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Investigating the Impact of COVID-19 on Sustainable Food Supply Chains

Abstract

Purpose- The ongoing pandemic has gravely affected different facets of society and economic trades worldwide. During the outbreak, most manufacturing and service sectors were closed across the globe except for essential commodities such as food and medicines. Consequently, recent literature has focused on studying supply chain resilience and sustainability in different pandemic contexts. This research adds to the existing literature by exploring the economic, environmental and societal aspects affecting the food supply chain and assessing the impact of COVID-19 on food sustainability.

Design/methodology/approach- A survey method has been adopted with a questionnaire instrument investigating the role of technology, government policies, geopolitics and intermediaries on sustainable organisational management. A five-point Likert scale (i.e., 1: strongly disagree; 5: strongly agree) is used to evaluate the responses. The findings are based on 131 responses from entry-level workers and senior executives of different food supply chains across Asia and Europe. The data has been analysed to derive insights into the impacts of this pandemic.

Findings- The survey concludes with the significant impact of COVID-19 on the three pillars of sustainability, i.e. economic, social, and environmental dimensions. The empirical analysis shows digitalization and its applications help mitigate the negative effect of COVID-19 on sustainability. In addition, the supportive government policies and intermediatory interventions were helpful in improving sustainability at each level.

Social/Research/Practical Implications- The findings have implications for businesses and policymakers. Companies can learn from the advantages of digitalization to counter the challenges imposed by the pandemic or similar situations in the future in maintaining the sustainability of their supply chains. Managers can also learn the importance of effective organisational management in driving sustainability. Finally, policymakers can devise policies to support businesses in adopting sustainable practices in their supply chains.

Originality/value- Our study adds to the limited literature exploring the impact of COVID-19 on food supply chain sustainability through the Triple Bottom Line (TBL) lens. This is also one of the first empirical studies to examine the effect of technology, government and organisational management practices on the sustainability of food supply chains.

Keywords: Sustainable Supply Chain, Food industry, COVID-19, Triple Bottom Line, Digitalization, Empirical Study

1. Introduction

As the population increases rapidly (Roser, 2019), the necessity for increased and quality food production becomes a vital issue. To deal with that necessity, food organisations require a prolonged reliable and stable supply of quality raw materials. On the other hand, there is an ongoing concern about the challenges of meeting that growing demand from quality and amount of yields perspectives due to the negative climate changes, water shortages, limited land usage, etc. (FAO, 2021).

Managing food supply chains is already complex due to including different asupply chain stakeholders (such as producers; processors adding value to the products, importers, retailers and wholesalers selling those products). In modern supply chains, these stakeholders are often speard across different countries/continents. Moreover, that management complexity further increases when the various crops and types of the food products increase as each crop has its own distinctive and often fragmented supply chain. In recent years consumers have become more conscious about their food products and are keen to know the farm-to-fork journey to understand whether they are produced responsibly and following food safety standards (Sustainable Food Lab, 2009; Wang et al., 2021). Thus, food industries are encouraged to consider the sustainability of their supply chains to ensure a reliable supply of food, also bringing new opportunities for enhancing their brands (Sustainable Food Lab, 2009). As a result, many food organisations see sustainability philosophy as vital for their supply chains (Woodward, 2021; Hochfelder, 2017).

Sustainability is often associated with the triple bottom line (TBL) (Phan et al. 2021). The TBL concept advocates the traditional shift of organisations from the economic value to the social and environmental value they deliver or compromise (Gold, Hahn and Seuring, 2013; Garza-Reyes et al., 2019; Phan et al., 2021). From a holistic perspective, the TBL approach is a unified sustainability concept of business activity performance (Wheeler and Elkington, 2001; Slaper and Hall, 2011; Phan et al., 2021). Many researchers have advocated the need for studies on the sustainable food supply chain from the TBL framework (Brandenburg, Govindan, Sarkis and Seuring, 2014; Rajeev, Pati, Padhi and Govindan, 2017; Kumar, 2020). Inspired by these studies, our paper aims to explore sustainability in food supply chains following the TBL framework.

The ongoing COVID-19 pandemic has affected all aspects of food supply chains, from farm production to final demand. However, the impact has varied across the different stages of the

supply chain (OECD, 2020). This unprecedented global event has also significantly affected the food supply chain sustainability (SCS), bringing supply-chain resilience subject to consideration seriously. Kumar (2020) highlights that the COVID-19 pandemic has raised the significance of responsible production and consumption of food in line with sustainability goals. During the pandemic, the food waste issues have been highlighted all across the globe that has resulted from stockpiling has further the need to follow a sustainable approach toward food products. In a recent study, Sarkis (2021) highlighted the inseparable relationship between the three dimensions of sustainability in the wake of the COVID-19 pandemic. However, the impacts of this pandemic on the three dimensions of TBL is still an area that hasn't been fully explored. Most existing studies in this context are theoretical, literature reviews, observation-based or opinion pieces. Hence our study is one of the first empirical studies to examine the effect of technology, government and organisational management practices on the sustainability of food supply chains in the COVID-19 context. Our study therefore aims to examine the impact of COVID-19 on sustainability of the food suppy chains from TBL perspective. The objectives of the study are (1) to understand the impact of COVID-19 on Food supply chain sustainability; (2) to identify the economic, social and environmental challenges faced by supply chains; (3) to investigate the role of digital technologies in mitigating the challenges imposed by the pandemic; and (4) to explore the role of government policies and effective organisational management practices in mitigating the negative impacts of COVID-19. We therefore explore the below research question:

RQ: How has the pandemic affected the sustainability of food supply chains from the triple bottom line (TBL) perspective?

The next section reviews the existing literature to tease out the theoretical underpinnings. Section 3 elaborates the methodology adopted where the details of the survey work along with the questionnaire questions are given. Section 4 presents the findings and discussions, whereas section 5 concludes this study.

2. Literature Review

Supply Chain Sustainability (SCS)

SCS is defined by UN Global Compact (2010) to be *"the management of environmental, social and economic impacts, and the encouragement of good governance practices, throughout the lifecycles of goods and services"*. In UN Global Compact (2010), the objective of SCS is to *"create, protect and grow long-term environmental, social and economic value for all*

stakeholders involved in bringing products and services to market". More specifically, SCS is defined by Neven (2014) as the chain's coordinated value-adding activities of all businesses, including farmers. SCS ensures the production and transformation of agricultural materials into food products in a profitable way by providing benefits to society and not permanently depleting the natural resources.

