



How did COVID-19 affect logistics and supply chain processes? Immediate, short and medium-term evidence from some industrial fields of Italy

Marta Rinaldi^a, Eleonora Bottani^{b,*}

^a Department of Engineering, University of Campania "Luigi Vanvitelli", via Roma 29, 81031, Aversa, Italy

^b Department of Engineering and Architecture, University of Parma, viale delle Scienze 181/A, 43124, Parma, Italy

ARTICLE INFO

Keywords:

Covid-19
Logistics
Empirical study
Questionnaire survey
Italy
Cross-sectorial study

ABSTRACT

This paper provides empirical evidence on the impact of the Covid-19 pandemic on logistics and supply chain processes of five industrial sectors of Italy, namely food & beverage, machine manufacturing, metal mechanical industry, logistics & transport, and textile & fashion. A questionnaire survey, with 82 useful responses, was conducted to investigate various effects of Covid-19 on these businesses, such as the volumes handled and the service performance in the immediate-, short- and medium-term, the countermeasures implemented by companies and the future decision-making strategies. The period of analysis spans from January 2020 to June 2021. Results show that the impact of Covid-19 on volumes and service performance varied across the sectors: the food & beverage and logistics & transport were poorly affected by the pandemic and experienced a general increase in the demand and volumes, while mechanical or textile & fashion industries were mostly affected by a decrease in demand. The positive/negative impacts were particularly evident at the beginning of the pandemics, but, depending on the sector, the effects could cease quite quickly or last in the short-term. The countermeasures adopted against the Covid-19 emergency differ again across sectors; in general, industry fields that were particularly impacted by the pandemic emergency have applied more countermeasures. Typical strategies for risk management (e.g., the diversification in transport modes or the stock increase) turned out to be applied as immediate countermeasures or in plan for the future in few industries only. Differences across sectors were also observed about the sourcing strategies already in use, implemented to counteract the pandemics or expected to be maintained in time. Empirical outcomes offered are expected to help researchers gain a deep understanding of Covid-19 related phenomena, thus inspiring further research activities.

1. Introduction

The Covid-19 pandemic has changed the global economy by increasing the uncertainty of all the markets, sectors, and businesses, and largely disrupting supply chains (SCs) and logistics systems worldwide.

Pandemic is a special case of disruption, characterized by long-term persistence, global propagation, and high unpredictability (Ivanov, 2020). The duration of the outbreak is crucial for companies which must react during the pandemic and face both short and long-term impacts (Baghersad and Zobel, 2021). In addition, disruptions usually affect one supply side, while pandemic impacts on both supply and demand dynamics (Kwon, 2020). This new aspect complicates the management of the ripple effect and leads to both forward and backward disruptive propagation (Ivanov and Dolgui, 2021). Furthermore, the three

Covid-19 waves, which occurred before the distribution of the vaccine, have forced many countries to rapidly change restriction and obligation measures in different periods, and many companies to adopt practical actions and adapt their business to quickly face the new challenges (Rothengatter et al., 2021). All these differences from the other disruptions make the study of the impact of the Covid-19 pandemic a promising area of research.

Since the beginning of 2020, studies have been conducted on the effects of the pandemic on SCs, logistics systems and operations management worldwide, and different strategies and mitigation measures have been explored (Ivanov, 2021a). Researchers have presented early analyses, whose aim was to provide an initial or general overview of the Covid-19 impact on SCs or logistics systems (e.g., Umaña-Hermosilla et al., 2020). Some of these studies have been in empirical form, such as interviews to capture the general aspects on the new phenomenon

* Corresponding author. Department of Engineering and Architecture, University of Parma, viale delle Scienze 181/A, 43124, Parma, Italy.

E-mail address: eleonora.bottani@unipr.it (E. Bottani).

<https://doi.org/10.1016/j.ijpe.2023.108915>

Received 6 October 2022; Received in revised form 5 April 2023; Accepted 14 May 2023

Available online 20 May 2023

0925-5273/© 2023 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

(Remko, 2020), surveys to investigate the role of SC risk management to mitigate the effects of the disruption (El Baz and Ruel, 2021; Sharma et al., 2022a), or case studies (Hohenstein, 2022; Butt, 2021; Rinaldi et al., 2021). Nonetheless, authors in general agree that empirical research on Covid-19 is still limited (Ivanov, 2020; El Baz and Ruel, 2021; Hohenstein, 2022) and additional investigations are needed to clarify the impact of the pandemic on SCs, in terms of how (and to what extent) companies have been affected by the Covid-19 crisis, and how to learn from this kind of exogenous disturbances (Dolgui & Ivanov, 2021; Ivanov and Dolgui, 2021), with the ultimate goal to delineate strategies for enhancing SC robustness and resilience and be more prompt in the future. Chowdhury et al. (2021) have expressively noted that the lack of empirical studies also limits the generalizability of the findings available in literature.

To date, literature has analyzed the adaptive behaviours of SCs during the pandemic, while few researchers have examined the after-shock risks and the pandemic's effects in the post-emergency period (Ivanov, 2021b), or its medium- and long-term effects (Zhao and Chen, 2022), which instead must be explored further (Pujawan and Bah, 2022). Studies on the effects of Covid-19 in different time horizons, with a focus on the short-, medium- and long-term are therefore needed (Montoya-Torres et al., 2021; Ardolino et al., 2022).

In addition, despite the pandemic has strongly affected the flow of materials because of unexpected restrictions and interruptions, a research gap still exists about the impacts of Covid-19 on logistics and SC processes (Queiroz et al., 2022), intended as the set of processes relating to the management of inventory, service level, materials flow, warehousing, transport and relating information (Christopher, 1987). As a matter of fact, what has received significant attention are actually "humanitarian" logistics activities, which have been extensively studied in literature (Chiappetta Jabbour et al., 2019; Queiroz et al., 2022); however, analysing the impact of Covid-19 on ("industrial") logistics and SC processes needs a different perspective and should be extended (Xu et al., 2021).

As a further point, it is well acknowledged that the Covid-19 outbreak caused a global economic catastrophe, with severe consequences on every type of SC and every sector across the globe. However, it is also evident that there have been differences in the level of severity of impact, the duration of the effect and the extent of recovery across the sectors (Xu et al., 2020; De Vet et al., 2021). Al-Hyari (2020) has suggested the tourism, trade, health, manufacturing, education, and transportation as the sectors most severely affected by the Covid-19 pandemic. However, differences between sectors have been less discussed in the available literature, as well as the medium- and long-term strategies of related companies in response to the impact observed; these aspects are relevant for developing knowledge on how to build more resilient systems in the future (Queiroz et al., 2022).

This paper merges the research gaps mentioned above and tries to enrich the literature in various ways. First, it contributes to the (still limited) empirical debate about the impact of the Covid-19 pandemic on logistics and SC processes. Second, the specific facet of this study is its multi-sectorial perspective, which is expected to highlight the differences or similarities in the impact across various industry fields. As such, this cross-sectoral study is among the first works that provide present and future insights on the impact of the Covid-19 pandemic on logistics and SC processes in different businesses. A questionnaire has been designed to this end and a survey was conducted involving companies from five main industrial sectors of Italy. Third, the horizon of analysis set in this study covers the three Covid-19 pandemic waves, to investigate the changes in the companies' behavior as the pandemic progressed, as well as its modified effects in time. Overall, the study aims at answering the following research questions (RQs):

RQ1. What are the effects of the Covid-19 pandemic (in the immediate- and short-term) on logistics and supply chain processes across different industry fields?

RQ2. What countermeasures have been implemented by the different industry fields? What decision-making strategies will be maintained in the medium-term to improve the post-pandemic business?

The contribution of this paper can also inspire further research since it offers reliable and real data useful for developing quantitative models which need a deep understanding of the involved phenomena and its stages before modelling the system (Rinaldi et al., 2022; Bottani et al., 2022b).

The rest of the paper is structured as follows. The next section first reviews the available empirical literature about Covid-19 and SCs, then provides the theoretical background for the two RQs of the study. Section 3 details the research methodology, Section 4 presents the results of the survey, and Section 5 discusses the key findings for answering the RQs, showing the theoretical/practical contributions, and suggesting future research directions. Section 6 delineates the limitations of the study, summarises and concludes.

2. Literature analysis

2.1. SCs and COVID-19: empirical studies

In recent years, empirical studies have been conducted to explore the impact of the pandemic on SCs (Taqi et al., 2020). These studies take different perspectives in terms of the specific facet of the Covid-19 impact they explore, of the supply chain player analyzed (e.g., focal companies, suppliers, logistic service providers or citizens), the industrial sector(s) targeted for the analysis, as well as the research methodology (case study/interviews vs. questionnaire surveys).

Among the first studies, Al-Hyari (2020) has investigated the effects of the Covid-19 pandemic on 45 small and medium-sized enterprises (SMEs) of the Jordanian manufacturing sector, using semi-structured interviews. The focus of the analysis was on how companies of different size have managed the disruptions caused by Covid-19; some prospects for the future are also delineated, so as to suggest political actions to the governments. An investigation of the consumers' perception of Covid-19 impact on the local economy (in particular, SMEs) of Chile has also been made by Umaña-Hermosilla et al. (2020). By reaching 313 citizens, the authors found a general concern about the capability of SMEs to ensure employment and job security. These results are confirmed by a similar, smaller scale, empirical investigation that the authors made on 51 companies of the country.

Suikowski et al. (2022) have analyzed the relationships between the innovations introduced by Poland logistic companies (courier-express-parcel in particular) in response to the Covid-19 pandemics, for increasing the service level delivered to customers. To this end, they have carried out an empirical analysis targeting the final consumers (citizens) and submitted it as an online survey. The logistics context has been analyzed also by Ketudat and Jeenanunta (2021), who have investigated the response of three companies, taken as case studies, to the pandemic emergency. They found that the impact of Covid-19 resulted sometimes in an increase and sometimes in a decrease in the volumes handled by the companies. A similar conclusion has been reached by Perkumiene et al. (2022), whose study has again targeted one company in the logistics and transport industry. Hohenstein (2022) has carried out a multiple case study-based research focusing on the strategies implemented by logistics service providers to counteract the Covid-19 pandemics, deriving eight key success factors critical to companies in this field.

Compared to the logistic sector, empirical studies focusing on the impact of Covid-19 in other industry fields are significantly less numerous. To the best of the authors' knowledge, the only empirical study targeting the agri-food supply chain has been by Mishra et al. (2022), who have investigated the impact of Covid-19 on a fruit and vegetable online retailer in India, using a case study approach. The final goal of the analysis was to identify the key disruptions generated by the Covid-19 pandemic and to determine the corresponding

countermeasures. Similarly, two empirical studies only have been carried out in the retail supply chain (Butt 2021; 2022), using a multiple case-study approach and with the specific aim to identify the countermeasures adopted against Covid-19. Two case studies in the fashion footwear context have been analyzed by Braglia et al. (2022), with the aim to investigate how companies in this field reacted to the disruption caused by the Covid-19 pandemic, so as to increase resilience in case of future disruptions. The papers by Tamtam and Tourabi (2021) and Ghadir et al. (2022) have instead analyzed the effects of Covid-19 in the automotive industry. The former authors have focused on the agile capability of automotive companies in the pandemic period, while the latter authors have proposed an approach for prioritizing risks induced by Covid-19 in the automotive supply chain. Finally, Ando and Hayakawa (2022) have used secondary data (export data) from the machinery industry as an example of global SC, for analyzing the supply-side impact of Covid-19 on global logistics systems.

Looking at cross-sectorial studies, El Baz and Ruel (2021) have investigated the role of supply chain risk management practices in mitigating the effects of disruptions in the context of Covid-19, by means of an empirical survey targeting French companies operating in various sectors (manufacturing, energy, transport, chemical, retail and service & humanitarian). They evaluated the risk management practices applied in the Covid-19 period, along with the four typical stages of risk management (i.e., risk identification, risk assessment, risk mitigation and risk control) plus some complementary aspects, namely SC robustness, resilience, and control. A cross-sectorial study has also been performed by Anakpo and Mishi (2021), covering nine industrial fields. The focus of the analysis was on the financial performance of the companies, in terms of turnover, as well as on the responses to counteract the effect of Covid-19. Belhadi et al. (2021) have carried out an empirical study involving 145 companies from the automotive and airline industries, to investigate the short-term strategies implemented by those companies in response to Covid-19; findings are analyzed distinctly for the two sectors.

Some specific facets of the Covid-19 impact on SCs have also been analyzed in literature. Wissuwa et al. (2022) have examined the topic of supplier “complexity” and its relationships with buyer disruptions, which were particularly evident in the Covid-19 period. By analyzing 59 buyer-supplier dyads, the authors found that supplier complexity is actually harmful for the buyer, and thus suggest its introduction as an important criterion for effective supplier selection. The study by Nader et al. (2022) has targeted three industrial sectors, such as the food, pharmaceutical and medical manufacturing, which are taken as representative of the production of essential goods. These authors have focused on the role of pandemic emergency planning (i.e., the practices implemented by companies to counteract the pandemic emergency) and of sustainability practices in enabling risk mitigation and enhancing company’s resilience and performance.

2.2. Theoretical background

2.2.1. Effects of Covid-19 on logistics and SC processes

One of the first and most influenced aspects of Covid-19 impact on SCs concerns the changes in global trade volumes (Aday and Aday, 2020). Early analyses carried out during the first stage of the pandemic have discussed demand-side shocks and the sudden changes in consumption patterns in food SCs (Hobbs, 2020), but also in the healthcare, medical tools, or personal protective equipment (PPE) production (Kraus et al., 2020; Milzam et al., 2020).

Looking at the food SC, the pandemic has adversely affected this context by causing both demand and supply uncertainty. A decrease in demand has been observed because of consumers’ less frequent store visits and restrictions/limitations to people movements (Ramakumar, 2020; Montenegro and Young, 2020); at the same time, however, various studies have shown that the early lockdown measures have changed the people’s purchasing behavior (the so-called “panic

buying”), causing unexpected peaks of demand that have strongly increased the food consumption (Borsellino et al., 2020; Loske, 2020). Sgroi and Modica (2022) have also demonstrated some changed consumers’ habits related to food consumption in the Covid-19 period.

In general terms, it could be conjectured that in crisis situations, people tend to buy essential goods (e.g., food or medical products), while avoiding purchasing non-essential ones (Nader et al., 2022). In this respect, Shafiee et al. (2022) have noted that a further challenge in the food or pharmaceutical SCs, exacerbated by the Covid-19, is the perishability of the items handled, which involves additional risks. Rinaldi et al. (2021) have in fact shown that the impact on food volumes also depends on the type of food category and distribution channel. Thus, despite the demand of some goods has experienced a significant growth, the pandemic has slowed down the sale of other products (Nandi et al., 2021). Overall, these considerations suggest that the consumer’s behavior and purchasing pattern, relating variations, and demand shocks (Chowdhury et al., 2021; Nandi et al., 2021) have played an important role in determining changes (either positive or negative) in the volumes handled by the SCs. Evidence in literature suggests that this could also be the case for the logistics sector, for which, indeed, the available empirical studies report controversial effects of Covid-19 on volumes (Ketudat and Jeenanunta, 2021; Perkumiene et al., 2021).

Other sectors, whose activity falls into the production of non-essential goods (like the automotive, textile and electronics industry), have typically experienced a sudden decrease in the sales volumes (Cai and Luo, 2020). Indeed, in response to the measures taken by some governments (such as stores closure, borders closure, and lockdown - Chowdhury et al., 2021; Khan et al., 2021), companies in various sectors were forced to shut down the production of finished goods, because the pandemic has stopped the demand for them (Korankye, 2020; Kraus et al., 2020; Cai and Luo, 2020), or severely limited the import/export activities (Khan et al., 2021). Anakpo and Mishi (2021) have observed that some industry fields (namely agriculture, hunting, forestry, fishing, and electricity/gas/water supply) were likely to operate at their normal level during the Covid-19 period, thus showing more resilience compared to other sectors that relied more on exports-driven businesses. In a similar way, export-driven businesses with local market potential or alternative transaction were more likely to withstand the pandemic shock and remain within the normal operating conditions. In terms of markets, a new challenge introduced by the Covid-19 pandemic is the necessity of being “online”, which was the only way to reach the customers; during the pandemic, sales and purchases through the e-commerce channel have increased (Sułkowski et al., 2022). From the supply side, instead, production stops in some sectors could further prevent other companies get the supplies they need to continue their own production, thus causing a forced reduction of activities in other sectors as well (Korankye, 2020; Aday and Aday, 2020; Cai and Luo, 2020). Some studies have observed that a further determinant of the impact of Covid-19 on volumes is the company’s size (Fitriasari, 2020; Qamruzaman, 2020); regardless of the sector, the underlying assumption is that SMEs are more susceptible to disturbances, because of the lower availability of resources, and thus the effects of the pandemic could be particularly severe. The above evidence indicates that the Covid-19 has significantly changed the sales volumes, with effects that could be different depending on industrial business, network, and sector (De Vet et al., 2021).

