalisation & localisation and adoption of a 'reduce-redesign-reuse' approach.

Limitations and Future Research Avenues

This research has some limitations. Firstly, the data are collected from branches based in Germany and Belgium. Therefore, the results can be verified in countries with comparable political, economic and geographical environments. This research offers the possibility to replicate it in other non-European countries with different economic and political contexts in order to ameliorate the external visibility of the results.

Secondly, the data are obtained from a rather small sample size of 24 participants and in a single semiconductor company. Accordingly, generalisation of these results to a larger population should be done with care. Our results should be tested with various semiconductor manufacturers with the involvement of more participants.

Thirdly, in measuring Excelsior's financial performance during Covid-19 period, the lack of observations made it challenging to gain a thorough understanding of its actual impact. Future research involving longitudinal data could assist in addressing this limitation.

Fourthly, this paper considers three financial measures, namely PM, ROA and ROE to assess the impact of SC disruptions on firm financial performance. However, they do not fully represent the overall picture of Excelsior's financial performance. Other financial indicators like working capital or operating cash flow can be used for future research to understand whether businesses have rushed towards cash and liquidity to maintain operations.

Finally, due to the uniqueness of Covid-19 and its impact on global SCs, it would have been more valuable to evaluate the effect of Covid-19 using a mixed-methods methodology. It is felt that the use of both interviews and surveys would have resulted in deeper insights and richer data.

Key Questions

1. Manufacturers make optimal SCRM decisions to handle demand and supply disruptions caused by the Covid-19 outbreak.
2. Demand and supply disruptions have a negative impact on Excelsior's productivity during Covid-19.
3. Demand and supply disruptions have a negative impact on Excelsior's (a pseudonym) of non-financial and financial performance during Covid-19.

Appendix 1. Factor Loadings, Average Variance Extracted and Composite Reliabilities

The steps to calculate the average variance extracted and composite reliabilities using SPSS version 27 are demonstrated below:

Step 1: I computed the factor loadings first.

- analyse→dimensionreduction→factor→movethevariablestotherightrotation→varimax→continue→options→suppresssmallcoefficients→absolutevaluebelow0.5→continue→ok

Rotated Component Matrix[a]

	Component				
	1	2	3	4	5
DR1	0.7232				
DR2		0.6157			
DR3		0.8414			
DR4		0.7607			
SR1	0.6431				
SR2				0.5676	
SR3	0.8788				
SR4	0.8362				
Fpro1					0.8229
Fpro2			0.8525		
Fpro3				0.8123	
FPer1				0.5843	
Fper2			0.7741		
Fper3					**-0.741**

Step 2: Copy the table to an excel sheet.

- Insert the factor loading as λ
- Calculate the $\boldsymbol{\lambda}^2$ (e.g. DR 0.7232^2 = 0.5231)
- To calculate the $\boldsymbol{\varepsilon} = \mathbf{1} - \boldsymbol{\lambda}^2$. (e.g. 1 – 0.5231 = 0.4769)
- Calculate the sum of $\boldsymbol{\lambda}$, $\boldsymbol{\lambda}^2$, $\boldsymbol{\varepsilon}$
- N represents the number of factor loadings (number of observations)

- To calculate the average variance extracted is equal to the sum of $\boldsymbol{\lambda^2/N}$ (e.g. = 2.1889/4 = 0.5472)

- To calculate the composite reliabilities is equal to sum $\boldsymbol{\lambda}$^2/($\boldsymbol{\lambda}$^2 + $\boldsymbol{\varepsilon}$) (e.g. = 2.941^2/(2.941^2 + 1.1811)

Variables	Factor loading λ	λ^2	ε
Demand disruption	0.7232	0.5231	0.4769
	0.6157	0.3791	0.6209
	0.8414	0.7080	0.2920
	0.7607	0.5787	0.4213
Sum	2.941	2.1889	1.8111

N	4
Average variance extracted	0.5472
Composite reliability	0.8269

Variables	Factor loading λ	λ^2	ε
Supply disruption	0.6431	0.4135	0.5865
	0.5676	0.3222	0.6778
	0.8788	0.7723	0.2277
	0.8362	0.6992	0.3008
Sum	2.9257	2.2072	1.7928

N	4
Average variance extracted	0.5518
Composite reliability	0.8268

Variables	Factor loading λ	λ^2	ε
Firm productivity	0.8229	0.6771	0.3229
	0.8525	0.7268	0.2732
	0.8123	0.6598	0.3402
Sum	2.4877	2.0637	0.9363

N	3
Average variance extracted	0.6879
Composite reliability	0.8686

Variables	Factor loading λ	λ^2	ε
Firm performance	0.5843	0.3414	0.6586
	0.7741	0.5992	0.4008
Sum	1.3584	0.9406	1.0594

N	2
Average variance extracted	0.4703
Composite reliability	0.6353

Appendix 2. Descriptive Statistics (Financial Performance)

Variables	Min. statistic	Max. statistic	Mean	SD	Skewness statistic	SE	Kurtosis statistic	SE
PM_Before	11.97	20.52	15.0200	4.11094	0.942	0.845	− 1.850	1.741
PM_During	9.64	21.06	15.3467	4.04894	− 0.056	0.845	− 0.373	1.741
ROA_Before	3.22	6.92	4.5683	1.72612	0.944	0.845	− 1.810	1.741
ROA_During	2.18	7.20	4.8100	1.83786	− 0.296	0.845	− 0.844	1.741
ROE_Before	4.10	8.73	6.0033	2.09458	0.850	0.845	− 1.850	1.741
ROE_During	2.94	9.03	6.3067	2.26449	− 0.565	0.845	− 0.845	1.741

Source: Secondary data (SPSS version 27).

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