Following the definitions of SCS, the three main components for SCS are i) environment-conscious practices, ii) social responsibility, and iii) economic viability, which is often termed as Triple Bottom Line (TBL) framework. Research studies such as Seuring and Muller (2008) and Azevedo and Barros (2017) indicate that the sustainability concept has gone beyond an individual firm to a supply chain perspective. Aday and Aday (2020) highlighted that the complex nature of the food industry makes it more challenging and complex to deal with a crisis such as the COVID-19 pandemic. Economic sustainability of the food products (e.g. rising cost of food products, demand and supply issues, etc.) while also ensuring social sustainability (e.g., farmers' livelihood) and reducing environmental impact (e.g. decrease in greenhouse gas emissions, food waste reduction, etc.) makes managing sustainability expectations quite challenging (Sharma, Adhikary and Borah, 2020) and the ongoing pandemic has added further woes on the food sustainability.

Economic Challenges

The existing research highlighting the economic challenges during the COVID-19 has mainly pointed toward the supply disruption and the falling demand. Kumar (2020) reports that during the pandemic lockdowns, every aspect of the global supply chains was heavily impacted across the globe. Maital and Barzani (2020) highlighted that the factory closures in China and around the globe have led to a contraction in the macroeconomic supply of goods and services affecting the global economy. This was also echoed in the work of Castañeda-Navarrete et al. (2021), who highlighted that the reduction of the output of materials in the world's manufacturing led to direct supply disruption during the pandemic (Haren and Simchi-Levi, 2020). A survey by Norwood and Peel (2021) in the US market shows that nearly 38 per cent of respondents agreed about their everyday struggles with out-of-stock food products, whereas 44 per cent of individuals admitted sometimes having faced these issues. Similar findings have also been reported by other researchers such as Hobbs (2020), Ivanov and Dolgui (2020), and Peña-Lévano et al. (2020). The declining demand directly affects sales and market share of the food supply chain. Therefore, the extreme short-term disruption in the food supply chain needs

careful consideration. According to Walters, Wade and Suttles (2020); Byington (2020), and Norwood and Peel (2021), in highly specialized food supply chains, it is costly and risky to connect one supply chain to another in the short term as the food supply chains serving households and foodservice institutions act separately. Since the outbreak, managing sustainable supply chains has been challenging as the food supply chains have experienced extreme disruption due to lockdown measures. The food supply chain also needs to adhere to safety regulations while packaging for the health benefits of individuals and communities throughout the life cycle of food.

Economic viability may provide equitable living and value distribution for each supply chain member. Figueroa-Rodríguez (2019) highlights that many international food companies are therefore integrating a fixed minimum number of small farmers in developing countries as recurrent suppliers that can contribute to their economic growth and, ultimately, their wellbeing. This concept also aims to create transparency among all supply chain stakeholders so that they can track their economic benefits contributing to the supply chain. In a recent study, Castañeda-Navarrete et al. (2021) highlighted the impact that outbreak has on sustainable supply chains. Sumner, Hoy and Ortiz-Juarez (2020) report that the reasons for the reduced demand in high-income countries are the recession, wait-and-see consumer purchase delays and investment delays by companies. Hence, this study puts forward the following assumption from the economic *perspective:*

H1: COVID-19 pandemic had a significant impact on the economic sustainability of the food supply chain

Social Challenges

Social responsibility aims for all supply chain players, specifically farmers, to gain fair acquisitions and work under good labour conditions (Aday and Aday, 2020; Wang et al., 2021). Following the social pillar of TBL, the supply chain should provide an environment for each player to access education, training and health services for themselves and their families. By training farmers, more improved and balanced income and the generation of new jobs in rural communities can be managed (Figueroa-Rodríguez, 2019). A study by Sharma, Adhikary, and Borah (2020) and Kumar (2020) highlights that outbreak has forced organisations to prioritise the safety, health and welfare of employees over the efficiency of supply chains. Castañeda-Navarrete et al. (2021) highlighted that women in supply chains had faced significant challenges during this pandemic as they often experience increasing unpaid care work and are

more frequently exposed to gender-based violence. Another study by Cuesta et al. (2020) highlights the challenges informal workers face during this outbreak as they are often not included in the holidays and other work-related social protection programs.

Additionally, female workers are the majority of the informal group, which means the working condition of females should be improved for the social sustainability of a supply chain, including the food supply chain. The increasing awareness of the importance of sustainability and pressure from customers also encourages organisations to be more sustainable because of the market competition (Walker and Jones, 2012). Other studies have also advocated the role of non-governmental organizations (NGOs) (Mani et al., 2015) and the government (Genovese et al., 2017; Rentizelas et al., 2020) in improving the sustainability of food supply chains. Following the discussions presented from a social perspective, in *H2,* we study the hypothesis:

H2: The COVID-19 pandemic significantly impacted the social sustainability of the food supply chain.

Environmental Challenges

Compared to the other two pillars of sustainability, few scholars (e.g. Bashir, Ma and Shahzad, 2020; Kumar et al., 2021) have directly attached great importance to the environment pillar in the context of COVID-19, as food production anyways accounts for over a quarter of global greenhouse gas emissions. Nevertheless, during the early part of the pandemic, the food waste affecting the environment was due to the lockdowns implemented by most countries (Kumar, 2020). The beginning of the COVID-19 pandemic drew considerable attention to food movement through key harvest, processing and distribution pinch points. These were widely reported in the media; for example, incidents of upstream food waste (dumping milk down the drain, farmers letting vegetables rot in their fields, smashing unhatched eggs, piglet euthanasia, etc.) were highlighted around the globe (Yaffe-Bellany and Corkery 2020; Kumar, 2020; Roe, Bender, & Qi, 2021). This food waste generated during the pandemic was also driven by changing consumer behaviour such as hoarding and stockpiling (Kumar, 2020). However, on the contrary, a recent study by Burlea-Schiopoiu et al. (2021) revealed that the pandemic has led to more people exhibiting food waste reduction behaviour and increased awareness of the ethics of food waste and the environmental consequences of food waste. However, this is not surprising as consumers are slowly becoming more environmentally cautious though evidence of this changing behaviour from around the globe is scarce. We, therefore, propose the following hypothesis from the environmental perspective:

H3: The COVID-19 pandemic had a significant impact on the environmental sustainability of the food supply chain.