A second key effect of Covid-19 on SCs is that the distortion of demand and supply has caused long lead times, because of delays in production and distribution processes (Magableh, 2021), ultimately resulting in poor service performance. At the beginning of the Covid-19 pandemic, consumers frequently experienced shortages of (even essential) goods, often because of disaggregated and globalized SCs with long lead times and lengthy recovery (Ivanov and Dolgui, 2020; Li et al., 2021; Paul and Chowdhury, 2021; Chowdhury et al., 2021; Sharma et al., 2022b). In general terms, accurate and timely deliveries are the result of good performance of all SC processes, encompassing

production, logistics and distribution. As far as production is concerned, restrictions imposed by governments worldwide had a negative effect on operations, as they have delayed the production of the necessary inputs to the next nodes of the system, thus delaying the flow of products (Pu and Zhong, 2020). Looking at logistics/distribution activities, travel restrictions or blocking of transport activities, reduced available workforce and, in the case of essential goods, an increase in demand, contributed to delays in production and distribution, preventing the possibility of completely fulfilling orders (Montenegro and Young, 2020) and undermining the related completeness (Ivanov, 2020). This is why researchers have analyzed the quality of the service level provided during the pandemic, considering cancelled orders (Zhang et al., 2020), unfilled orders (Altig et al., 2020), shipping delays (Gereffi, 2020), and out of stocks (Pantano et al., 2020). Sathyanarayana et al. (2020) have also evaluated the impact of the pandemic on the service level and discussed the performance of a SC when varying the distance between supplier and customer. As the role of logistics service is crucial for competitiveness, Choi (2021) and Hohenstein (2022) have renewed the need for empirical research on how SCs will be able to maintain adequate service performance in the pandemic and post-pandemic period. Sharma et al. (2020) have argued that digital tools could be somehow useful to companies for maintaining a satisfactory service level, in terms of on-time order fulfilment, as they allow enhancing collaboration mechanisms between SC players. The rise of the e-commerce and electronic payment are good examples of digitalization involved by the Covid-19 pandemic (Perkumiene et al., 2021); at the same time, e-commerce causes high demand for logistics service, being in direct contact with the customer.

2.2.2. Countermeasures and decision-making strategies against Covid-19

It is widely known that the Covid-19 has a very high potential of being transmitted from one individual to another, causing dangerous health consequences; this forced many countries (including Italy) to implement specific containment measures. Physical/social distancing was among the most applied countermeasures, also recommended by the World Health Organization to reduce the transmission of the Covid-19 virus (Qian and Jiang, 2022). That policy was basically implemented in any company, regardless of the size and sector, in various ways depending on the activity carried out. Social distancing has obviously been complemented by other physical measures, all intended to reduce the spread of the virus by decreasing the number of workers in common spaces; examples of these measures are work re-organization (Narayanamurthy and Tortorella, 2021), re-layout of offices and workspaces (Ardjmand et al., 2021), sometimes coupled with the installation of protective barriers between workstations (Bottani et al., 2022b), and the definition of new working procedures (Agba et al., 2020; Narayanamurthy and Tortorella, 2021). Other common measures are the usage of PPE, e.g., masks (Cai and Luo, 2020), or the sanitization of equipment between work shifts (Bottani et al., 2022a), which were recommended by governments in almost all businesses. Digital technologies also have a role in avoiding or reducing the physical contacts (Ye et al., 2022), as demonstrated by the wide diffusion of home/smart working practices (Green et al., 2020) and of online meetings (Pratama et al., 2020). Other practices, which have been observed in logistics companies, include opportunities for revisiting the allocation of items in warehouses (Butt, 2021) or introducing rules for loading/unloading of goods at warehouses (Rinaldi et al., 2021), always with the aim to avoid the simultaneous presence of more workers. Changes in the production activities or the employees' tasks have instead been suggested in manufacturing industries (Lutfi et al., 2020; Telukdarie et al., 2020). Empirical analyses have demonstrated that these practices have strongly affected the economic performance of SMEs (Aday and Aday, 2020), leading companies to implement structural changes that are needed to adapt the business to these new protocols (Lutfi et al., 2020). The available literature on the effects of the practices implemented to counteract Covid-19 has mainly targeted the governmental measures

(Anakpo and Mishi, 2021), given their widespread diffusion; on the contrary, the effects of internal or specific measures on the system's performance have instead been explored to a lower extent.

As a final general effect, the pandemic as an unexpected disruption has increased the attention towards the resilience of production and distribution systems. Most of the researchers have analyzed the impact of different strategies, which could be adopted to face SC disruptions and mitigate their negative effects (Raj et al., 2022). Literature suggests various practices which have been commonly implemented for building resilient SCs and reacting to general disturbances; well-known strategies are sourcing decisions and (safety) stock policies (Christopher and Peck, 2004). The relevance of sourcing strategies has been particularly emphasized by the Covid-19 pandemic, which made some electronic components (e.g., semiconductors used in the automotive or computer industries) completely unavailable (Suikowski et al., 2022). Consequently, multiple, or local sourcing strategies started being implemented as opposed to single sourcing practices, for guaranteeing the supply of raw materials and critical components (Zhu et al., 2020; Belhadi et al., 2021). These practices are often associated to increased inventory levels, for mitigating supply disruption risks (Chopra and Sodhi, 2004). Additional, more specific (and more structured), adaptation strategies have emerged during the pandemic period, and besides being implemented as immediate countermeasures, have the potential of being maintained in the future. These strategies include revising the production activity (Bottani et al., 2022a) or reorganizing the workplace and workforce to minimize the probability of infection among workers (Telukdarie et al., 2020).

Unexpected and unplanned lockdowns imposed by the governments in response to Covid-19 have also severely affected the transport activity (Mashud et al., 2022; Koerber and Schiele, 2022). Nonetheless, global SCs cannot do without these activities, as they must ensure a seamless flow of goods between partners and countries; therefore, outsourcing of logistics functions to third-party logistics services providers or diversification of transport activities through alternative channels have been proposed as additional countermeasures against Covid-19 (Twinn et al., 2020). Digital technologies have also been suggested as a leverage to increase the resilience of companies (Chowdhury et al., 2021), especially in the logistics and transport sector (Suikowski et al., 2022; Klein et al., 2022) and in the automotive industry (Balakrishnan and Ram-anathan, 2021). Looking at the internal processes, sharing of data and usage of digital technologies can improve process visibility and enhance automation (Ye et al., 2022); in terms of SC processes, these tools have been indicated as leverages for developing stronger and more robust networks of relationships with upstream and downstream players (Chowdhury et al., 2021), thus helping companies be quicker in restoring their operations, and ultimately increasing resilience.

3. The research methodology

3.1. Questionnaire development

3.1.1. Structure

The questionnaire used in this study was designed for capturing the key impact (in the immediate-, short- and medium-term) of Covid-19 on logistics and SC processes. Based on the evidence emerged from the literature, four main impacts have been targeted for the analysis: 1) the impact of Covid-19 on the sales volumes, 2) the impact of Covid-19 on the service level; 3) the impact of Covid-19 on work organization; 4) the impact of Covid-19 on present and future decision-making strategies.

The questionnaire consists of five sections, as illustrated in the scheme in Table A-1 (Appendix 1). Section 1 includes questions intended to delineate the company's profile and respondent's role. Companies were analyzed in terms of their size, according to the European Commission's (2003) recommendations, and industrial sector; for this latter, a list was proposed to the respondents including the five sectors previously mentioned, plus an additional option ("other"), for specifying

a different field (in case).

The next four sections of the questionnaire address, instead, the four aspects of the Covid-19 impact on logistics and SC processes, in line with the previous list. Respondents were asked to indicate their opinion on the impact of Covid-19 using two different 5-point scales (Taherdoost, 2019), depending on the question and on the scope of the analysis (cf. Table A-1):

- Scale#1 (unipolar Likert scale): from 1 = “not at all” (or “no changes”) to 5 = “completely” (or “significant changes”);
- Scale#2 (bipolar Likert scale): from 1 = “significant worsening” to 5 = “significant improvement”. In this scale a score of 3 means that “no changes” were observed.

In detail, Section 2 contains questions intended to evaluate the impact of Covid-19 on the sales volumes handled by the company at the various nodes of the SC. Respondents were asked about the positive and negative changes in volumes they observed in the whole period of analysis (cf. section 3.1.2). That change was to be evaluated in comparison with the pre-Covid activity of the company, represented, for simplicity, by year 2019. The causes that determined the observed change (either positive or negative) in the volumes handled were also investigated. A predefined list of nine possible factors, derived from the literature as well as from the direct observation of the Italian scenario, was proposed to the respondent to this end.

Section 3 includes questions relating to the impact of Covid-19 on the quality of the service offered by the company to its customers. Three service factors, typically used by companies to measure the quality of their service were targeted for the analysis; respondents were asked to evaluate whether the service performance against these factors experienced a change (either positive or negative) because of the pandemic emergency. The subsequent question aims at investigating the causes of the worsening or improvement in the quality of the service offered; the analysis targeted the role of three key dynamics involved by the Covid-19 pandemic (blocking of transport activities, production delays and supplier delays) as factors which could have affected the service performance. The extent to which each factor influenced the service performance was evaluated.

Section 4 investigates the countermeasures adopted by companies to deal with the early Covid-19 infection. A predefined list of 11 mitigation strategies, summarized from the literature, was investigated in terms of the implementation level. The next question investigates the impact these precautionary measures could have on some key company’s performance, such as costs, productivity, and service.

Finally, Section 5 investigates various strategies implemented for reducing risks in the SC, including more traditional measures as well as additional solutions enabled by digital technologies. As far as the traditional strategies, questions in this section aim at evaluating the extent to which they were implemented for counteracting the Covid-19 pandemics, as well as the willingness of companies to maintain each strategy in the future. To this end, respondents were asked to state the degree of usage on an ad hoc 4-point scale, according to which a strategy could be: 1-already used in the company; 2-temporary adopted to face the Covid-19 emergency; 3-adopted to face the emergency and expected to be maintained in the future; 4-not adopted and not in plan for the future. Looking instead at the digital solutions, respondents were asked to judge whether their company would be willing to favor the usage of these strategies in the future, and thus, if an increase in the usage of digital tools is to be expected.

For enhancing effectiveness in collecting the responses, the questionnaire was elaborated online using Google Forms.

3.1.2. Period of analysis

Recalling that one of the goals of the study is to evaluate the immediate-, short- and medium-term impact of Covid-19, a timespan of six quarters (Q1 ...,Q6, from January 2020 to June 2021) was taken into

account. This timespan was selected as the “period of analysis” (and referred to in that way from now on) for being able to capture possible variations in the behavior and performance of companies during the various phases of the pandemic. As a matter of fact:

- Q1 (January 2020–March 2020) corresponds to the spread of the virus, first in China and then globally, with the first outbreaks, and then the lockdowns measures implemented by the governments;
- Q2 (April 2020–June 2020) reflects the beginning of what was called the “phase 2” by the Italian government and involved some initial post-lockdown re-openings and resumption of travelling activities;
- Q3 (July 2020–September 2020) was overall characterized by a slow economic recovery;
- Q4 (October 2020–December 2020) was characterized by the outbreak of the second wave of the virus, with the consequent return to social distancing policies, albeit with an easing in the Christmas holiday period;
- Q5 (January 2021–March 2021) involved a new period of closure for some activities because of the beginning of the third wave, depending on the sanitary condition of the region, and with the beginning of the vaccination campaign;
- Q6 (April 2021–June 2021) involved a gradual reopening of activities, following the improvement in the sanitary conditions and the positive effects of the vaccination campaign.

To consider the immediate- and short-term impact of Covid-19 on the various industry field and answer RQ1, the six quarters were taken into account, where appropriate, for questions included in sections 2 and 3 of the questionnaire; answers had to be provided by the respondent for each quarter. Instead, questions of sections 4 aim at capturing the immediate-term changes caused by the pandemic, focusing on the early adopted strategies to counteract to the emergency during the first three trimesters. Then, questions included in sections 5 investigate the past, present and future adoption of mitigation strategies across the different sectors; “past” refers to the pre-Covid period, “present” captures both the immediate- (from Q1 to Q3) and short-term (from Q4 to Q6) effects, and “future” refers to the medium-term response (from July 2021 onwards). These last two sections of the questionnaire have been designed to answer to RQ2.

3.2. Sample construction

An appropriate sample of companies was created by querying the Kompass database (www.kompass.com), which provides various pieces of information about the companies indexed and lists companies from more than 70 countries in the world. We targeted companies headquartered in Italy, possibly known to the authors of the paper (e.g., because of previous collaborations for research purposes), in the attempt to increase the likelihood to get a reply from the interviewees. The sample was built to be representative of various industry fields and to include companies of different size, with the aim to investigate the effects of Covid-19 on different industrial sectors and as a function of the company’s characteristics. Five sectors were taken into consideration, namely: food & beverage (F&B); plant and machinery manufacturing (MACH); logistics & transport (L&T); metal mechanical industry (MEM), which includes the producers of metal goods that supply parts to industries such as manufacturing, construction, automotive, agriculture and many other sectors; and textile & fashion (T&F). These sectors are among the top producers of the Italian economy (Italian Institute of Statistics, 2021a; 2021b) and are therefore expected to well depict the Italian scenario. Overall, the sample consisted in 288 companies which were involved in the study. The sample construction took from March to May 2021 approximately.

3.3. Pre-testing, data collection and elaboration

A preliminary version of the questionnaire was discussed with three companies of the sample, for pre-testing purpose (Malhotra and Grover, 1998). These companies belong to three different industry fields, i.e., F&B, MACH, and MEM, to check whether the proposed questions were appropriate to the various industrial contexts. During the interviews, the answers to the questionnaire were collected and further specific aspects - which could not be captured by the questionnaire itself - were discussed. Evidence from these interviews were used to substantiate the research outcomes (cf. section 5). A personal email was then sent to the remaining 285 companies, with a link to the questionnaire on Google Form, in its final version. A cover letter was included in the email for briefly illustrating the research aim and scope and asking for the company's participation. The data collection phase took from October to November 2021 approximately.

All items of the questionnaire were elaborated using statistical techniques, supported by Statistical Package for the Social Sciences (SPSS) release 28 for Windows software package (IBM® Corp., <https://www.ibm.com/it-it/analytics/spss-statistics-software>). The overall validity and reliability of the responses gathered was preliminary evaluated using the Cronbach's alpha parameter (Nunnally, 1978), which returned a value of 0.872 significantly higher than the threshold of 0.6 recommended for conducting effective survey research (Malhotra and Grover, 1998).

Questions in Section 1 were primarily used to provide an overview of the sample of respondent companies, through descriptive statistics in the form of frequencies or contingency tables. Items of Sections 2 and 3 were again elaborated using descriptive statistics; the trends in time of the answers provided was also derived for each industry field under examination. The average value of the responses obtained by companies belonging to the different industry fields was computed to this end; contingency tables were instead used to show the average responses as a function of the industrial context. Similar considerations can be made for items in Sections 4 and 5, for which, besides an overview of the responses collected, the average value of the answers obtained for the different industrial fields was computed and used for comparison purpose. Analysis of variance (ANOVA) with F-test (Lomax, 2007) was used, whenever appropriate, to check the statistical differences of the items tested across the industry fields. For the sake of brevity, the full ANOVA analyses are reported in Appendix 2 (Table A- 2); significant outcomes are mentioned while presenting the results from the survey.

4. Results from the survey

Out of the 288 companies involved in the study, a total of 79 responses was obtained, which become 82 including the three companies involved in the pre-testing of the questionnaire; the overall response rate was therefore $82/288 = 28.5\%$. That value is in general appropriate in survey research, as it is above the suggested threshold of 20% (Yu and Cooper, 1983; Malhotra and Grover, 1998). The sample of companies itself is in line with empirical studies in similar fields (cf. Henkel et al., 2022; Wissuwa et al., 2022).

4.1. Overview of the sample

The descriptive results presented in this section outline the characteristics of the sample of companies involved in the study. The main features of the respondent companies are shown in Table 1.

Overall, the sample is sufficiently heterogeneous and as such, it is representative of various industries. More than half of the sample is represented by SMEs (57.3%); this is not surprising as the vast majority (approx. 95%) of the Italian manufacturing system consists of these companies, which also have a primary role in workforce employment (Italian Institute of Statistics, 2019; Fortis and Sartori, 2016). At the same time, 32.9% of the respondents are large companies and the rest of

the sample consists of micro-sized organizations (9.8%). A sufficient heterogeneity has also been reached looking at the industrial sectors involved in the study; indeed, the responses reflect the targeted industrial sectors, with four companies only belonging to a context different from those targeted in the analysis.¹ As far as the area of expertise, most of the respondents (24.4%) have a managerial role in the company and therefore they are expected to know quite well the internal business process and functions; otherwise, respondents were SC (20.7%), operations (14.6%) and marketing (15.9%) managers. The remaining quota of respondents (24.4% in total) belong to other business functions. Overall, top managers provided the 49% or responses, followed by directors (30%) and employees (21%).

4.2. Statistical analyses

This section describes the key results of the survey and following the structure of the questionnaire, consists of four sub-sections.

4.2.1. Impact of Covid-19 on volumes

The first analysis aims at identifying the variations in volumes during the six quarters considered; outcomes from questions relating to the increase and/or decrease of volumes observed by companies were elaborated to this end and results are depicted in Fig. 1(a and b). According to Scale#1, a score of 1 in Fig. 1(a) means that the respondent has not observed an increase in the volumes, but this does not necessarily mean that he/she has observed a decrease; conclusions can be reached by comparing the two graphs (a) and (b).

The first evidence from Fig. 1 is the peak of volumes observed for F&B, followed by MACH and L&T, during the first wave of the Covid-19 compared to the other sectors (MEM and T&F); statistically significant differences among sectors are also observed in Q2 and Q3. Then, during the following quarters, all the sectors investigated show a constant growth up to Q6, with no statistical differences. The second outcome involves again F&B, which maintains a high level of increase in volumes in the whole period of analysis. L&T has faced a trend similar to F&B during the first three quarters, which could suggest a correlation between the two sectors. Instead, the peak of the last three quarters is probably due to the increasing volumes observed in all the sectors. MACH is the only field that maintained a middle-high increase and experienced a slow but constant growth moving from Q1 to Q6. The remaining sectors (MEM and T&F) exhibit a similar trend: at first, they have been negatively affected by the pandemic outbreak, facing a decrease in volumes, with the worst situation during Q2 (the lockdown period). Significant differences against the decrease in volumes are also evident in Q2, which again confirms that the immediate effect of lockdown varied across the sectors. Then, during the following four quarters, T&F has faced a slight increase in volumes, while MEM has strongly increased its volumes, registering the maximum growth compared to the remaining sectors.

The next analysis investigated the impact of nine selected factors on the increase/decrease of sales volume faced by the companies, as previously presented. Results are proposed in Fig. 2.

From Fig. 2 it is evident that the main factors that have affected the F&B volumes are related to the downstream part of the SC and linked to the consumer behavior (factors 1 and 2) or to the interruption or limitations downstream the SC (factors 4 and 8) - these latter, presumably, with negative effects. A very similar result has been obtained for L&T, for which lower scores have been registered but with the same relative importance assigned to the nine factors. This outcome reinforces the previous consideration about a possible correlation between the results

¹ Those companies are included in the general overview of the sample, for completeness, but they will not always be included in future elaborations; in particular, they will not be included in elaborations focusing the specific industrial fields.

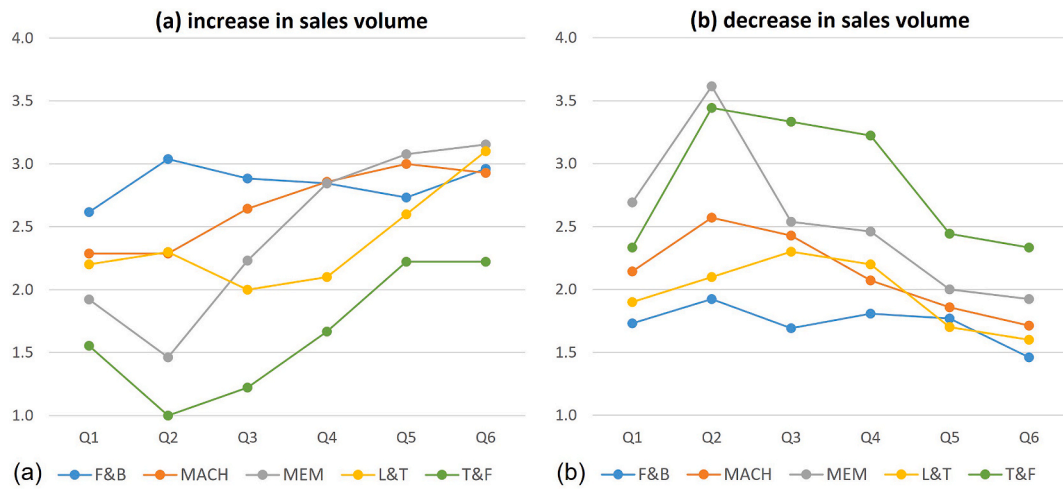


Fig. 1. Average increase (a) and decrease (b) in sales volume per sector during the period of analysis (note: scale#1 is used).

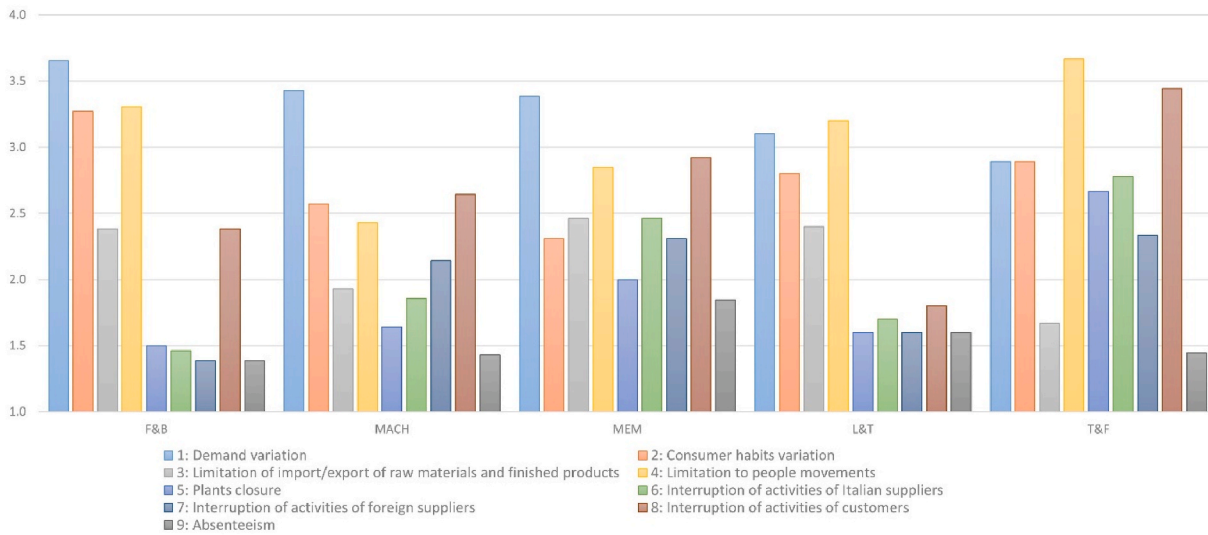


Fig. 2. Average impact of factors that led to the variation of sales volume (note: scale#1 is used).

of the two sectors, and more in general, about the relationships between them. Compared to these sectors, MACH shows a similar result with an increasing importance, however, of the interruptions upstream the SC, further highlighted by MEM, that has assigned a moderate importance to all the factors. Indeed, in MEM and MACH, the variation in volumes is also due to the interruption of suppliers' activities (factors 6 and 7).

These latter factors were also observed to have a statistically different impact across the sectors investigated. Finally, T&F has been strongly affected by the limitations to people mobility (factor 4), and by the closure of shops and shopping centers (factor 8); compared to the remaining sectors, the variation in demand seems instead a secondary factor, while the interruption of production activities (factors 5, 6 and 7)

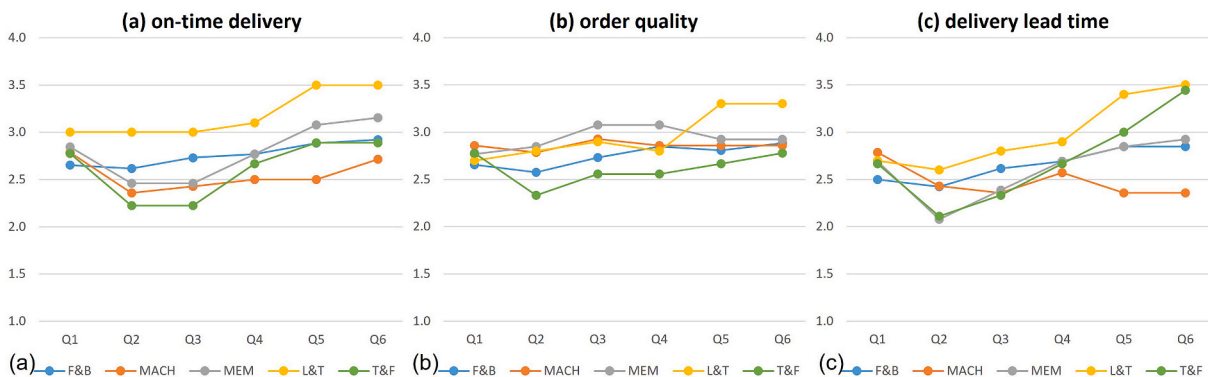


Fig. 3. Average variation of on-time delivery (a), order quality (b), delivery lead time (c) per sector during the period of analysis (note: scale#2 is used).

achieves a noteworthy importance.

4.2.2. Impact of Covid-19 on service level

Items of section 3 of the questionnaire were used to evaluate the impact of the pandemic on three selected performance indexes typically used to express the service level of companies throughout the period of analysis. Results are shown in Fig. 3(a–c).

From the outcomes in Fig. 3, it appears that L&T differs from the remaining fields; in fact, that sector did not experience negative variations, and it exhibits a slight improvement in the last quarters. The remaining sectors, instead, have all observed a slight worsening of delivery performance during the early period of emergency, with a minimum reached in Q2; then, a gradual recovery was observed for all sectors in the last quarters, up to approximately restoring their pre-pandemic state. Once again, T&F seems to be the most affected sector; however, no significant differences across the sectors are observed in on-time delivery and order quality. Looking at the delivery lead time, it emerges that MACH experienced a worsening of its performance in the two quarters of 2021 (Q5 and Q6). This highlights a kind of return to a critical situation with the advent of the third wave of Covid-19 for that sector. On the contrary, the remaining sectors experienced quite negative performance at the beginning of the pandemic, with a gradual recovery registered during the last quarter; indeed, some significant differences across sectors emerge in Q5 and Q6.

The possible causes for the variations in the service performance experienced by the companies were then investigated, focusing on three factors expressing some key problems involved by the Covid-19 and presented in Fig. 4(a–c). As can be seen from this figure, the perception about the changing role of the three factors in time is similar across the industry fields under examination. Indeed, all sectors have rated as particularly relevant the impact of all three factors analyzed during Q2, corresponding to the months of lockdowns and closures imposed to cope with the first wave of the pandemic, with a trend towards the decrease in their importance when reaching the last months of the analysis. Overall, this indicates that these factors were more problematic at the beginning of the pandemic period but have gradually gone back to normal.

However, differences emerge in the role of these factors across the various industries. The impact of blocks in transport shows significant differences across sectors in Q2 and Q3, suggesting that the effect was particularly relevant in some industries (T&F and MEM in particular). As for production delays, the perception of its effects varies as well across the industries, highlighting statistical differences in Q2, Q3, Q4 and Q6. Similarly, for supply delays a significant difference is observed in Q6, in which the perception of the companies from the T&F sector is particularly low (suggesting an almost negligible effect), while the remaining sectors still perceive an effect of that factor.

4.2.3. Impact of Covid-19 on work organization

The next analysis focuses on the impact of the pandemic on the early

(re-)organization of work and workplaces. To this end, two different analyses were made, focusing on the strategies adopted to counteract the emergency, and the impact of these measures on the company’s performance, in terms of costs, productivity and service level. Fig. 5 shows the results of the first analysis.

In general, the main strategies adopted across the industrial sectors turn out to be the use of PPE (strategy 9), the re-layout of spaces (strategy 1) combined with the use of protective barriers (strategy 10) to limit the direct contact and the physical proximity of workers, the introduction of new rules intended for guaranteeing the social distancing during the loading/unloading activities (strategy 11), and finally the smart working (strategy 2) and the adoption of digital systems (strategy 8), again with the purpose of avoiding physical contacts. These last two strategies exhibit significant differences across the various sectors; the former strategy indeed is more common in the L&T and MEM fields, compared to the remaining industries; MEM also shows a peak in the usage of digital systems, significantly higher than other sectors. Reinforced sanitization practices have instead been equally adopted in all the sectors excluding L&T; this result could be due to the manual production activities that are required in most of the sectors, as well as to the consequent need of disinfecting shared workstations.

The remaining strategies have received less attention and they have been less applied; no trends emerge. Despite the lack of significant differences, outcomes in Fig. 5 seem to suggest that some strategies are somehow industry-specific. This is the case for strategy 3, quite common in L&T, probably because of the kind of business carried out by logistics companies, or of strategies 4–6, more diffused in the F&B sector compared to the remaining fields.

The impact of the above-mentioned measures on the company’s performance has then been evaluated, with outcomes presented in Tables 2-4.

From the outcomes in those tables, it is evident that the adoption of the preventive strategies has strongly impacted on costs, generating a negative effect (i.e., a cost increase) in all sectors involved in the study, without notable differences across sectors. Instead, the protective measures seem to have a slightly negative effect on productivity, with the main consequences observed in MEM, MACH, and T&F sectors. No impacts on service level are observed.

4.2.4. Impact of Covid-19 on present and future decision-making strategies

The last set of elaborations focuses on the implementation of typical risk mitigation strategies and investigates their adoption before the pandemic emergency (“past”), as opposed to their introduction in response to the pandemic itself (“present”), as well as their removal or usage in the medium-term (“future”). Fig. 6(a–e) shows the level of implementation of three sourcing strategies (i.e., multiple, global, and local sourcing) across the sectors investigated, as a response to SC disruptions caused by the pandemic. The y-axis of this figure reflects the percentage of companies that have chosen a particular answer, while the

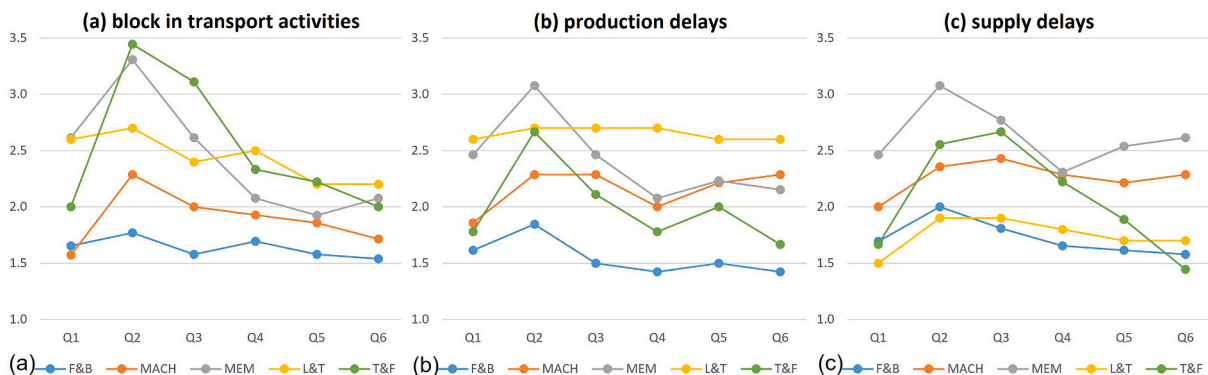


Fig. 4. Effect of the block in transport activities (a), production delays (b), and supply delays (c) on service performance (note: scale#1 is used).