Role of Digital Technologies

The existing literature shows that organisations can make the most use of technology to improve the performance of organizational sustainability (Pathak et al., 2020; Mandal and Dubey, 2020; Mangina et al., 2020). A study by O'Rourke (2014) highlighted the importance of technology in monitoring, measuring, and analysing information related to the sustainable supply chain. Whereas, Dahlmann and Roehrich (2019) and Dadhich et al. (2015) highlighted the importance of information sharing by cooperating stakeholders in overcoming information asymmetry. A recent study by Norwood and Peel (2021) further asserts that digital technologies play an important role in mapping the supply chain, demand planning, identifying the disruption risks and monitoring CO2 emissions. These changes enable the food supply chain to improve its sustainability during this pandemic. The ongoing pandemic has made the world admit that the global supply chain is sensitive and is easily disrupted when encountering unexpected events. However, evidence also shows that digital technologies can help organisations map the supply chain and identify disruption risks (Norwood and Peel, 2021), supporting the global supply chain's resilience and consequently improving its sustainability. Digital technologies also enable the supply chain to address customers' concerns about social and environmental issues. Ahmed, Akter and Ma (2018) show how blockchain can be used to monitor CO2 emissions and water consumption in the production process. More recently, Kumar (2020) emphasised that digital technologies have the potential to assist with the challenges imposed by the COVID-19 pandemic. Particularly when it comes to enabling agile responses in the wider food supply chains, such as collecting real-time data to improve communication between suppliers and buyers, simplify the redistribution of food, and reduce waste. In other words, digital technologies can help the food supply chains manage sustainability-related challenges. This leads to the following hypothesis.

H4: Technology has a significant impact on mitigating the negative effects of the COVID-19 pandemic on the sustainable food supply chain.

Effective organisational management

The importance of effective organisational management in driving sustainability has recently been an interest of many researchers. For example, Adesanya et al. (2020) and Huang and Yao (2021) highlighted the effectiveness of social networks in helping organisations to cooperate

with partners efficiently, leading to a more sustainable food supply chain. The existing studies have identified several aspects of organisational management, such as resource management (Pathak et al., 2020), risk management (Ewbank et al.,2020), and skilful policy (Florescu et al.,2019) that play an important role in improving social, economic and environmental sustainability. In contrast, some scholars have highlighted ineffective management as a barrier to improving sustainability performance. In their study, Narayanan et al. (2019) report that financial pressure and lack of top-level management commitment could affect sustainability performance. In contrast, Frostenson and Prenkert (2015) have highlighted the negative impacts of lacking control of resources. Kumar et al. (2018) described the influence of ineffective cooperation as a major factor that creates barriers to sustainability performance in organisations. Following these arguments, we, therefore, hypothesise that

H5: Effective organizational management has a significant impact on mitigating the negative effects of the COVID-19 pandemic on the sustainable food supply chain.

Government Intervention

The research studies have also shown that government intervention is a double-edged sword for a sustainable food supply chain. For example, Narayanan et al. (2019) and Kumar et al. (2018) highlight that it could be challenging to improve sustainability with ineffective governmental initiatives and policies, a view that has also been supported by Abbasi (2017) and Gardas et al. (2019). Sodhi and Tang (2020) report that unstable geopolitics could bring a lot of challenges to the sustainable food supply chain. Sodhi and Tang (2020), De Sousa Jabbour et al. (2020) and Mirghafoori and Jalilian (2019) have all recognised governmental intervention as one of the opportunities to improve sustainability. There is a general perception that the government can push corporates to enhance their sustainability. Barnett et al. (2018) suggested that stakeholder pressures can bring sustainability to the fore. However, government intervention is necessary, and without government intervention, self-interested stakeholders can pressure firms to move away from sustainability's complex, long-term challenges. Hence, this study assumes that

H6: Government support significantly impacted mitigating the negative effects of the COVID-19 pandemic on the sustainable food supply chain.

The conceptual framework depicting all the hypotheses is shown in Figure 1 below.