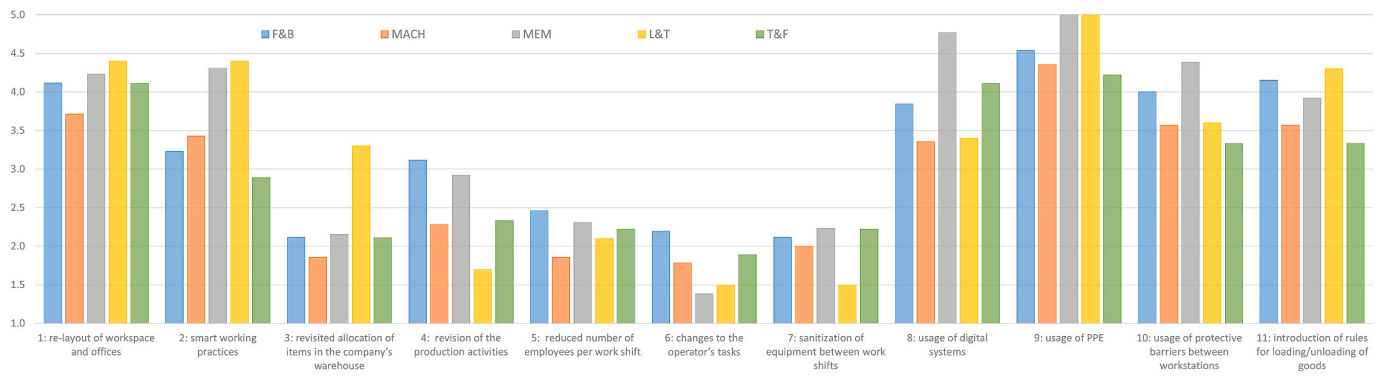


Fig. 5. Average usage of the preventive strategies adopted by companies (note: scale#1 is used).

Table 1

Characteristics of the final sample (note: F&B = food & beverage; MACH = plant and machinery manufacturing; L&T = logistics & transport; MEM = metal mechanical industry, T&F = textile & fashion).

Characteristics of respondents (sample = 82)	Number	Percentage
Sector		
F&B	28	34.1%
MACH	14	17.1%
MEM	13	15.9%
L&T	12	14.6%
T&F	11	13.4%
Other	4	4.9%
Plant size		
Micro	8	9.8%
Small	21	25.6%
Medium	26	31.7%
Large	27	32.9%
Respondents' area of expertise		
General manager	20	24.4%
SC and logistics	17	20.7%
Marketing	13	15.9%
Operations	12	14.6%
Quality and Safety	7	8.5%
Administration and Finance	6	7.3%
Other	3	3.7%
Research and development	2	2.4%
Human resources	2	2.4%

x-axis depicts the corresponding answer, in line with the description in section 3.1.1.

A first consideration from the outcomes in Fig. 6(a–c) is that most of the companies belonging to F&B, MACH and MEM were adopting all three sourcing strategies investigated even before the pandemic emergency, with the general aim to improve the performance of their business and make the supply side more resilient. It is also interesting to note that the three sectors mentioned privileged the application of one specific sourcing strategy before the pandemic, and in particular, the most implemented practice was multiple sourcing in F&B, local sourcing in MACH, and global sourcing for MEM. Fig. 6(b and c) also show that MACH and MEM have instead preferred a different (sometimes even opposite) strategy as the countermeasure to be implemented in the pandemic period; in particular, multiple, and local sourcing, respectively, became the preferred strategies temporarily used by companies of the two fields to counteract the pandemic emergency. The perception of the companies towards the future adoption of multiple sourcing also exhibits statistically significant differences across the industrial sectors. On the contrary, 31% of companies belonging to F&B has adopted the global sourcing strategy as the ad hoc measure to counteract the emergency and is willing to maintain it in the future to enhance the robustness of the network (Fig. 6(a)). It is also evident from Fig. 6(d) that the L&T has basically not changed its sourcing strategy, nor it has adopted additional measures to counteract the emergency. Finally, a relevant quota of companies belonging to T&F were not implementing any specific sourcing strategy before the pandemic, but have adopted all of

Table 2

Impact of the preventive strategies on costs (note: scale#2 is used).

Impact on cost		Strongly negative	Slightly negative	No impact	Slightly positive	Strongly positive	Total
Industrial sector	F&B	8	14	3	1	2	28
	MACH	5	5	1	2	1	14
	MEM	4	8	0	1	0	13
	L&T	6	2	3	1	0	12
	T&F	3	5	2	1	0	11
	Total	26	34	9	6	3	78

Table 3

Impact of the preventive strategies on productivity (note: scale#2 is used).

Impact on productivity		Strongly negative	Slightly negative	No impact	Slightly positive	Strongly positive	Total
Industrial sector	F&B	2	6	16	2	2	28
	MACH	1	6	4	3	0	14
	MEM	1	7	3	1	1	13
	L&T	1	3	6	2	0	12
	T&F	1	6	4	0	0	11
	Total	6	28	33	8	3	78

Table 4
Impact of the preventive strategies on service level (note: scale#2 is used).

Impact on service level		Strongly negative	Slightly negative	No impact	Slightly positive	Strongly positive	Total
Industrial sector	F&B	2	3	22	0	1	28
	MACH	1	4	8	1	0	14
	MEM	1	3	7	1	1	13
	L&T	0	3	6	2	1	12
	T&F	1	3	7	0	0	11
	Total	5	16	50	4	3	78

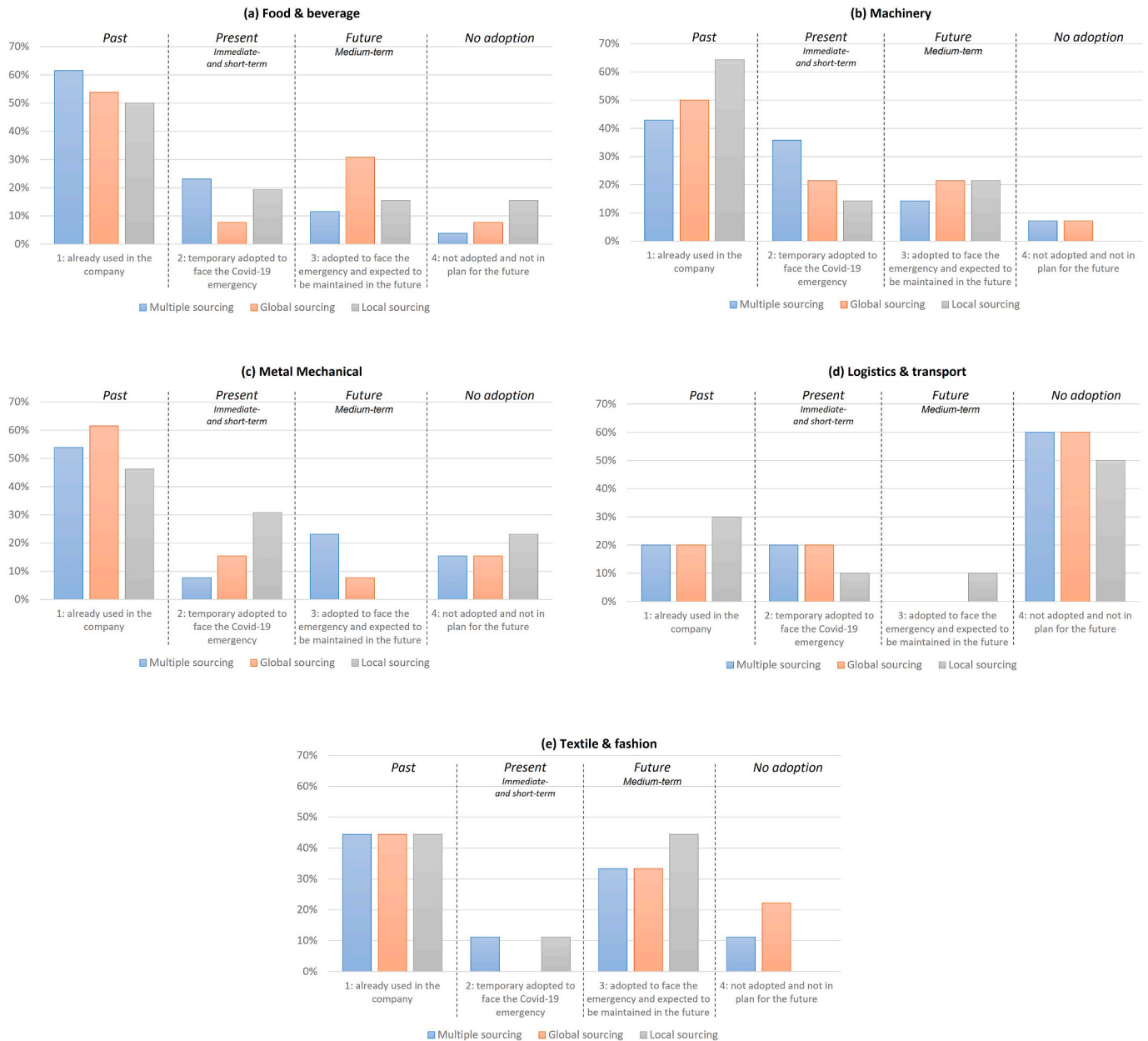


Fig. 6. (a–e): past, present, and future adoption of mitigation strategies across the different industry field - sourcing strategies.

them during the pandemic, being willing to maintain the chosen strategy after the end of the pandemic emergency.

Besides the sourcing strategies, two additional well-known countermeasures to (general) SC risks have been investigated; relating results are shown in Fig. 7(a and b) as a function of the industry field.

The outcomes show that, without remarkable differences across the

industrial fields, most of the companies have replied negatively to the possibility of increasing the stock level to counteract the pandemic emergency, being unwilling to implement that practice not now nor ever (Fig. 7(b)). This is particularly the case for companies belonging to L&T (60%) and T&F (67%) sectors. Nonetheless, the remaining quota of T&F companies (33%) has chosen to increase the inventory level during the

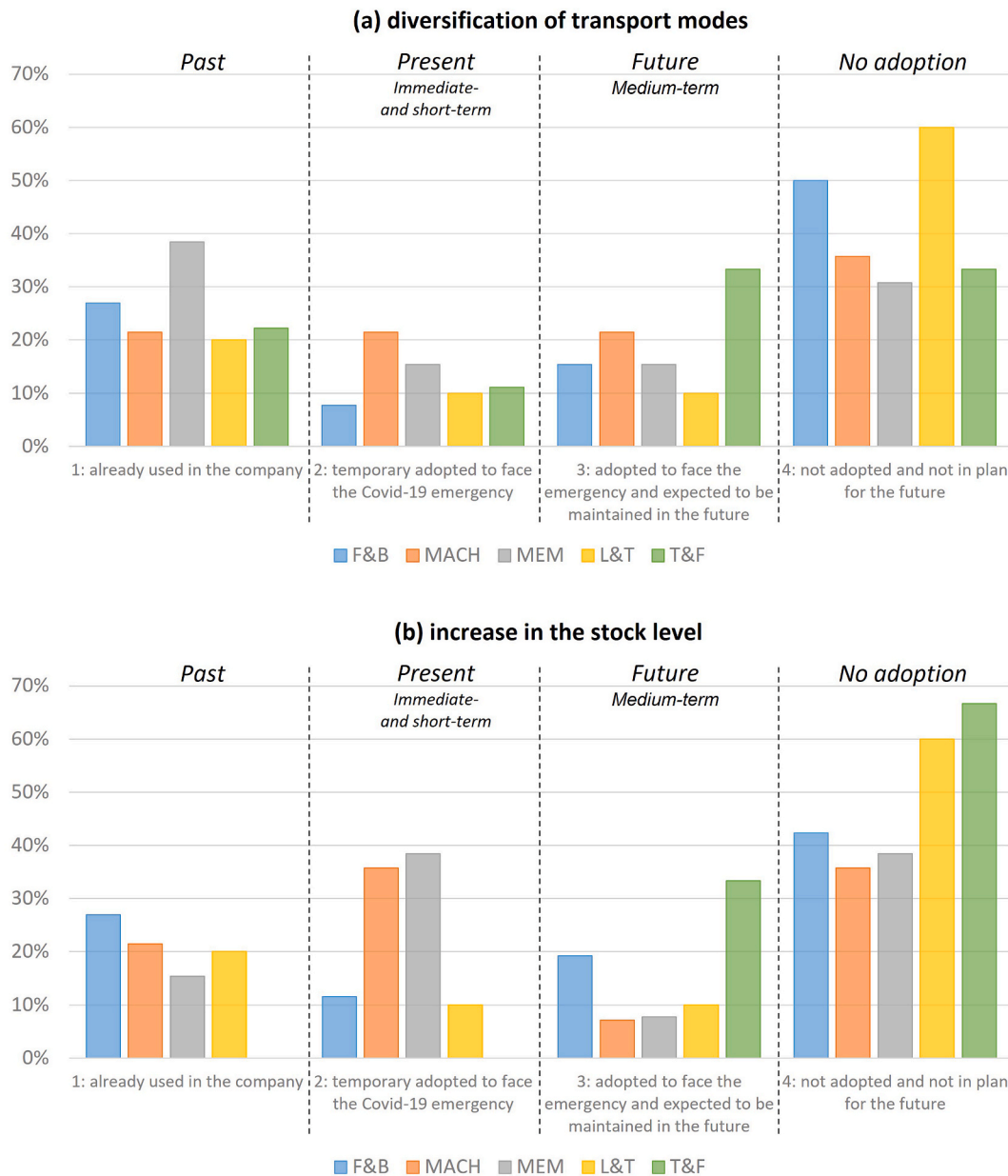


Fig. 7. (a–b): past, present and future adoption of mitigation strategies across the different industry field – increase in the stock level and diversification of transport modes (note: scale#1 is used).

pandemic emergency and is willing to maintain this practice to cope with unexpected interruptions along the SC in the future. Some MACH and MEM companies have temporarily implemented the same strategy, but, in general, they do not seem to be motivated in maintaining a high stock level after the pandemic.

Similar considerations can be made for the other strategy (Fig. 7(a)). Outcomes confirm that, without significant differences across the industry fields, in general the companies surveyed have not adopted the diversification of transport modes. Nonetheless, outcomes reveal that T&F companies are somehow predisposed to implement diversified transport modes: in fact, 33% of respondents have used this strategy to react to the pandemic and would like to maintain it in the future.

A last analysis was made for understanding the willingness of companies to favor (and thus increase) the future adoption of additional mitigation strategies, always suitable for counteracting the pandemic emergency, and linked to digitalization, Industry 4.0, and automation of processes. Results (Fig. 8) show that there is not a difference among the responses of the various sectors, since all respondents confirm the

importance of adopting these new strategies to rapidly react to future emergencies and mitigate the relating negative effects; the absence of statistically significant differences across the sectors also emerges from the ANOVA analysis. The main need for improving cooperation (strategy 1) and information sharing (strategy 2) have been observed in MEM, while F&B returned the highest score against process automation (strategy 3). This latter strategy is overall less considered than the remaining ones, and many companies seem not to be particularly interested in enhancing the implementation of Industry 4.0 technologies for improving process automation.

5. Discussion and implications

5.1. Answer to the research questions

Starting from the outcomes from the survey, the following considerations can be formulated for answering the RQs of this study.