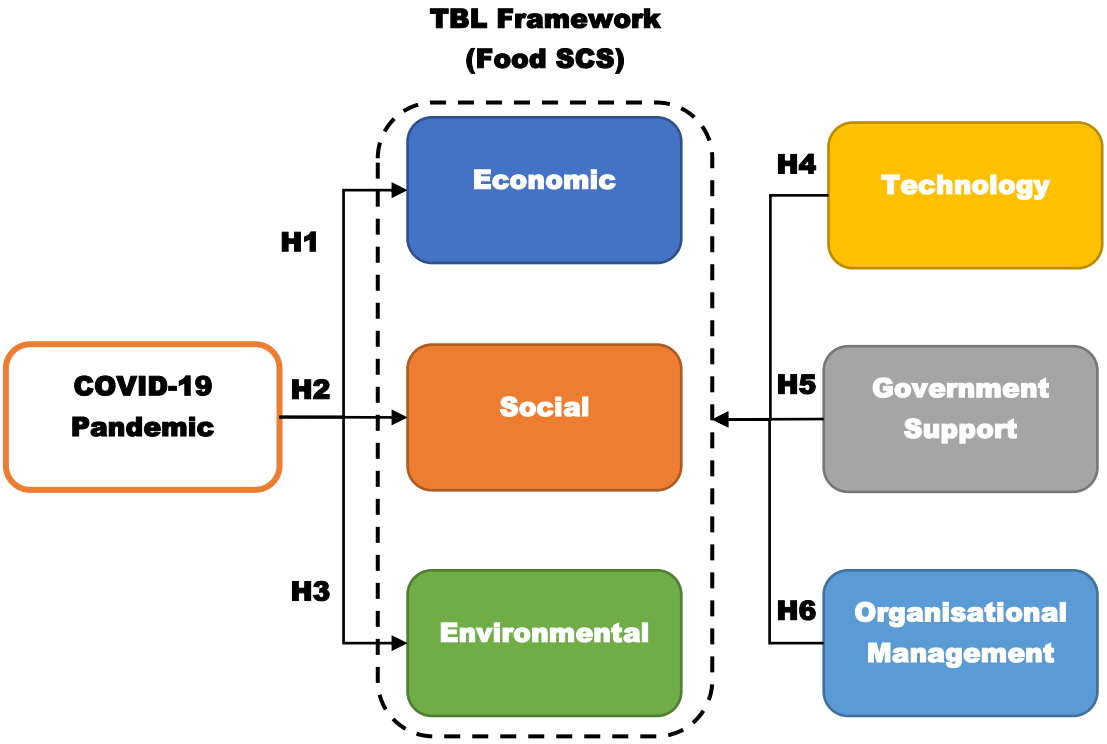


Figure 1: Conceptual Framework

3. Methodology and Data Analysis

As this study is explanatory in nature, a survey questionnaire-based approach for data collection was deemed most appropriate as it enables consistency and accuracy of data collection to measure the intended concepts (Saunders et al., 2018). In addition, a number of studies focusing on food supply chains have also adopted a survey-based approach (Falguieres et al., 2015; Kumar et al., 2017; Wang et al., 2021). Moreover, the generalisation of the study requires a large sample size and survey-based approach provides this opportunity. The methodological step followed in this study is shown in Figure 2 below.

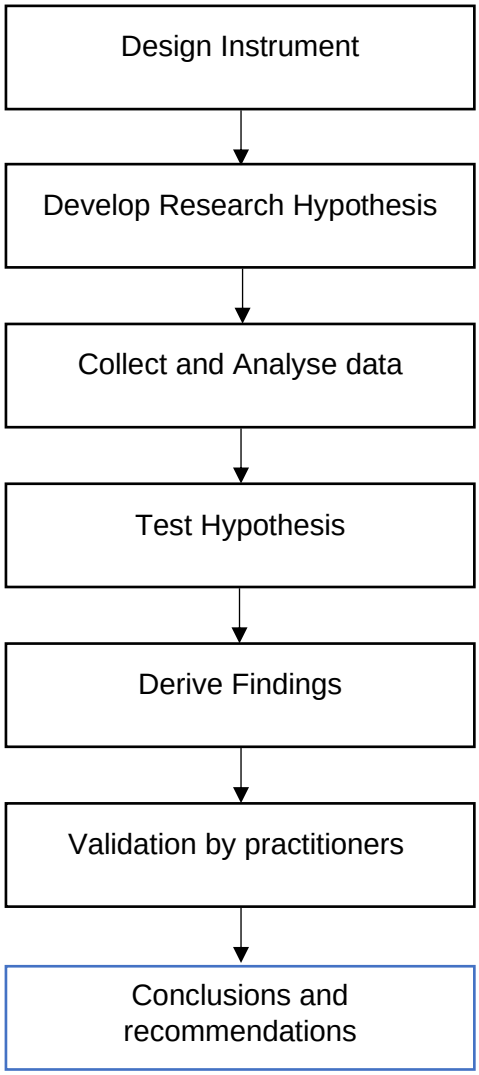


Figure 2: Methodological Framework

Saunders et al. (2018) suggest that a valid questionnaire enables accurate data collection to measure the intended concepts and ensures consistency. A survey questionnaire was developed using Qualtircs and circulated to supply chain professionals working in the food sector via social media channels (Linkedin and WeChat). Quatrics based survey is easily accessible via mobile devices or web browsers and provide easy storage, classification, and analysis of the data collected. Ethical approval was taken before the data collection. In total, 201 questionnaires were distributed through this survey resulting in 131 valid responses. The response rate was, therefore, roughly 65 per cent. This included contacting 76 supply chain professionals on LinkedIn, resulting in 37 completed responses and circulating to a WeChat group of supply professionals with over 500+ members, resulting in 94 fully completed responses. The main categories of the questions directed to the participants are shown in Table 1. The first four categories aim to collect the demographic data from participants, whereas the

remaining ones explore the SCS-based information. The survey questionnaire included questions covering demographics and core focus areas, as shown in Table 1. A Likert scale from 1 to 5 (1= strongly disagree and 5= strongly agree) is considered. The observed results are analyzed and explained in Section 3.1.

Table 1: Category of survey questions

Category	Target Information
1	Location
2	Job level of participants
3	Working experience based on working years at the company
4	Size of the business
5	Impact of COVID-19 on economic sustainability
6	Impact of COVID-19 on social sustainability
7	Impact of COVID-19 on environmental sustainability
8	Role of technology in improving SCS
9	Role of effective, sustainable organisational management
10	Role of governmental policies and interventions

4. Data Analysis

As stated earlier, the survey resulted in 131 valid responses. A 5-point Likert is used to evaluate the responses where it is assumed that data is an ordinal type of data, and the results do not follow a normal distribution (Keller, 2022). Keller (2022) states that the *t*-test cannot be used if the data are ordinal. The survey data was first analysed through descriptive analysis by considering the first four categories in Table 1. To analyse categories 5-10 data from Table 1, we apply the non-parametric tests, Chi-square and Wilcoxon signed-rank tests. We explain each of those tests and formulations in the statistical analyses in the below sections.

4.1 Chi-square test

We first applied the Chi-square test for the hypothesis testing (Montgomery and Runger, 2018). Here, this test aims to determine if there is a difference between the proportions of categorical variables. The hypothesis test in the Chi-square test is given by equation (1):

Null hypothesis: There is no difference in the proportion of responses voting between 1-5

Alternative hypothesis: There is a significant difference in the proportion of responses voting between 1-5 (1)

Here, by testing (1), we understand whether there is a significant difference between the proportion of responses among the Likert values 1-5. If we reject the null hypothesis, the alternative hypothesis would be true, meaning that there is a significant difference in the proportion of responses. Then, it would be worth exploring what Likert value is voted most by the respondents. We conducted a Wilcoxon signed-rank test for that purpose, which is explained later in Section 4.2.

The Chi-square test statistic formulation is given by equation (2):

$$\chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i} \tag{2}$$

Where O_i is the observed frequencies, and E_i is the expected frequencies. k represents the number of categories which is 5 in this case (i.e. Likert scale). To show how χ^2 is computed, we give the following case. For instance, when we have 50 respondents who voted for the Likert scale 1-5 as in Table 2, then $k = 5$, and $O_1 = 2$, $O_2 = 5$, $O_3 = 8$, $O_4 = 25$, and $O_5 = 10$. E_i is computed by (3), which is obtained to be 10.