Moving from a general evaluation of the impact of the Covid-19 on

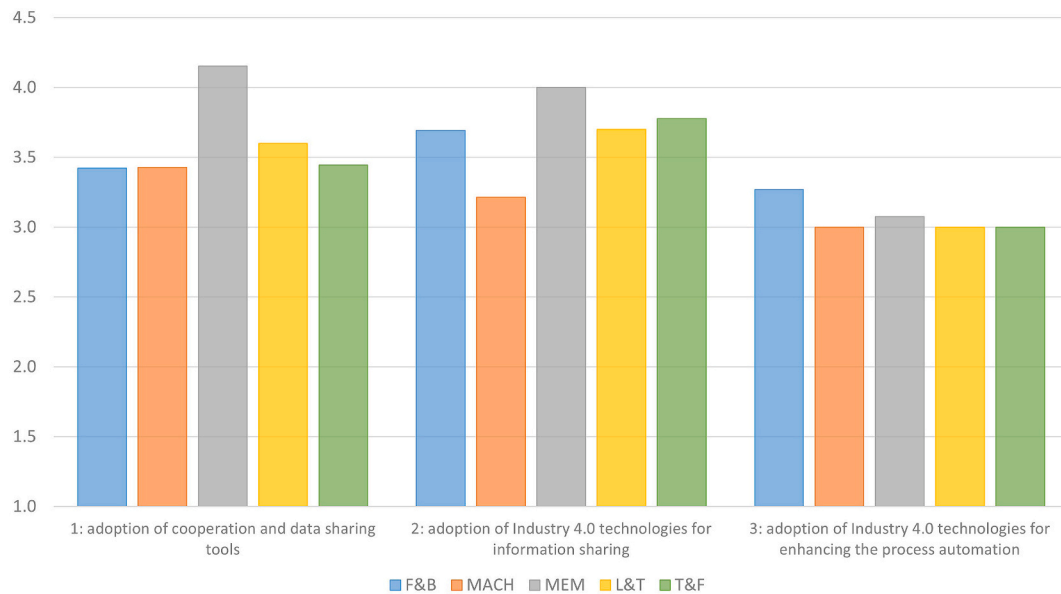


Fig. 8. Expected increase in the adoption of digital strategies in the future (note: scale#1 is used).

logistics and SC processes, results of this study allow formulating additional considerations along the horizon of analysis, focusing on difference in severity, duration and appearance of the impact across different industry fields. Our empirical analysis confirms a strong impact of Covid-19 on the volumes handled in the immediate term (Kraus et al., 2020), with positive or negative changes mainly depending on the peculiarity of goods (respectively essential vs. non-essential goods) (De Vet et al., 2021). However, although authors have suggested that the effects of Covid-19 have been different across the industrial sectors (Xu et al., 2020; De Vet et al., 2021), the available studies have provided evidence on some sectors only. While L&T, in its various segments, has been somehow discussed (e.g., Perkumiene et al. 2022; Hohenstein, 2022; Ketudat and Jeenanunta, 2021), other sectors (e.g., MACH or MEM) have been almost neglected in literature.

Also, the available knowledge about the impact of the pandemic has mainly focused on the early effects seen during the first pandemic wave (Hobbs, 2020; Ketudat and Jeenanunta, 2021), while the duration in time of these effects has not been so explored. The results of this work show that all sectors have restored the pre-Covid conditions at the end of the period of emergency and underline a gradual recovery with an important increase of sales in the short-term across all the sectors. In addition, although theory has so far considered the negative impact in service performance caused by disruptions (Magableh, 2021), the (very few) cross-sectorial studies about Covid-19 have not deepened the effect of the pandemics on the company's service performance, nor its duration in time, while focusing, more in general, on the company's financial performance (cf. Anakpo and Mishi, 2021). In this regard, results of this research provide evidence of the severity of that impact on service, highlighting that the worsening of service performance was in general light, particularly evident at the beginning of the pandemic emergency, and affected almost all industry fields. Instead, results from the short-term period generally show no significant variations in the service level, but also highlight the return to a critical situation for some sectors only during the third wave of Covid-19. This result is significant since it calls the attention to the strong difference in the propagation of disruptions among different business.

Starting from the F&B sector, the outcomes of this work generally confirm an increase in the volumes handled across the period considered (Borsellino et al., 2020; Loske, 2020). This is in line with the outcomes by Anakpo and Mishi (2021), who have found that food-related industry fields were likely to operate at their normal level during the Covid-19

period. Furthermore, this study also confirms that results for the F&B sector mainly depend on consumer-related factors, in line with the "impulse" or "panic" buying behavior against to food products (Hobbs, 2020); at the same time, we also show that this behavior was evident at the beginning of the pandemic emergency, but also had short-term effects, thus supporting the conclusion of generally changed food consumption habits by customers (Sgroi and Modica, 2022). Despite the increased requests, results also show that F&B was able to guarantee good service performance to customers, seeing only a slightly worse performance during the lockdown period, probably due to interruptions or limitations downstream the SC, which as well emerged as relevant causes of the change in the volumes handled.

Similarly, MACH seems not to have been significantly impacted by the Covid-19 pandemic in terms of sales volumes, which tended to increase in the whole period of analysis, albeit with a lower trend compared to F&B. Our results thus highlight that, even in the Italian context, the impact of Covid-19 on the MACH industry was particularly relevant at the very beginning of the pandemic emergency, as observed by Ando and Hayakawa (2022), with no effects in the short-term. This study also provides additional findings on the activity of the MACH sector, which was explored to a very limited extent in the literature. In particular, it is shown that this sector suffered because of interruptions downstream and upstream in the SC after the end of the early emergency period; this is in line with the type of business, since MACH companies usually work on an engineer-to-order basis, with very long delivery times and quite high dependency on their suppliers (Ando and Hayakawa, 2022). This is also reflected by the worsened service performance during the third wave, thus highlighting a delayed negative impact of the pandemic on the MACH sector.

The T&F and MEM sectors, instead, have been more severely affected by the pandemic outbreak which caused a significant decrease in volumes in the whole 2020, with a gradual recovery in 2021. While the available literature has typically indicated these sectors as the most affected by the pandemic (Cai and Luo, 2020), outcomes of this study better depict the effect of the Covid-19 in time and analyze the causes of variation. One of the key characteristics of T&F is that models and items offered on the market for sale try to capture the trends of the moment, with a very limited possibility to sell past collections in the future (Braglia et al., 2022). This makes T&F particularly exposed to risk of losing sales compared to other sectors and makes it essential for T&F companies to simultaneously ensure short lead times and low costs of

items, driven also by the “fast fashion” business model (Shen and Chen, 2019); this is true in normal situations and exacerbated in times of uncertainty, such as during the Covid-19 pandemic. In addition, as opposed to F&B, T&F is non-essential business, which led governments to order the closure of shops during the lockdown period. Our outcomes confirm that shop closure, coupled with limitation to people’s mobility, was the key cause of the observed decrease in volume in the T&F sector (Braglia et al., 2022). This study also adds considerations on interruptions in the SC, both at the supplier and production level, which emerged as important aspects as well, showing that T&F companies are particularly exposed to supply and production risks. Indeed, to enhance cost efficiency, fashion SCs typically spread worldwide, with production located in low-cost countries, such as China or India (McMaster et al., 2020); unfortunately, China was also the first country that had to face the Covid-19 pandemic, which caused a drastic reduction of supply availability. Moreover, causes of poor service performance have been investigated for extending the current knowledge. Our findings show that for T&F companies, supply delay or unavailability had consequences on the service performance, with stronger effects in 2020. Production delays and blocks of transport activities also had an important role in early worsening of the service performance, again in line with the global spread of the fashion SCs.

Focusing instead on the MEM industry, the available literature has provided some evidence on the automotive industry (Tamtam and Tourabi, 2021; Ghadir et al., 2022), which is a very specific segment of this sector; hence, results of these previous studies are not always suitable for a direct comparison with the present paper. Having said that, it is first to be observed that the drop in the volumes handled for the MEM industry appears as less relevant compared to T&F. Similar considerations hold true for the service level delivered to customers: MEM companies suffered from poor service performance mainly at the very beginning of the pandemic period, corresponding to the lockdown of many countries, but the pre-Covid conditions were easily restored. Findings of this study, therefore, indicate that no long-term effects of Covid-19 on volumes or service performance are to be expected in the future for MEM industries. Issues in the procurement phase have impacted on that sector, which reflects, once again, the characteristics of global MEM SCs, in which low-cost countries are usually identified as the main suppliers of raw materials and semi-finished products. Again, this adds knowledge to the results provided by Ghadir et al. (2022), who (more generically) reported “suppliers” and “suppliers’ temporary closure” among the top-10 risks associated to the automotive industry during the Covid-19 outbreak.

Finally, outcomes of this study show that the L&T field is somehow unique compared to the remaining sectors. Results from the current literature show that Covid-19 impacted on L&T, with some companies experiencing a negative impact and others being relatively less affected by the pandemic (Ketudat and Jeevanunta, 2021; Perkumiene et al., 2021). However, the analysis of different time horizons and the multi-sectorial perspective allows this study to provide additional findings. Overall, we can conclude that the trend in the volumes handled by L&T companies exhibits a prevalent increase, and even after six quarters, these volumes remain greater than those handled in the pre-Covid period. A similar outcome was suggested by Ketudat & Jeevanunta (2021): these authors found that one of the companies they analyzed experienced a decreased volume at the beginning of the pandemic, then a slow recovery from the volume loss, and finally (September 2021), the volume handled exceeded the loss.

At first glance, the prevalent increase experienced by the L&T sector could be justified on the basis of a possible correlation with the F&B industry, as results from this study show similarities between these sectors in terms of immediate-term trend and causes of the variation in the volumes handled; Ketudat & Jeevanunta (2021) have reported a similar consideration, observing that logistics companies handling food or medical products benefited from increased volume. Nonetheless, it is evident that L&T companies do not work with F&B companies only, but

with companies belonging to various industrial sectors, which also experienced a decrease in the volumes handled during the first months of the pandemic. Moreover, L&T differs from the remaining sectors in various aspects. In terms of service, it emerged as the only sector that did not experience variations during the lockdown period, and that exhibited generally good performance; this enhances the available literature, which lacks considerations about service performance of L&T companies. An explanation for this outcome is that logistics companies typically embrace various transport activities (e.g., rail, road, sea, or air freight services), as well as additional services (e.g., warehousing and distribution), but, most importantly, L&T is a highly creative sector, with great development potential and great ability to apply new/modern solutions and innovate itself in case of issues, such as disruptions (Klein et al., 2022).

The first evidence of this study on mitigation strategies is in line with the current literature: different strategies were used by the surveyed companies to counteract the Covid-19 emergency, either as temporary solutions or as definitive ones (Cai and Luo, 2020; Raj et al., 2022). In addition, our study captures differences across the sectors investigated and depending on the specific characteristics of the business, such as the SC structure or the production process. In general, our empirical findings confirm that immediate protective measures have been implemented by companies of any industrial field (Anakpo and Mishi, 2021), but apart from the (popular) usage of PPE, other measures are somehow industry-specific and were implemented in some sectors only. Also, the decision of maintaining some of them strongly depends on the kind of business and the impact the Covid-19 had on the specific sector. In general, industry fields that were particularly impacted by the pandemic emergency (e.g., T&F) are more interested in applying almost all the possible measures to mitigate SC disruptions, as well as to maintain these measures in the future, with the aim to make their business more resilient. A change in these business fields can thus be forecasted in the future. On the contrary, less affected sectors (e.g., L&T) have no interest in adopting new strategies to face the pandemic and are not expected to implement them to address post-Covid SC disruptions; in that case, no changes in the business are expected. Some typical mitigation strategies (unexpectedly) resulted to be not adopted in any sector, probably because of the unique behavior that the progress of Covid-19 had in time, which made it strongly different from other disruptions (Rinaldi et al., 2022). Regardless of the specific measures and concerning their general effects, we confirm a negative impact on the system’s cost, in line with Aday and Aday (2020). Moreover, our empirical results add significant considerations to the literature by providing further evidence on the slightly negative impact of the pandemic on the productivity, and on the (again unexpected) not appreciable effects on the service level provided by the companies.

Starting from the F&B sector, food companies involved in this study have highlighted the need to increase the usage of global sourcing strategy in the future. This measure is also indicated by the available literature as implemented strategy for guaranteeing the supply of raw materials and critical components (Zhu et al., 2020). This result is probably linked to the structure of food SCs, which consist of many players, and, depending on the final product, raw materials can be also numerous (Bottani et al., 2019). The lack of a critical raw material could compromise the production, thus preventing the possibility of reaching the final customer with finished products. In case of supply disruption, the food SC must be able to reconfigure its structure by resorting to alternative suppliers, possibly not involved in the disruption. Hence, these outcomes indicate that, in a short while, food companies could include in the procurement network suppliers located outside the own country or continent, increasing the likelihood of having the supplier available (Bottani et al., 2019; Koerber and Schiele, 2022). However, our empirical results add new information, by indicating that addressing new suppliers during a disruption is not feasible in F&B. This aspect could have encouraged F&B companies to develop substitute products with the available raw materials, as suggested by the food company

interviewed in the pre-testing phase. Similar considerations hold true for the diversification of transport modes, which is not adopted nor in plan for most of the F&B companies involved. If not already in place in the pre-Covid period, it is in general hard to think that a food company could introduce new transport modes during the pandemic period, as F&B requires specific transport conditions for guaranteeing the food preservation and transport tariffs have significantly increased in various countries worldwide (Mogaji, 2020). In addition, results show that the characteristics of the F&B sector have led companies to face the first stage of the pandemic without revising the production processes. Indeed, F&B production processes already have a good level of automation, and employees typically act as supervisors of these processes; this is expected to favor (by itself) the distance among workers. At the same time, however, food production processes are hard to change, because of the greater level of complexity compared to the remaining sectors, and the strict constraints and protocols about product quality and conformity. Empirical findings from this study also underline that digitalization within the food SC is an ongoing process, which is expected to be accelerated by the pandemic. This outcome is in line with the current literature, which highlights that any technology that facilitates social distancing, reduces business travels, and possibly increases food security (e.g., by providing reliable traceability data) is welcome in that sector (Hobbs, 2021a, 2021b).

A well-known trend in the MACH industry is the implementation of just in time and/or lean strategies, whose general aim is to reduce the inventory level to a minimum (Sanci et al., 2021). However, it is interesting to note that this is the only sector in which several companies have considered to temporarily increase the stock level to counteract the emergency (although they are not willing to maintain it in the future). Just in time and/or lean strategies are often coupled with single sourcing policies with one partner supplier, to take advantage of economic benefits of the partnership (lower transaction costs, higher quality, or specialization) and of opportunities for better coordinating the supplier's deliveries with the production schedule (Sanci et al., 2021). In line with these considerations, it is not surprising that MACH companies investigated in this study have indicated multiple sourcing as the most frequently adopted strategy in response to the Covid-19 emergency, for enabling the purchase of components from more suppliers and thus enhancing the robustness of the SC (also suggested by Ando and Hayakawa, 2022). Our results also confirm that MACH companies are fully convinced about the importance of global/transcontinental sourcing and do not plan to abandon this strategy despite the difficulties in transport due to the Covid-19 (Koeber and Schiele, 2022). Furthermore, contrary to F&B, some companies have started to introduce new transport modes during the pandemic, moving from road to rail to improve the on-time delivery and avoid issues linked to the limitation of movements between countries. Digitalization of the MACH industry, although could be accelerated by Covid-19 (Roosefert Mohan et al., 2022), was already at a quite good level in the pre-pandemic period (Yang et al., 2019). In addition, the pandemic has boosted firm investments in digital technologies and automation in many sectors, by increasing the requests and sales to MACH industries. Finally, it is also interesting to note that immediate protective measures focusing on reorganizing the employee's tasks have been judged as poorly adopted by respondents from the MACH sector; the peculiarities of the production activities, usually carried out by high skilled and not interchangeable workforce, prevented the possibility of adopting that strategy.

About the T&F field, our outcomes indicate that this is almost the only sector in which a relevant quota of respondents has indicated the diversification of transport modes as a strategy adopted to counteract the pandemic emergency and to be maintained in the future. That strategy, instead, is not so popular (and probably underestimated in its effectiveness) in the remaining industrial fields, while it appears as an effective response of the fashion SCs to the block of transport activities, which has particularly affected that sector. A further interesting outcome from this study is that none of the T&F companies surveyed

mentioned the increase in the stock level as an existing (pre-Covid) risk management strategy. The presence of high stock levels, indeed, contradicts the fact that many T&F companies work on a make-to-order basis (Braglia et al., 2022), as well as the characteristics of volatility, velocity and variety typical of the T&F context (McMaster et al., 2020). Another outcome of this study concerns the positive inclination towards investing in data and information sharing, which confirms the expected increase in the usage of information tools by T&F companies, for enhancing their online presence (also discussed by Achille and Zipser, 2020). The current literature indicates these results as an obvious effect of the Covid-19 and specifically of the closure of shops, which accelerated the shift towards a more digital world and triggered changes in consumer's behavior, shifting towards online shopping (Alderighi, 2021). Finally, the empirical findings of this study also underline that the adopted early preventive measures are in line with the pre-Covid low level of automation and the need of skilled workers which characterize the T&F sector.