Table 2: Votes of 50 respondents on a Likert scale of 1-5

Likert scale (i)	Number of responses (O_i)
1	2
2	5
3	8
4	25
5	10
Total	50

$$E_i = \frac{\sum_{i=1}^{k} O_i}{k} \tag{3}$$

Consequently, by (2), χ^2 is computed as 31.8. Here, if χ^2 is larger than the critical value, $\chi^2_{\alpha,k-1}$ then, we reject the null hypothesis and assume that the alternative hypothesis is true. Here, the critical value is obtained from the Chi-square table by $\chi^2_{0.05,4}$ as 9.49 (Montgomery and Runger, 2018). Since 31.8 > 9.49, we reject the null hypothesis in (1) and assume that "there is a significant difference in the proportion of responses voting between 1-5". After concluding that the responses do not have an equal proportion for the Likert scale, then we may be interested in which scale tends to receive a higher vote from the respondents. As mentioned, we apply the Wilcoxon signed-rank test for this purpose (Keller, 2022). The methodology is explained in Section 4.2.

4.2 Wilcoxon signed-rank

Wilcoxon signed-rank test is a non-parametric test used to test the null hypothesis (Montgomery and Runger, 2018). Here, after the χ^2 If we observe that the responses are skewed, meaning that the Likert scales do not have the same proportion, it might be interesting whether the responses are left-skewed or right-skewed. If responses are left-skewed (e.g., Figure 3a), then it would be expected that the median is larger than the mean value (e.g. > 3). Otherwise, if the responses are right-skewed (e.g., Figure 3b), then it would be expected that the median is smaller than the mean value (e.g. < 3). In other words, In Figure 3a case, the respondents would tend to agree or strongly agree with the instruction in the survey, while in Figure 3b, the respondents would disagree or strongly disagree with the direction of the survey.

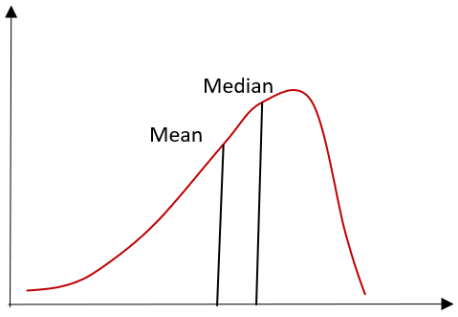


Figure 3a: Left-skewed

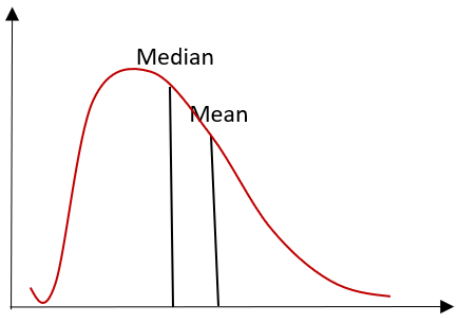


Figure 3b: Right-skewed

Figure 3: Data skewness cases

By the Wilcoxon signed-rank, we develop a one-way hypothesis testing given by equation (4). Here, our aim is to test whether the median is larger than the mean of the Likert scale (i.e., 3). If the null hypothesis is rejected, then we would assume that the median is larger than 3, meaning that the respondents tend to agree with the instruction.

$$\begin{aligned} &\textit{Null hypothesis}\text{: The median } (\eta) \text{ is } \leq 3 \\ &\textit{Alternative hypothesis}\text{: The median } (\eta) \text{ is larger than } > 3 \end{aligned} \tag{4}$$

If the null hypothesis in equation (4) is rejected, then we would assume that the hypothesis (*H1-H6*) defined in Section 2 is true. Therefore, in the following sub-sections, we complete the statistical analysis for each category of Table 1.

4.3 Descriptive Analysis for Categories 1-4

Most of the respondents were from Asia, accounting for 85 per cent, whereas 14 per cent of respondents were from Europe. As shown in Figure 4, around 80 per cent of participants were working in entry-level jobs, and around 15 per cent were working in senior-level jobs. While around 1.5 per cent of respondents were directors, and nearly 3 per cent of them were general managers. From Figure 5, it can be observed that the majority were employed for less than three years, and around 8.3 per cent of individuals have been working for more than three years. Roughly 62 per cent of respondents were employed in medium-sized organisations. The rest were from large companies employing more than 500 people, making up around 37 per cent of respondents.

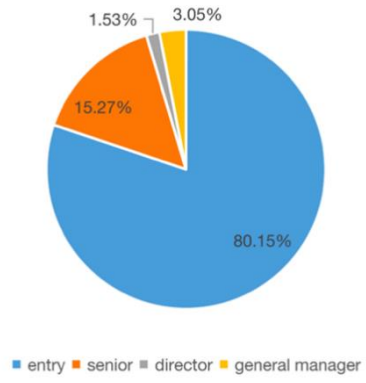


Figure 4: Job level ratios of participants

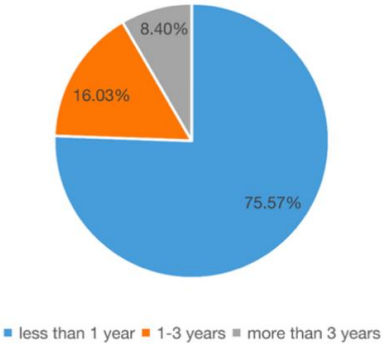


Figure 5: Working experience of participants based on working years

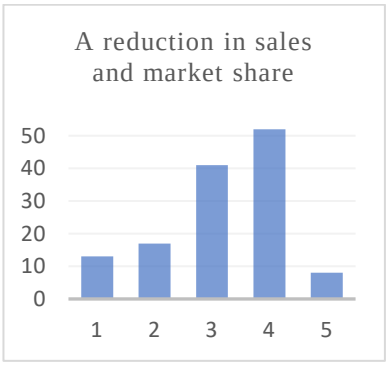
4.4 COVID-19 effect on economic sustainability

Category 5 of Table 1 is developed to test the hypothesis of *H1*. Table 3 shows each question directed to participants to measure the effect of COVID-19 on economic sustainability.