Our findings about the MEM sector indicate that multiple sourcing and global sourcing were quite diffused among companies, which, coupled with the previous consideration, reinforces the idea that suppliers were located in low-cost countries and thus were particularly affected by the pandemic emergency. It is not surprising that the present study indicates the local sourcing as provisional countermeasure adopted by MEM companies to face the pandemic, coupled with the temporary increase in the stock level, which obviously enhances the resilience of the system. The trend for the future, instead, is to maintain past strategies; this confirms the previous consideration about the primary role of global/transcontinental sourcing for various industrial fields and the willingness to keep this strategy unchanged in the future (Koeber and Schiele, 2022). Our study has also shown that a quite relevant (compared to the remaining sectors) quota of MEM companies already makes use of different transport modes. Although the specific types of transport have not been investigated in the survey, from the interview carried out in the pre-testing it emerged that sea transport is frequently used when importing components from global suppliers or exporting finished products worldwide; intermodal transport can be used to the same extent, while road transport is mainly used for deliveries in Italy. Because of the problems in exchanging goods from/to China by sea, rail has started being used as the primary transport mode for long distances, to increase punctuality. A last outcome concerns the future adoption of data and information sharing tools, which was judged very positively by the companies surveyed. By the way, the current literature has already debated on the crucial role of digitalization for MEM, where it is expected to positively impact, among others, on traceability of assets (e.g., between the company's sites or facilities), production monitoring and communication among SC partners (Granillo-Macías et al., 2020). This result is also consonant with the usage of digital solutions as immediate countermeasure adopted to face the spread of the pandemic, grounding on the wide automation and digitalization started by this sector even before the pandemic itself. Similarly, the need for specialized manpower has limited the possibility of changing the operators' tasks and reorganizing the work shifts to guarantee the social distancing.

Once again, results of this study highlight some traits of uniqueness of the L&T field with respect to the adoption of mitigation strategies. L&T emerged the only sector that has no interest in applying any strategy among those typically used to counteract risks and disturbances in the SC. This result, although surprising at first glance, can be justified if thinking about the kind of activity carried out by L&T companies, as most of these companies will probably act as third-party logistics service providers. This outcome confirms the current literature, which identify the possibility to even increase the logistics services during the pandemic as more companies outsource SC and logistics activities (Perkumiene et al., 2021). Hence, the choice of increasing the stock level or to implement a given sourcing strategy does not apply to this sector. However, findings from this study reveal that some industry-specific countermeasures against Covid-19 were nonetheless adopted by L&T

companies, such as the revision of the allocation of items in the company's warehouse, or the definition of new procedures for loading/unloading of goods. These practices thus fit particularly L&T companies, because of the peculiarities of the logistics activities, while they are not popular in the remaining contexts. Instead, the only mitigation strategy of interest to L&T companies for a future implementation is the usage of data and information sharing tools (Twinn et al., 2020); however, the expected increase in the usage of these tools is not so striking.

5.2. Managerial implications

The present study also provides several practical implications and valuable suggestions for companies on how to manage disruption and post-disruption periods within their organizations and overall SCs. The primary lesson that emerged is the possibility for firms to exploit the acquired experience to convert the Covid-related disruptions into opportunities for improvement. As we found that mitigation measures typically did not involve consequences on service performance and productivity of companies, some of these measures can be maintained and even reinforced in the future. As far as their cost, this needs to be converted into an investment for the future for maintaining these measures. Hence, two key areas of strategic intervention arise from this study:

- a) Internal (Re-)organization: the strong variations in volumes and SC conditions resulting from this study have attested the importance of agility and digitalization; by the way it has long been known that "resilience implies agility" (Christopher and Peck, 2004). The promotion of agile work and agile processes needs a change in the vision of the company and the awareness that a new concept of work must be developed. The findings of this study reveal that smart working has been adopted to face the pandemic and guarantee the social distancing. However, once restored the pre-Covid conditions, this measure should be adapted to the industrial context, since it should no longer be conceived as the same work, simply made from home (Brown, 2008; Clack et al., 2019). Also, the implementation of this practice should be designed with the aim of capturing the peculiarities of the specific sector. New practices, new objectives, and new system to measure workers' performance should be also designed. Agile work also needs the revision of social relations and workspaces, reducing the space for individual offices (individual work can be performed at home), and increasing the space dedicated to social interaction and brainstorming (meeting, workshop, training, mentorship) (Holeman and Kane, 2020). At the same time, agile processes need the implementation of Industry 4.0 tools to provide digital and automated solutions to adopt in global and volatile markets. All the companies involved in this study have confirmed the importance of adopting these tools to rapidly react to pandemic and mitigate the relating negative effects. Hence, companies should consider the need to re-design the workspaces and revise the working processes to allow for smart technologies to support more and more the human work. Technology should be pulled and not pushed by the manufacturing system (Tortorella et al., 2023), and the organizational conditions should be prepared for automation and digitalization before their adoption.
- b) External (Re-)organization: if our findings indicate that the implemented countermeasures strongly depend on the industrial sector, it is equally clear that all the sectors attribute to other SC players the cause of the change experienced in volumes and service performance. The only difference is observed in the origin of the perturbation, which mainly comes from the upstream (MACH, and MEM) or downstream (F&B, L&T, and T&F) the SC. This result should encourage companies to adopt or maintain in the future all the measures aiming to enhance the robustness of the whole network. It is interesting to note from this study that, regardless of the industry

field, the diversification of the sourcing strategy has been considered as a winning practice to manage unexpected interruptions along the SC. On the contrary, outcomes reveal that only sectors mainly structured in global SCs (T&F, MEM, and MACH) have considered the diversification of transport modes to overcome the difficulties in transport due to the Covid-19. Some authors have reported that among the future effects of the Covid-19, a decrease in transport activities could be expected, as global SCs will become less global, being distant destinations perceived as less reliable than closer ones (Alderighi, 2021); other authors, instead, claim that global/transcontinental transport will not be affected by medium-/long-term effects of the pandemic, as various industrial fields cannot do without global sourcing strategies (Koerber and Schiele, 2022). Looking at the outcomes of this study, most of the companies surveyed declared not to be predisposed to change their transport modes; however, the evidence on the L&T field seems to support the idea that Covid-19 will not involve a decrease in transport activities in the future; this should lead companies to reflect on the possibility to revise the organization of transport to increase resilience of its business.

5.3. Future research directions

This study is expected to fuel various lines of research, by offering, in the meanwhile, reliable data that could help researchers gain a deep understanding of Covid-19 related phenomena. The following research directions are suggested for future studies:

- the future role of L&T companies and the medium-/long-term effect of Covid-19 on L&T activities need further analysis. Outcomes of our study suggest that Covid-19 will not involve a decrease in the demand of L&T services in the short-/medium-term, but the fact that some industry fields investigated experienced a decrease in the volumes handled could somehow contradict that conclusion. Repeating an analysis similar to that made in this paper in a suitable time (e.g., one year) or carrying out a dedicated empirical study targeting L&T companies would allow to derive additional insights on this topic;
- more in general, dedicated analyses, in the form of surveys or case studies, would be appropriate for each of the sector investigated in this paper, to increase the level of detail of the results obtained;
- similar behaviours were observed for some sectors (e.g., F&B and L&T), which seems to suggest correlations and interdependences across industries. Analysing these aspects was out of scope for the present study, but could represent an interesting future research step;
- to enhance the generalization of the outcomes, other sectors could be taken into consideration for expanding the present analysis and gaining further insights. Similarly, an enlarged sample of companies could be analyzed in the near future to further substantiate the outcomes observed.

6. Conclusions

This paper has proposed an empirical survey whose aim was to investigate the impact of Covid-19 pandemic on logistics processes, looking at five different industry fields and considering a time span of 18-month (from January 2020 to June 2021). As such, this study contributes to the literature in various ways. First, it fuels the debate about the relationships between Covid-19 and logistics and supply chain activities across different sectors and periods, which, despite the wide literature on Covid-19, is not so investigated. Second, it reports real (empirical) data on various industry fields; this is an important point, as some industrial sectors have been widely investigated as far as the impact of Covid-19 (e.g., F&B), while other (e.g., MEM or MACH) have been significantly less explored. Also, even if looking at well-debated industry fields, empirical studies on the impact of Covid-19 are still limited and the available studies often refer to contexts outside Europe,

with no studies carried out in Italy.

At the same time, the fact that our research sample consists of companies from Italy only could be seen as a limitation. Actually, focusing the analysis on a specific country is a common procedure in empirical studies targeting industry fields, and is often an effective approach, since the country delimitation offers a homogeneous context among the firms investigated. In this specific case, also restrictions imposed by the Italian government across the considered periods are homogeneous among and into sectors; this makes the sample suitable for the proposed analysis. Unfortunately, however, a country-specific study could reduce the potential for generalizing our findings. Hence, it is recommended to conduct future studies in other international contexts, in which different scenarios could have affected the same sectors in different ways.

Authors contribution

Conceptualization (Ideas; formulation or evolution of overarching research goals and aims) Marta Rinaldi; Eleonora Bottani. Methodology (Development or design of methodology; creation of models) Eleonora Bottani. Software (Programming, software development; designing computer programs; implementation of the computer code and supporting algorithms; testing of existing code components) Not applicable. Validation (Verification, whether as a part of the activity or separate, of the overall replication/reproducibility of results/experiments and other research outputs) Not applicable. Formal analysis (Application of statistical, mathematical, computational, or other formal techniques to analyze or synthesize study data) Marta Rinaldi; Eleonora Bottani. Investigation (Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection) Marta Rinaldi; Eleonora Bottani, Resources (Provision of study materials,

reagents, materials, patients, laboratory samples, animals, instrumentation, computing resources, or other analysis tools) Not applicable, Data Curation (Management activities to annotate (produce metadata), scrub data and maintain research data (including software code, where it is necessary for interpreting the data itself) for initial use and later reuse) Marta Rinaldi, Writing - Original Draft (Preparation, creation and/or presentation of the published work, specifically writing the initial draft, including substantive translation) Marta Rinaldi; Eleonora Bottani. Writing - Review & Editing (Preparation, creation and/or presentation of the published work by those from the original research group, specifically critical review, commentary or revision – including pre-or postpublication stages) Eleonora Bottani, Marta Rinaldi, Visualization (Preparation, creation and/or presentation of the published work, specifically visualization/data presentation)Marta Rinaldi; Eleonora Bottani. Supervision (Oversight and leadership responsibility for the research activity planning and execution, including mentorship external to the core team) Eleonora Bottani. Project administration (Management and coordination responsibility for the research activity planning and execution) Not applicable. Funding acquisition (Acquisition of the financial support for the project leading to this publication) Not applicable.

Data availability

Data will be made available on request.

Acknowledgment

The authors wish to express their thanks to all the companies for their participation in this work.

Appendix 1

Table A- 1

Scheme of the questionnaire used in the survey

Sections	Items	Question type (scale)
Section 1: general questions	Respondent’s area of expertise	Open question
	Respondent’ role in the company	Open question
	Industry field	Closed question (response options)
	Number of employees	Closed question (response options)
Section 2: impact of Covid-19 on the sales volumes	Annual turnover	Closed question (response options)
	Please rate the increase in the volumes handled by the company compared to 2019, from Q1 to Q6	Closed question (scale #1)
	Please rate the decrease in the volumes handled by the company compared to 2019, from Q1 to Q6	Closed question (scale #1)
	Please rate the role of the following causes in determining a change in the sales volume:	Closed question (scale #1)
	1. Demand variation	
	2. Consumer habits variation	
	3. Limitation of import/export of raw materials and finished products	
Section 3: impact of Covid-19 on service quality	4. Limitation to people movements	
	5. Plant closure	
	6. Interruption of activities of the Italian suppliers	
	7. Interruption of activities of the foreign suppliers	
	8. Interruption of activities of customers	
	9. Absenteeism.	
	Please rate the changes in the following service performance, from Q1 to Q6:	Closed question (scale #2)
1. On-time delivery		
2. Order quality		
3. Delivery lead time		
Please rate the role of the following causes in determining a change in the service performance:	Closed question (scale #1)	
1. Blocking of transport activities due to lockdowns		
2. Production delays		
3. Supplier delays		

(continued on next page)

Table A- 1 (continued)

Sections	Items	Question type (scale)	
Section 4: impact of Covid-19 on work organization	Please rate the level of usage of the following measures in response to the Covid-19 emergency:	Closed question (scale #1)	
	1. Re-layout of workspace and offices		
	2. Smart working practices		
	3. Revisited allocation of items in the company's warehouse		
	4. Revision of the production activities for enhancing the social distance		
	5. Reduced number of employees per work shift		
	6. Changes to the operator's tasks		
	7. Sanitization of equipment between work shifts		
	8. Usage of digital systems to reduce physical contacts		
	9. Usage of personal protective equipment (PPE)		
	10. Usage of protective barriers between workstations		
Section 5: impact of Covid-19 on present and future decision-making strategies	11. Introduction of rules for loading/unloading of goods.	Closed question (scale #2)	
	Please rate the impact of the above measures on the following company's performance:		
	1. Costs		
	2. Productivity		
Section 5: impact of Covid-19 on present and future decision-making strategies	3. Service level	Closed question (ad hoc 4-point scale)	
	Please rate the level of usage of the following strategies:		
	1. Sourcing strategies: multiple sourcing, global sourcing, and local sourcing		
	2. Increase in the stock level		
	3. Diversification of transport modes		
	Please rate the level of usage of the following digital solutions in the future:		Closed question (scale #1)
	1. Cooperation and data sharing tools downstream and upstream the SC		
2. Industry 4.0 technologies for a rapid and safe information sharing			
Section 5: impact of Covid-19 on present and future decision-making strategies	3. Industry 4.0 technologies for enhancing the process automation	Closed question (scale #1)	

Appendix 2

Table A- 2

Details of the statistical tests (Note: statistically significant outcomes at $p < 0.05$ are highlighted)

RQ	Item tested	Details	F-value	Sign.
1	Increase in the sales volume vs. industry field (ref. Fig. 1(a))	Q1	1.371	0.245
		Q2	4.666	0.001
		Q3	3.662	0.005
		Q4	1.932	0.099
		Q5	0.990	0.430
		Q6	1.957	0.095
1	Decrease in the sales volume vs. industry field (ref. Fig. 1(b))	Q1	1.018	0.413
		Q2	3.267	0.010
		Q3	2.272	0.056
		Q4	1.817	0.119
		Q5	0.676	0.643
		Q6	1.406	0.232
1	Impact of factors on the variation of sales volume vs. industry field (ref. Fig. 2)	demand variation	0.998	0.425
		consumer habits variation	1.402	0.233
		limitation of import/export of raw materials and finished products	0.784	0.564
		limitation to people movements	1.357	0.250
		plant closure	1.501	0.199
		interruption of activities of the Italian suppliers	3.416	0.008
		interruption of activities of the foreign suppliers	3.133	0.013
		interruption of activities of customers	1.537	0.188
		absenteeism.	0.774	0.571
		1	Variation of service parameters vs. industry field - on time delivery (ref. Fig. 3(a))	Q1
Q2	1.383			0.240
Q3	1.567			0.180
Q4	0.910			0.479
Q5	2.473			0.039
Q6	1.284			0.279
1	Variation of service parameters vs. industry field - order quality (ref. Fig. 3(b))	Q1	0.492	0.781
		Q2	1.698	0.145
		Q3	1.405	0.232
		Q4	0.918	0.474
		Q5	1.084	0.376
		Q6	0.896	0.488
1	Variation of service parameters vs. industry field - delivery lead time (ref. Fig. 3(c))	Q1	0.991	0.429
		Q2	1.776	0.128
		Q3	1.705	0.143
		Q4	0.863	0.510
		Q5	2.861	0.020

(continued on next page)

Table A- 2 (continued)

RQ	Item tested	Details	F-value	Sign.
1	Causes of variation of service performance vs. industry field - block in transport activities (ref. Fig. 4(a))	Q6	4.319	0.002
		Q1	1.997	0.088
		Q2	4.287	0.002
		Q3	4.047	0.003
		Q4	1.577	0.177
		Q5	1.413	0.229
1	Causes of variation of service performance vs. industry field - production delays (ref. Fig. 4(b))	Q6	1.433	0.222
		Q1	1.555	0.183
		Q2	2.506	0.037
		Q3	2.672	0.028
		Q4	2.474	0.039
		Q5	2.237	0.059
1	Causes of variation of service performance vs. industry field - supply delays (ref. Fig. 4(c))	Q6	2.365	0.047
		Q1	1.179	0.327
		Q2	2.091	0.076
		Q3	1.856	0.112
		Q4	1.341	0.256
		Q5	2.017	0.086
2	Usage of the preventive strategies adopted by companies vs. industry field (ref. Fig. 5)	Q6	2.515	0.037
		re-layout of workspace and offices:	0.496	0.779
		smart working practices	2.533	0.035
		revisited allocation of items in the company's warehouse	1.416	0.228
		revision of the production activities for enhancing the social distance	1.907	0.103
		reduced number of employees per work shift	1.262	0.289
		changes to the operator's tasks	1.509	0.197
		sanitization of equipment between work shifts	0.863	0.510
		usage of digital systems to reduce physical contacts	2.486	0.038
		usage of personal protective equipment (PPE)	1.525	0.192
		usage of protective barriers between workstations	1.033	0.404
		introduction of rules for loading/unloading of goods	0.867	0.507
2	Impact of the preventive strategies vs. industry field (ref. Tables 2–4)	on cost	0.337	0.889
		on productivity	0.462	0.803
2	Past, present and future adoption of mitigation strategies vs. industry field (ref. Fig. 6(a-e))	on service level	0.595	0.704
		sourcing strategies - multiple sourcing	2.660	0.029
		sourcing strategies - global sourcing	2.164	0.067
		sourcing strategies - local sourcing	1.461	0.212
		increase in the stock level	1.178	0.328
		diversification of transport modes	0.539	0.746
2	Level of adoption of digital solution in the future vs. industry field (ref. Fig. 8)	cooperation and data sharing tools downstream and upstream the SC	0.986	0.432
		Industry 4.0 technologies for a rapid and safe information sharing	0.651	0.662
		Industry 4.0 technologies for enhancing the process automation	0.747	0.591

References

- Achille, A., Zipser, D., 2020. A perspective for the luxury-goods industry during—and after—coronavirus. McKinsey & Company, p. 1.
- Aday, S., Aday, M.S., 2020. Impact of COVID-19 on the food supply chain. *Food Quality and Safety* 4 (4), 167–180. <https://doi.org/10.1093/fqsafe/fyaa024>.
- Agba, A.M.O., Ocheni, S.I., Agba, M.S., 2020. COVID-19 and the world of work dynamics: a critical review. *Journal of Educational and Social Research* 10 (5), 119–130. <https://doi.org/10.36941/jesr-2020-0093>.
- Alderighi, M., 2021. Il post pandemia: l'effetto di lungo termine sulle attività economiche. *EyesReg* 11 (3). Available at: <https://www.eyesreg.it/2021/il-post-pandemia-leffetto-di-lungo-termine-sulle-attivita-economiche>.
- Al-Hyari, K., 2020. Initial empirical evidence on how Jordanian manufacturing SMEs cope with the COVID-19 pandemic. *Acad. Strat. Manag. J.* 19, 1–12.
- Altig, D., Baker, S., Barrero, J.M., Bloom, N., Bunn, P., Chen, S., Thwaites, G., 2020. Economic uncertainty before and during the COVID-19 pandemic. *J. Publ. Econ.* 191 <https://doi.org/10.1016/j.jpubeco.2020.104274> article no. 104274.
- Anakpo, G., Mishi, S., 2021. Business response to COVID-19 impact: effectiveness analysis in South Africa. *Southern African Journal of Entrepreneurship and Small Business Management* 13 (1), 1–7. <https://doi.org/10.4102/SAJESBM.V13I1.397>.
- Ando, M., Hayakawa, K., 2022. Does the import diversity of inputs mitigate the negative impact of COVID-19 on global value chains? *J. Int. Trade Econ. Dev.* 31 (2), 299–320. <https://doi.org/10.1080/09638199.2021.1968473>.
- Ardjmand, E., Singh, M., Shakeri, H., Tavasoli, A., Young II, W.A., 2021. Mitigating the risk of infection spread in manual order picking operations: a multi-objective approach. *Appl. Soft Comput.* 100 <https://doi.org/10.1016/j.asoc.2020.106953> article no. 106953.
- Ardolino, M., Bacchetti, A., Ivanov, D., 2022. Analysis of the COVID-19 pandemic's impacts on manufacturing: a systematic literature review and future research agenda. *Oper. Manag. Res.* 1–16. <https://doi.org/10.1007/s12063-021-00225-9>.
- Baghersad, M., Zobel, C.W., 2021. Assessing the extended impacts of supply chain disruptions on firms: an empirical study. *Int. J. Prod. Econ.* 231 <https://doi.org/10.1016/j.ijpe.2020.107862> article no. 107862.
- Balakrishnan, A.S., Ramanathan, U., 2021. The role of digital technologies in supply chain resilience for emerging markets' automotive sector. *Supply Chain Manag.* 26 (6), 654–671.
- Belhadi, A., Kamble, S., Jabbar, C.J.C., Gunasekaran, A., Ndubisi, N.O., Venkatesh, M., 2021. Manufacturing and service supply chain resilience to the COVID-19 outbreak: lessons learned from the automobile and airline industries. *Technol. Forecast. Soc. Change* 163, 120447 article no.
- Borsellino, V., Kaliji, S.A., Schimmenti, E., 2020. COVID-19 drives consumer behaviour and agro-food markets towards healthier and more sustainable patterns. *Sustainability* 12 (20). <https://doi.org/10.3390/su12208366> article no. 8366.
- Bottani, E., Bottari, B., Milanese, D., Montanari, R., Sciancalepore, C., Volpi, A., Solari, F., Tebaldi, L., 2022a. Re-engineering of a food oven for thermal sanitization of Personal Protective Equipment against Sars-CoV-2 virus. *Sustain. Futures* 4. <https://doi.org/10.1016/j.sfr.2022.100093> article no. 100093.
- Bottani, E., Bigliardi, B., Rinaldi, M., 2022b. Logistics Management in the COVID-19 Period: a Case Study in the Food Sector. *Proceedings of the 8th International Food Operations & Processing Simulation Workshop (FoodOPS 2022)*, September 19–21, Rome, Italy. Paper ID: 93.
- Bottani, E., Murino, T., Schiavo, M., Akkerman, R., 2019. Resilient food supply chain design: modelling framework and metaheuristic solution approach. *Comput. Ind. Eng.* 135, 177–198. <https://doi.org/10.1016/j.cie.2019.05.011>.
- Braglia, M., Marrazzini, L., Padellini, L., 2022. The impact of COVID-19 on the Italian footwear supply chain of small and medium-sized enterprises (SMEs)—evaluation of two case studies. *Design* 6 (2). <https://doi.org/10.3390/designs6020023>.

- Brown, T., 2008. Design thinking. *Harv. Bus. Rev.* 86 (6), 1–10.
- Butt, A.S., 2021. Strategies to mitigate the impact of COVID-19 on supply chain disruptions: a multiple case analysis of buyers and distributors. *Int. J. Logist. Manag.* 11 <https://doi.org/10.1108/IJLM-11-2020-0455>.
- Butt, A.S., 2022. Building resilience in retail supply chains: lessons learned from COVID-19 and future pathways. *Benchmarking* 29 (10), 3057–3078. <https://doi.org/10.1108/BLJ-09-2021-0514>.
- Cai, M., Luo, J., 2020. Influence of COVID-19 on manufacturing industry and corresponding countermeasures from supply chain perspective. *J. Shanghai Jiaot. Univ.* 25 (4), 409–416. <https://doi.org/10.1007/s12204-020-2206-z>.
- Clack, L., Stühlinger, M., Meier, M.-., Wolfensberger, A., Sax, H., 2019. User-centred participatory design of visual cues for isolation precautions. *Antimicrob. Resist. Infect. Control* 8 (1). <https://doi.org/10.1186/s13756-019-0629-9>.
- Chiappetta Jabbour, C.J., Sobreiro, V.A., Lopes de Sousa Jabbour, A.B., de Souza Campos, L.M., Mariano, E.B., Renwick, D.W.S., 2019. An analysis of the literature on humanitarian logistics and supply chain management: paving the way for future studies. *Ann. Oper. Res.* 283 (1), 289–307. <https://doi.org/10.1007/s10479-017-2536-x>.
- Choi, T.M., 2021. Risk analysis in logistics systems: a research agenda during and after the COVID-19 pandemic. *Transport. Res. E Logist. Transport. Rev.* 145 <https://doi.org/10.1016/j.tre.2020.102190> article no. 102190.
- Chopra, S., Sodhi, M., 2004. Managing risk to avoid supply chain breakdown. *MIT Sloan Manag. Rev.* 46, 53–61.
- Chowdhury, P., Paul, S.K., Kaisar, S., Muktadir, M.A., 2021. COVID-19 pandemic related supply chain studies: a systematic review. *Transport. Res. E Logist. Transport. Rev.* 148 <https://doi.org/10.1016/j.tre.2021.102271> article no. 102271.
- Christopher, M., 1987. *Effective Logistics Management*. GowerPublishing Co., Cambridge.
- Christopher, M., Peck, H., 2004. Building the resilient supply chain. *Int. J. Logist. Manag.* 15 (2), 1–14.
- De Vet, J.M., Nigohosyan, D., Ferrer, J.N., Gross, A.K., Kuehl, S., Flickenschild, M., 2021. Impacts of the COVID-19 Pandemic on EU Industries. *European Parliament, Strasbourg, Francuska*, pp. 1–86.
- Dolgui, A., Ivanov, D., 2021. Ripple effect and supply chain disruption management: new trends and research directions. *Int. J. Prod. Res.* 59 (1), 102–109. <https://doi.org/10.1080/00207543.2021.1840148>.
- El Baz, J., Ruel, S., 2021. Can supply chain risk management practices mitigate the disruption impacts on supply chains' resilience and robustness? Evidence from an empirical survey in a COVID-19 outbreak era. *Int. J. Prod. Econ.* 233, 107972 <https://doi.org/10.1016/j.ijpe.2020.107972>.
- European Commission, 2003. Commission Recommendation 2003/361/EC of 6 May 2003 Concerning the Definition of Micro, Small and Medium-Sized Enterprises. Official Journal of the European Union. L124 of 20 May 2003. <https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:124:0036:0041:en:PDF>.
- Fitriarsari, F., 2020. How do small and medium enterprise (SME) survive the COVID-19 outbreak? *Jurnal Inovasi Ekonomi* 5 (2), 53–62.
- Fortis, M., Sartori, A., 2016. *Pillars of the Italian Economy*. Springer International Publishing Switzerland, Cham.
- Gereffi, G., 2020. What does the COVID-19 pandemic teach us about global value chains? The case of medical supplies. *J. Int. Bus. Pol.* 3, 287–301. <https://doi.org/10.1057/s42214-020-00062-w>.
- Ghadir, A.H., Vandchali, H.R., Fallah, M., Tirkolaei, E.B., 2022. Evaluating the impacts of COVID-19 outbreak on supply chain risks by modified failure mode and effects analysis: a case study in an automotive company. *Ann. Oper. Res.* <https://doi.org/10.1007/s10479-022-04651-1>.
- Granillo-Macías, R., Simón-Marmolejo, I., González-Hernández, I.J., Zuno-Silva, J., 2020. Traceability in industry 4.0: a case study in the metal-mechanical sector. *Acta Logistica* 7 (2), 95–101. <https://doi.org/10.22306/al.v7i2.162>.
- Green, N., Tappin, D., Bentley, T., 2020. Working from home before, during and after the Covid-19 pandemic: implications for workers and organisations. *N. Z. J. Employ. Relat.* 45 (2), 5–16.
- Henkel, M., Boffelli, A., Olhager, J., Kalchschmidt, M., 2022. A case survey of offshoring–backshoring cases: the influence of contingency factors. *Int. J. Prod. Econ.* 253 <https://doi.org/10.1016/j.ijpe.2022.108615>.
- Hobbs, J.E., 2020. Food supply chains during the COVID-19 pandemic. *Can. J. Agric. Econ./Revue can. d'agroeconomie* 68 (2), 171–176. <https://doi.org/10.1111/cjag.12237>.
- Hobbs, J.E., 2021a. The Covid-19 pandemic and meat supply chains. *Meat Sci.* 181 <https://doi.org/10.1016/j.meatsci.2021.108459> article no. 108459.
- Hobbs, J.E., 2021b. Food supply chain resilience and the COVID-19 pandemic: what have we learned? *Can. J. Agric. Econ.* 69 (2), 189–196. <https://doi.org/10.1111/cjag.12279>.
- Hohenstein, N.O., 2022. Supply chain risk management in the COVID-19 pandemic: strategies and empirical lessons for improving global logistics service providers' performance. *Int. J. Logist. Manag.* <https://doi.org/10.1108/IJLM-02-2021-0109>.
- Holeman, I., Kane, D., 2020. Human-centered design for global health equity. *Inf. Technol. Dev.* 26 (3), 477–505. <https://doi.org/10.1080/02681102.2019.1667289>.
- Italian Institute of Statistics, 2019. *Annuario statistico italiano - cap.14: imprese*. <https://www.istat.it/it/files/2019/12/C14.pdf>.
- Italian Institute of Statistics, 2021a. *Rapporto sulla competitività dei settori produttivi - Edizione 2021*. Available at: <https://www.istat.it/storage/settori-produttivi/2021/Rapporto-competitivita%20C3%A0.pdf>.
- Italian Institute of Statistics, 2021b. *Fatturato dell'industria*. https://www.istat.it/it/files/2021/08/foit_202106.pdf.
- Ivanov, D., 2020. Predicting the impacts of epidemic outbreaks on global supply chains: a simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case. *Transport. Res. E Logist. Transport. Rev.* 136 <https://doi.org/10.1016/j.tre.2020.101922> article no. 101922.
- Ivanov, D., 2021a. Supply chain viability and the COVID-19 pandemic: a conceptual and formal generalisation of four major adaptation strategies. *Int. J. Prod. Res.* 59 (12), 3535–3552. <https://doi.org/10.1080/00207543.2021.1890852>.
- Ivanov, D., 2021b. Exiting the COVID-19 pandemic: after-shock risks and avoidance of disruption tails in supply chains. *Ann. Oper. Res.* 1–18. <https://doi.org/10.1007/s10479-021-04047-7>.
- Ivanov, D., Dolgui, A., 2020. Viability of intertwined supply networks: extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak. *Int. J. Prod. Res.* 58 (10), 2904–2915. <https://doi.org/10.1080/00207543.2020.1750727>.
- Ivanov, D., Dolgui, A., 2021. OR-methods for coping with the ripple effect in supply chains during COVID-19 pandemic: managerial insights and research implications. *Int. J. Prod. Econ.* 232, 107921 <https://doi.org/10.1016/j.ijpe.2020.107921>.
- Ketudat, S., Jeenanunta, C., 2021. Impact of the COVID-19 pandemic on logistics firms and their resilience: case studies in Thailand. *Eng. Manag. Prod. Services* 13 (3), 86–98. <https://doi.org/10.2478/emj-2021-0023>.
- Khan, S.A.R., Razzaq, A., Yu, Z., Shah, A., Sharif, A., Janjua, L., 2021. Disruption in food supply chain and undernourishment challenges: an empirical study in the context of Asian countries. *Soc. Econ. Plann. Sci.* 82 <https://doi.org/10.1016/j.seps.2021.101033> article no. 101033.
- Klein, M., Gutowska, E., Gutowski, P., 2022. Innovations in the T&L (transport and logistics) sector during the COVID-19 pandemic in Sweden, Germany and Poland. *Sustainability* 14 (6). <https://doi.org/10.3390/su14063323>.
- Koerber, T., Schiele, H., 2022. Is COVID-19 a turning point in stopping global sourcing? Differentiating between declining continental and increasing transcontinental sourcing. *J. Global Oper. Strategic Sourc.* 15 (2), 219–234. <https://doi.org/10.1108/JGOSS-02-2021-0018>.
- Korankye, B., 2020. The impact of global covid-19 pandemic on small and medium enterprises in Ghana. *Int. J. Manag. Account. Econ.* 7 (6), 255–276.
- Kraus, S., Clauss, T., Breier, M., Gast, J., Zardini, A., Tiberius, V., 2020. The economics of COVID-19: initial empirical evidence on how family firms in five European countries cope with the corona crisis. *Int. J. Entrepreneurial Behav. Res.* 26 (5), 1067–1092. <https://doi.org/10.1108/IJEBR-04-2020-0214>.
- Kwon, O.K., 2020. How is the COVID-19 pandemic affecting global supply chains, logistics, and transportation? *J. Int. Logistics Trade* 18 (3), 107–111. <https://doi.org/10.24006/jilt.2020.18.3.107>.
- Li, Y., Chen, K., Collignon, S., Ivanov, D., 2021. Ripple effect in the supply chain network: forward and backward disruption propagation, network health and firm vulnerability. *Eur. J. Oper. Res.* 291 (3), 1117–1131. <https://doi.org/10.1016/j.ejor.2020.09.053>.
- Lomax, R.G., 2007. *Statistical Concepts: A Second Course*, 978-0-8058-5850-1.
- Loske, D., 2020. The impact of COVID-19 on transport volume and freight capacity dynamics: an empirical analysis in German food retail logistics. *Transp. Res. Interdiscip. Perspect.* 6 <https://doi.org/10.1016/j.trip.2020.100165> article no. 100165.
- Lutfi, M., Buntuang, P.C.D., Kornelius, Y., Hasanuddin, B., 2020. The impact of social distancing policy on small and medium-sized enterprises (SMEs) in Indonesia. *Probl. Perspect. Manag.* 18 (3), 492. [https://doi.org/10.21511/ppm.18\(3\).2020.40](https://doi.org/10.21511/ppm.18(3).2020.40).
- Magable, G.M., 2021. Supply chains and the COVID-19 pandemic: a comprehensive framework. *Eur. Manag. Rev.* 18 (3), 363–382. <https://doi.org/10.1111/emre.12449>.
- Malhotra, M.K., Grover, V., 1998. An assessment of survey research in POM: from constructs to theory. *J. Oper. Manag.* 16, 407–425. [https://doi.org/10.1016/S0272-6963\(98\)00021-7](https://doi.org/10.1016/S0272-6963(98)00021-7).
- McMaster, M., Nettleton, C., Tom, C., Xu, B., Cao, C., Qiao, P., 2020. Risk management: rethinking fashion supply chain management for multinational corporations in light of the Covid-19 outbreak. *J. Risk Financ. Manag.* 13, 173. <https://doi.org/10.3390/jrfm13080173>.
- Milzam, M., Mahardika, A., Amalia, R., 2020. Corona virus pandemic impact on sales revenue of micro small and medium enterprises (MSMEs) in Pekalongan City, Indonesia. *J. Vocational Stud. Appl. Res.* 2 (1), 7–10. <https://doi.org/10.14710/jvsar.v2i1.7600>.
- Mishra, R., Singh, R.K., Subramanian, N., 2022. Impact of disruptions in agri-food supply chain due to COVID-19 pandemic: Contextualised resilience framework to achieve operational excellence. *Int. J. Logistics Manag.* 33 (3), 926–954. <https://doi.org/10.1108/IJLM-01-2021-0043>.
- Mogaji, E., 2020. Impact of COVID-19 on transportation in lagos, Nigeria. *Transp. Res. Interdiscip. Perspect.* 6 <https://doi.org/10.1016/j.trip.2020.1010154> article no. 1010154.
- Montenegro, L., Young, M.N., 2020. Operational challenges in the food industry and supply chain during the COVID-19 pandemic: a literature review. *Proc. 7th Int. Conf. Front. Industrial Eng. (ICFIE 2020)* 1–5. <https://doi.org/10.1109/ICFIE50845.2020.9266743>.
- Montoya-Torres, J.R., Muñoz-Villamizar, A., Mejia-Argueta, C., 2021. Mapping research in logistics and supply chain management during COVID-19 pandemic. *Int. J. Logist. Res. Appl.* 1–21. <https://doi.org/10.1080/13675567.2021.1958768>.
- Nader, J., El-Khalil, R., Nassar, E., Hong, P., 2022. Pandemic planning, sustainability practices, and organizational performance: an empirical investigation of global manufacturing firms. *Int. J. Prod. Econ.* <https://doi.org/10.1016/j.ijpe.2022.108419>.
- Nandi, S., Sarkis, J., Hervani, A.A., Helms, M.M., 2021. Redesigning supply chains using blockchain-enabled circular economy and COVID-19 experiences. *Sustain. Prod. Consum.* 27, 10–22. <https://doi.org/10.1016/j.spc.2020.10.019>.