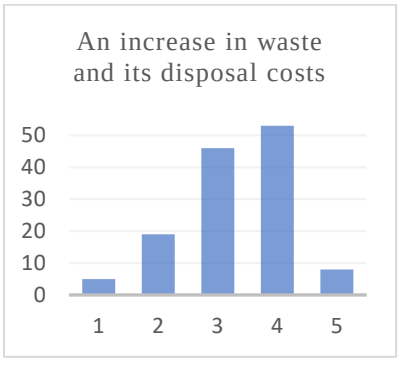
Table 3: Economic Sustainability: Please rate the following statements considering the impact of COVID-19 on the economic sustainability of the food supply chains

Statement	1	2	3	4	5
A reduction in sales and market share					
An increase in waste and its disposal costs					
An increase in the packaging cost for health benefits of individuals and communities throughout the life cycle of food					

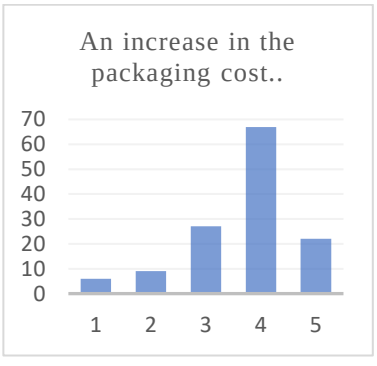
Figure 6 shows the frequency of responses voted for Table 3 questions. From Figure 5, it is observed that respondents vote higher for the third question than for the other first two questions. That might show that respondents think that COVID-19 cause an increase in packaging costs for food products more importantly. Similar findings are also presented by Oliveira et al. (2021), suggesting that by the increase in recent e-commerce by the COVID-19 pandemic, packaging waste has also increased dramatically. From Figure 6, it can also be observed that more than 50 per cent of respondents vote for "somewhat agree" and "strongly agree", supporting *H1*. To accept or reject H1 statistically, we first apply a Chi-square and then the Wilcoxon signed-rank test.



a) Respondents reflect on a reduction in sales and market share



b) Respondents reflect on an increase in waste and its disposal costs



c) Respondents reflect on an increase in the packaging cost..

Figure 6: Likert scale frequencies for economic sustainability (Table 3) questions

Table 4 shows the Chi-square test results of Table 3 questions obtained by the Minitab 21.1. The test statistic was 56.29, 74.15 and 91.1 for Q1-Q3, respectively. Their *p*-values are 0.00.

The hypothesis test is given in equation (1) can be evaluated either by the *Chi-Sq* value or the *p*-value. Namely, we reject the hypothesis given by (1) if the *Chi-Sq* value in Table 4 is larger than the table value $\chi^2_{0.05,4}$ = 9.49, or the *P*-value in Table 4 is smaller than the desired α value, 0.05. Here, since all the *Chi-sq* values in Table 4 are larger than 9.49, or the *P-values* are smaller than 0.05, we reject the null hypothesis and assume that there is a significant difference between participants in the proportion of their responses voting between 1-5. Later, we apply the Wilcoxon signed-rank test to test the hypothesis given by (4). The results are shown in Table 5.

Table 4: Chi-square test results for questions of Table 3

Question	*N*	*DF*	*Chi-Sq*	*P-Value*
Q1	131	4	56.29	0.00
Q2	131	4	74.15	0.00
Q3	131	4	91.1	0.00

Table 5: Wilcoxon signed-rank test for questions of Table 3

Sample	*N for Test*	*Wilcoxon Statistic*	*P-Value*
Q1	90	2460.0	0.049
Q2	85	2566.5	0.001
Q3	104	4570.5	0.000

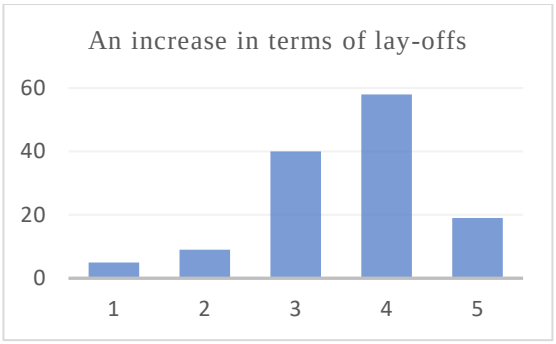
From Table 5, it is evident that the *P-values* are smaller than 0.05, so we reject the null hypothesis and assume that the median of the responses is always higher than 3. Specifically, participants usually vote for "somewhat agree" or "strongly agree" for the questions in Table 3. As a result of the statistical analyses, we accept *H1*. Namely, we assume that the *COVID-19 pandemic had a significant impact on the economic sustainability of the food supply chain".*

4.5 COVID-19 impact on social sustainability

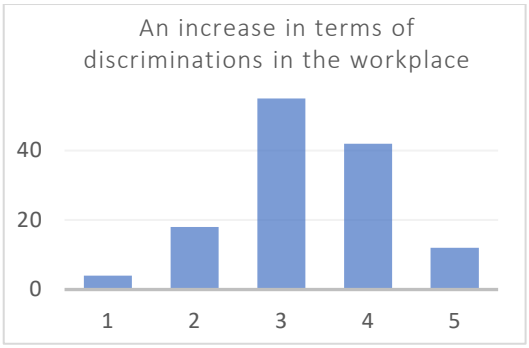
Category 6 of Table 1 was developed to test the hypothesis of *H2*. Social sustainability is significant for individuals, society, and for businesses. For example, providing a respectful and safe environment for employees, suppliers, and partners may result in more loyal and productive behaviour for individuals. Unequal societies may dampen long-term economic growth. Specifically, Table 6 questions are directed to respondents to measure the COVID-19 impact on social sustainability.

Table 6: Social Sustainability: Please rate the following statements considering the impact of COVID-19 on the social sustainability of the food supply chain					
Statement	**1**	**2**	**3**	**4**	**5**
An increase in terms of lay-offs					
An increase in terms of discrimination in the workplace					
An increase in customers' attention to the sustainability performance of organisations					
An improvement in relations with community stakeholders, e.g., Non-governmental organisations (NGO)					
An improvement in relations with governments					

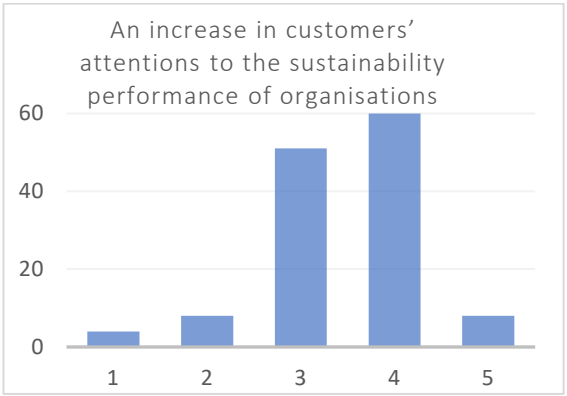
The response frequencies are summarized in Figure 7. It is observed that respondents mostly vote for responses of "somewhat agree" and "strongly agree". To accept or reject *H2*, first, we apply the Chi-square test and the Wilcoxon signed-rank test again. Tables 7 and 8 show the Chi-square test and the Wilcoxon signed-rank test results, respectively.



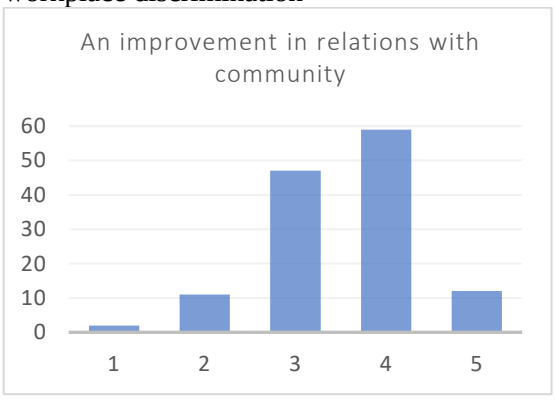
a) The respondents reflect on the increase in lay-offs



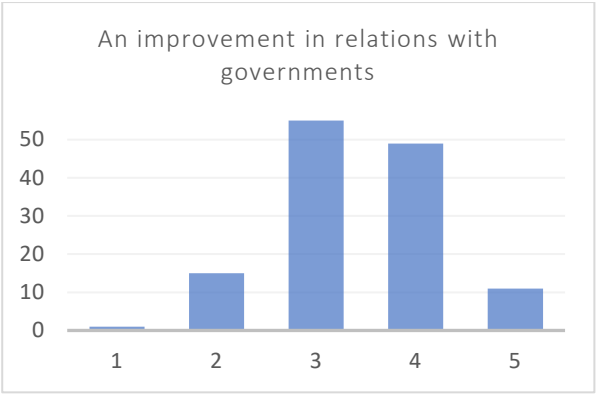
b) The respondents reflect on the increase in workplace discrimination



c) The respondents reflect on the increase in customers' attention to the sustainability performance of organisations



d) The respondents reflect on improvement in relations with the community



e) The respondents reflect on improvement in relations with governments

Figure 7: COVID-19 effect on social sustainability

According to Table 7, the null hypothesis was rejected and assumed that there is a significant difference between participants in the proportion of their responses voting between 1-5.

Table 7: Chi-square test results for questions of Table 6

Question	*N*	*DF*	*Chi-Sq*	*P-Value*
Q1	131	4	76.29	0.00
Q2	131	4	70.26	0.00
Q3	131	4	111.18	0.00
Q4	131	4	96.44	0.00
Q5	131	4	89.34	0.00

According to Table 8, we again reject the null hypothesis of the Wilcoxon signed-rank test since the *P-values* are always smaller than 0.05. Hence, we assume that the median of the responses is always higher than 3. Therefore, we accept hypothesis *H2* amd assume that "*The COVID-19 pandemic had a significant impact on the social sustainability of the food supply chain*".

Table 8: Wilcoxon signed-rank test for questions of Table 6

Sample	*N for Test*	*Wilcoxon Statistic*	*P-Value*
Q1	91	3482.5	0.000
Q2	76	2103.0	0.000
Q3	80	2666.0	0.000
Q4	84	3024.5	0.000
Q5	76	2368.0	0.000

4.6 COVID-19 effect on environmental sustainability

Here, we analyze category 7 of Table 1 to test the hypothesis of *H3*. According to the United Nations (UN) Environment Program (2020), environmental sustainability is about acting to ensure future generations have the natural resources available to live an equal, if not better, way of life than current generations.

There is a lack of a blueprint for how sustainability practices can be pursued due to the differences in the countries' ecological, economic and social conditions. Therefore, each country works on their own policies to ensure that environmental sustainability is carried out as a global objective. For instance, US Environment Protection Agency (EPA) enforces the below regulations involving environmental sustainability and protection (EPA, 2021).

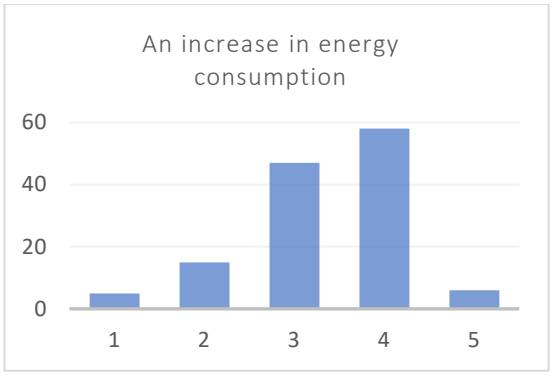
- Air quality
- Water quality
- Soil quality
- Greenhouse gas emissions
- Plantlife
- Animals and wildlife habitats
- Hazardous waste

Table 9 shows the directed two main questions to figure out how COVID-19 affected environmental sustainability. First, it is asked whether it affects the energy increase in food supply chains. Second, we ask whether it affects food waste. The frequency of respondents' answers to those questions is summarized in Figure 8. According to Figure 8, as in previous cases, the respondents mostly vote for "somewhat agree" and "strongly agree".