- Narayanamurthy, G., Tortorella, G., 2021. Impact of COVID-19 outbreak on employee performance—moderating role of industry 4.0 base technologies. *Int. J. Prod. Econ.* 234, 108075 <https://doi.org/10.1016/j.ijpe.2021.108075>.
- Nunnally, J.C., 1978. *Psychometric Theory*. McGraw-Hill, New York.
- Pantano, E., Pizzi, G., Scarpi, D., Dennis, C., 2020. Competing during a pandemic? Retailers' ups and downs during the COVID-19 outbreak. *J. Bus. Res.* 116, 209–213. <https://doi.org/10.1016/j.jbusres.2020.05.036>.
- Paul, S.K., Chowdhury, P., 2021. A production recovery plan in manufacturing supply chains for a high-demand item during COVID-19. *Int. J. Phys. Distrib. Logist. Manag.* 51 (2), 104–125. <https://doi.org/10.1108/IJPDLM-04-2020-0127>.
- Perkumiene, D., Osamede, A., Andriukaitiene, R., Beriozovas, O., 2021. The impact of COVID-19 on the transportation and logistics industry. *Probl. Perspect. Manag.* 19 (4), 458–469. [https://doi.org/10.21511/ppm.19\(4\).2021.37](https://doi.org/10.21511/ppm.19(4).2021.37).
- Pratama, H., Azman, M.N.A., Kassymova, G.K., Duisenbayeva, S.S., 2020. The trend in using online meeting applications for learning during the period of pandemic COVID-19: a literature review. *J. Innov. Edu. Cultural Res.* 1 (2), 58–68. <https://doi.org/10.46843/ijecr.v1i2.15>.
- Pu, M., Zhong, Y., 2020. Rising concerns over agricultural production as COVID-19 spreads: lessons from China. *Global Food Secur.* 26 <https://doi.org/10.1016/j.gfs.2020.100409> article no. 100409.
- Pujawan, I.N., Bah, A.U., 2022. Supply chains under COVID-19 disruptions: literature review and research agenda. *Supply Chain Forum Int. J.* 23 (1), 81–95. <https://doi.org/10.1080/16258312.2021.1932568>.
- Qamruzzaman, M., 2020. COVID-19 Impact on SMEs in Bangladesh: an Investigation of what They Are Experiencing and How They Are Managing? Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3654126.
- Qian, M., Jiang, J., 2022. COVID-19 and social distancing. *J. Publ. Health* 30 (1), 259–261. <https://doi.org/10.1007/s10389-020-01321-z>.
- Queiroz, M.M., Ivanov, D., Dolgui, A., Fosso Wamba, S., 2022. Impacts of epidemic outbreaks on supply chains: mapping a research agenda amid the COVID-19 pandemic through a structured literature review. *Ann. Oper. Res.* 319, 1159–1196. <https://doi.org/10.1007/s10479-020-03685-7>.
- Raj, A., Mukherjee, A.A., de Sousa Jabbour, A.B.L., Srivastava, S.K., 2022. Supply chain management during and post-COVID-19 pandemic: mitigation strategies and practical lessons learned. *J. Bus. Res.* 142, 1125–1139. <https://doi.org/10.1016/j.jbusres.2022.01.037>.
- Ramakumar, R., 2020. Agriculture and the Covid-19 pandemic: an analysis with special reference to India. *Review of Agrarian Studies* 10 (1), 72–110. Available at: http://www.ras.org.in/agriculture_and_the_covid_19_pandemic.
- Remko, V.H., 2020. Research opportunities for a more resilient post-COVID-19 supply chain—closing the gap between research findings and industry practice. *Int. J. Oper. Prod. Manag.* 40 (4), 341–355. <https://doi.org/10.1108/IJOPM-03-2020-0165>.
- Rinaldi, M., Murino, T., Bottani, E., 2021. The impact of COVID-19 on logistic systems: an Italian case study. *IFAC-PapersOnLine* 54 (1), 1035–1040. <https://doi.org/10.1016/j.ifacol.2021.08.123>.
- Rinaldi, M., Murino, T., Gebennini, E., Morea, D., Bottani, E., 2022. A literature review on quantitative models for supply chain risk management: can they be applied to pandemic disruptions? *Comput. Ind. Eng.* 170 <https://doi.org/10.1016/j.cie.2022.108329> article no. 108329.
- Roosefer Mohan, T., Preetha Roselyn, J., Annie Uthra, R., 2022. Anomaly detection in machinery and smart autonomous maintenance in industry 4.0 during covid-19. *IETE J. Res.* <https://doi.org/10.1080/03772063.2022.2101556>.
- Rothengatter, W., Zhang, J., Hayashi, Y., Nosach, A., Wang, K., Oum, T.H., 2021. Pandemic waves and the time after Covid-19—Consequences for the transport sector. *Transport Pol.* 110, 225–237. <https://doi.org/10.1016/j.tranpol.2021.06.003>.
- Sanci, E., Daskin, M.S., Hong, Y.-C., Roesch, S., Zhang, D., 2021. Mitigation strategies against supply disruption risk: a case study at the Ford Motor Company. *Int. J. Prod. Res.* <https://doi.org/10.1080/00207543.2021.1975058>.
- Sathyarayanan, A., Shukla, N., Taghikhah, F., 2020. Modelling the impact of COVID-19 pandemic on a hardware retail supply chain. *Proceedings of the 2020 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM 2020)* 807–811. <https://doi.org/10.1109/IEEM45057.2020.9309973>.
- Sgroi, F., Modica, F., 2022. Consumers' eating habits during the covid-19 pandemic: evidence of an experimental analysis in Italy. *Int. J. Gastron. Food Sci.* 28 <https://doi.org/10.1016/j.ijgfs.2022.100538> article no. 100538.
- Shafiee, M., Zare-Mehrjerdi, Y., Govindan, K., Dastgoshade, S., 2022. A causality analysis of risks to perishable product supply chain networks during the COVID-19 outbreak era: an extended DEMATEL method under Pythagorean fuzzy environment. *Transport. Res. E Logist. Transport. Rev.* 163 <https://doi.org/10.1016/j.tre.2022.102759> article no. 102759.
- Sharma, M., Alkathheeri, H., Jabeen, F., Sehrawat, R., 2022a. Impact of COVID-19 pandemic on perishable food supply chain management: a contingent Resource-Based View (RBV) perspective. *Int. J. Logist. Manag.* 33 (3), 796–817. <https://doi.org/10.1108/IJLM-02-2021-0131>.
- Sharma, M., Luthra, S., Joshi, S., Kumar, A., 2022b. Developing a framework for enhancing survivability of sustainable supply chains during and post-COVID-19 pandemic. *Int. J. Logist. Res. Appl.* 25 (4–5), 433–453. <https://doi.org/10.1080/13675567.2020.1810213>.
- Shen, B., Chen, C., 2019. Quality management in outsourced global fashion supply chains: an exploratory case study. *Prod. Plann. Control* 31, 757–769. <https://doi.org/10.1080/09537287.2019.1683774>.
- Sulkowski, L., Kolasinska-Morawska, K., Brzozowska, M., Morawski, P., Schroeder, T., 2022. Last mile logistics innovations in the courier-express-parcel sector due to the COVID-19 pandemic. *Sustainability* 14. <https://doi.org/10.3390/su14138207> article no.8207.
- Taherdoost, H., 2019. What is the best response scale for survey and questionnaire design; review of different lengths of rating scale/attitude scale/likert scale. *Int. J. Acad. Res. Manag.* 8 (1), 1–10. Available at: https://papers.ssrn.com/sol3/Delivery.cfm/SSRN_ID3588604_code2177801.pdf?abstractid=3588604&mirid=1.
- Tamtam, F., Tourabi, A., 2021. Analysis of the agility of the automotive industry supply chain in times of COVID-19: a case study. *EUREKA - Physics and Engineering* 2021 (6), 112–120. <https://doi.org/10.21303/2461-4262.2021.001949>.
- Taqi, H.M.M., Ahmed, H.N., Paul, S., Garshasbi, M., Ali, S.M., Kabir, G., Paul, S.K., 2020. Strategies to manage the impacts of the COVID-19 pandemic in the supply chain: implications for improving economic and social sustainability. *Sustainability* 12 (22). <https://doi.org/10.3390/su12229483> article no. 9483.
- Telukdarie, A., Munsamy, M., Mohlala, P., 2020. Analysis of the impact of COVID-19 on the food and beverages manufacturing sector. *Sustainability* 12 (22), 9331. <https://doi.org/10.3390/su12229331>.
- Tortorella, G., Fogliatto, F.S., Kumar, M., Gonzalez, V., Pepper, M., 2023. Effect of Industry 4.0 on the relationship between socio-technical practices and workers' performance. *J. Manuf. Technol. Manag.* 34 (1), 44–66. <https://doi.org/10.1108/JMTM-04-2022-0173>.
- Twinn, I., Qureshi, N., Conde, M.L., Guinea, C.G., Rojas, D.P., 2020. The impact of COVID-19 on logistics. <https://www.ifc.org>.
- Umaña-Hermosilla, B., de la Fuente-Mella, H., Elórtigue-Gómez, C., Fonseca-Fuentes, M., 2020. Multinomial logistic regression to estimate and predict the perceptions of individuals and companies in the face of the covid-19 pandemic in the Ñuble region, Chile. *Sustainability* 12 (22), 1–20. <https://doi.org/10.3390/su12229553>.
- Wissuwa, F., Durach, C.F., Choi, T.Y., 2022. Selecting resilient suppliers: supplier complexity and buyer disruption. *Int. J. Prod. Econ.* 253 <https://doi.org/10.1016/j.ijpe.2022.108601>.
- Xu, Y., Li, J.P., Chu, C.C., Dinca, G., 2021. Impact of COVID-19 on transportation and logistics: a case of China. *Economic Research-Ekonomiska Istrazivanja* 35 (1), 2386–24041. <https://doi.org/10.1080/1080/1331677X.2021.1947339>.
- Xu, Z., Elomri, A., Kerbache, L., El Omri, A., 2020. Impacts of COVID-19 on global supply chains: facts and perspectives. *IEE Eng. Manag. Rev.* 48 (3), 153–166. <https://doi.org/10.1109/EMR.2020.3018420>.
- Yang, H., Kumara, S., Bukkapatnam, S.T.S., Tsung, F., 2019. The internet of things for smart manufacturing: a review. *IIEE Transactions* 51, 1190–1216. <https://doi.org/10.1080/24725854.2018.1555383>.
- Ye, F., Liu, K., Li, L., Lai, K.H., Zhan, Y., Kumar, A., 2022. Digital supply chain management in the COVID-19 crisis: an asset orchestration perspective. *Int. J. Prod. Econ.* 245, 108396 <https://doi.org/10.1016/j.ijpe.2021.108396>.
- Yu, J., Cooper, H., 1983. A qualitative review of research design effects on response rates to questionnaires. *J. Market. Res.* 36, 36–44.
- Zhang, Y., Diao, X., Chen, K.Z., Robinson, S., Fan, S., 2020. Impact of COVID-19 on China's macroeconomy and agri-food system—an economy-wide multiplier model analysis. *China Agric. Econ. Rev.* 12 (3), 387–407. <https://doi.org/10.1108/CAER-04-2020-0063>.
- Zhao, H., Chen, N., 2022. Medium and long-term impact of SARS on total factor productivity (TFP): empirical evidence from Chinese industrial enterprises. *J. Asian Econ.* 82, 101507 <https://doi.org/10.1016/j.asieco.2022.101507>.
- Zhu, G., Chou, M.C., Tsai, C.W., 2020. Lessons learned from the COVID-19 pandemic exposing the shortcomings of current supply chain operations: a long-term prescriptive offering. *Sustainability* 12 (14), 5858. <https://doi.org/10.3390/su12145858>.

Marta Rinaldi has a Ph.D. in Industrial Engineering and she graduated cum laude at the University of Parma. Currently, she is an Assistant Professor and researcher in the Department of Engineering at the University of Campania “Luigi Vanvitelli”. She teaches and conducts research in the field of industrial system design and management, supply network mapping, modelling and simulation, inventory management and sustainability. She published more than 50 scientific papers, published in International ISI journals or in proceeding of international conferences Peer Reviewed. She is an Editorial Board Member of Healthcare Analytics and Supply Chain Analytics Journals.

Eleonora Bottani is Full professor of Industrial Logistics at the Department of Engineering and Architecture of the University of Parma since November 2019. She graduated cum laude in Industrial Engineering and Management in 2002 and got her Ph.D. in Industrial Engineering in 2006, both at the University of Parma. Her research activities concern logistics and supply chain management issues. She is author (or co-author) of >200 scientific papers (citations on Scopus>3400; H-index = 31), referee for more than 60 international journals, editorial board member and associate editor of various journals, and editor-in-chief of a scientific journal.