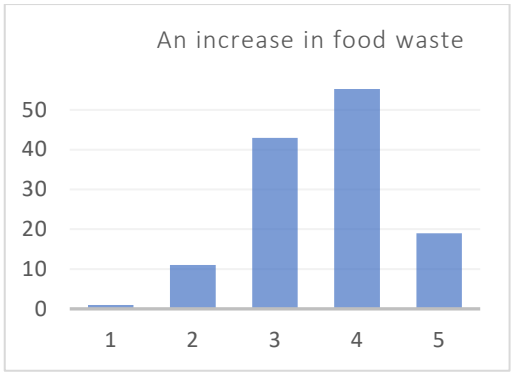
Table 9: Environmental Sustainability: Please rate the following statements considering the impact of COVID-19 on the environmental sustainability of the food supply chain

Statement	**1**	**2**	**3**	**4**	**5**
An increase in energy consumption					
An increase in food waste					

To accept or reject *H3*, we first complete the Chi-square test and then implement the Wilcoxon signed-rank test. Tables 10 and 11 show the Chi-square test and the Wilcoxon signed-rank test results, respectively.



a) The respondents reflect on an increase in energy consumption



b) The respondents reflect on an increase in food waste

Figure 8: COVID-19 effect on environmental sustainability

Table 10: Chi-square test results for questions of Table 9

Question	*N*	*DF*	*Chi-Sq*	*P-Value*
Q1	131	4	96.63	0.00
Q2	131	4	82.02	0.00

Table 11: Wilcoxon signed-rank test for questions of Table 9

Sample	*N for Test*	*Wilcoxon Statistic*	*P-Value*
Q1	84	2620	0.000
Q2	88	3458	0.000

According to Tables 10 and 11, we reject the null hypothesis of Chi-square and Wilcoxon signed-rank tests since the *P-values* are always smaller than 0.05. Hence, we assume that the median of the responses is always higher than 3, and we accept hypothesis *H3*. Namely, we assume that "*The COVID-19 pandemic had a significant impact on the environmental sustainability of the food supply chain*".

4.7 Role of technology in improving SCS

The utilization of technology may eliminate the negative impacts of COVID-19 on SCS. Here, our aim is to ask participants whether they believe that the utilization of technology could affect economic, social, and environmental sustainability. Table 12 summarizes the directed questions under category 8. Those questions explore the role of technology (i.e., blockchain

technology, AI, cloud computing, machine learning, decision tools and information systems, etc.) in improving sustainable food supply chains.

Note that category 8 in Table 1 aims to test hypothesis *H4*.

Table 12: Role of technology in improving SCS

Statement	**1**	**2**	**3**	**4**	**5**
The application of technology improves economic sustainability					
The application of technology improves social sustainability					
The application of technology improves environmental sustainability					

Similar statistical analyses are also completed for Table 12 questions as well. According to both chi-square and the Wilcoxon signed-rank test results, *H4* is accepted, and it is assumed that "*Technology had a significant impact on mitigating the negative effects of COVID-19 pandemic on the sustainable food supply chain."*

4.8 Role of effective, sustainable organisational management

Sustainable organisational management can be defined as managing businesses in such a way that, by sustainable practices, current and future generations benefit. Here, we aim to explore category 9 in Table 1 by testing the hypothesis of *H5*.

The directed questions towards that target are given in Table 13, which evaluates the role of effective organisational management (i.e., social networks, resource commitment, relationship management, knowledge, rational abilities, risk management and skilful policy entrepreneurship, etc.) for SCS.

Table 13: Role of effective, sustainable organisational management

Statement	**1**	**2**	**3**	**4**	**5**
Effective, sustainable organisational management allows for improving economic sustainability					
Effective, sustainable organisational management allows for improving social sustainability					
Effective, sustainable organisational management allows for improving environmental sustainability					

Both the Chi-square and the Wilcoxon signed-rank test results suggest *H5* be accepted. Namely, "*Effective organizational management had a significant impact on mitigating the negative effects of COVID-19 pandemic on the sustainable food supply chain*".

4.9 Role of positive governmental policies and interventions

Governmental policies and interventions play an important role in driving the implementation of sustainability initiatives among organisations. Therefore, we survey the effect of positive governmental policies and intervention on SCSin Table 14 questions. In other words, we aim to test hypothesis *H6*. According to the Chi-square and the Wilcoxon signed-rank test results, *H6* is accepted where we assume that "*Government support had a significant impact on mitigating the negative effects of COVID-19 pandemic on the sustainable food supply chain*".

Table 14: Role of positive governmental policies and interventions

Statement	**1**	**2**	**3**	**4**	**5**
Positive governmental policies and interventions allow for improving economic sustainability					
Positive governmental policies and interventions allow for improving social sustainability					
The application of digitalization allows for improving environmental sustainability					

Conclusions

This study researches how the pandemic affected the sustainability of food supply chains from the triple bottom line (TBL) perspective. First, we study the significant impacts of the COVID-19 pandemic on sustainable supply chains' economic, social, and environmental dimensions. A questionnaire study was distributed to entry-level workers and senior executives of different food supply chains across Asia and Europe. The survey resulted in responses from 131 respondents. The findings confirm that there is a significant impact of the COVID-19 pandemic on the economic, social, and environmental dimensions of sustainable supply chains. Our study also shows that digital technologies play an important role in mitigating the challenges imposed by the COVID-19 pandemic on the sustainability of the food supply chains. Additionally, effective organisational management and government support emerged as critical factors that mitigate the negative effects of the COVID-19 pandemic on the sustainable food supply chains.

Our work adds to the growing body of literature that aims to address the challenges faced by the food supply chains. The majority of the existing studies on COVID-19 are theoretical, literature reviews, observation-based or opinion pieces. Additionally, studies examining the sustainability of food supply chains from the triple bottom line (TBL) perspective in COVID-19 context is scant. This study is also one of the first empirical studies to examine the effect of technology, government and organisational management practices on the sustainability of food

supply chains in the COVID-19 context. Hence, we contribute to the limited empirical literature in this domain. The ongoing pandemic has severely disrupted the supply chains and compelled us to rethink how we approach tackling sustainability challenges. Our work provides empirical evidence of these challenges and shows how some of these issues can be addressed. Thus, this study provides a strong basis for future researchers to understand these issues in the food sector. From the managerial perspective, our study helps supply chain managers to understand how the pandemic has affected the sustainability aspects. Our findings suggest that managers need to adopt effective organisational management practices to address the sustainability challenges. Our analysis also shows that government intervention can make a huge difference in our effort to address challenges linked to the pandemic, thus paving the way for future supportive policies. Thus, our study makes significant contributions to the theory, practice, and policy.

Like most studies, our work also has some limitations. Most of the respondents in this study were entry-level employees, which is one of the study's main limitations. In addition, the findings are based on only 131 valid responses. Therefore, in the future, this study can be expanded to other sectors with large and more balanced responses from all levels of employees and different geographical regions.

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