

The impact of the SARS-Cov-2 Pandemic on the food chain on the island of Ireland:

A Horizon Scanning Study



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Foreword

Since early 2020, the food chain on the island of Ireland, and indeed worldwide, has been impacted by the Sars-Cov-2 (Covid-19) pandemic which has imposed shocks on all segments of the food supply chain, simultaneously affecting primary production, food processing, transport and logistics, and consumer demand. Primary production has been impacted through direct on-farm labour shortages and the movement of raw materials. Food processing has been impacted through workforce curtailment and outright shutdowns in many cases, particularly with virus-hit workforces. All modes of goods transportation have been negatively affected by the pandemic with decreases of up to 50% recorded in some forms of transport in the EU. Consumer food buying behaviour has witnessed sporadic buying/hoarding sprees and a massive shift to online shopping and food purchasing which is not without its food safety concerns.

The food chain on the island of Ireland is complex and international and therefore subject to macro risks from the pandemic. We set out to analyse how this food chain is currently operating under the crisis conditions brought about by the pandemic, and what vulnerabilities have already been identified and are likely to be experienced in the short to medium term – vulnerabilities that may have ramifications for food safety and food fraud. It was opportune to garner current expert opinion on where the pandemic will likely impact this food chain and how these upsets will likely evolve. The aspiration is that this will contribute to the augmentation of food chain resilience on the island of Ireland, thereby protecting the indigenous food industry, as well as public health and consumer choice.

This report was prepared by Dr Vincent Hargaden, Associate Professor of Engineering Management and Head of the Systems Engineering Subject Area in the School of Mechanical and Materials Engineering, University College Dublin. The current scientific and open literature was interrogated for the known impacts the pandemic has had/is having on food chains worldwide and on the island of Ireland. This was used as the basis for designing semi-structured interview protocols for use with food business and trade association representatives from across the food sector on the island of Ireland (Republic of Ireland and Northern Ireland).

Executive summary

This report is prepared in response to ConsultUCD being awarded the contract following a call for tender process by **safefood** for a horizon-scanning study titled “*Current and potential impacts of the SARS-Cov-2 Pandemic on Island of Ireland Food Chain Vulnerabilities*”. The aim of this study is to collate the known impacts the current SARS-Cov-2 (Covid-19) pandemic is having, and has already had, on the food chain on the island of Ireland, by garnering expert opinion regarding the short/medium/long term impacts and the degree of uncertainty associated with these predictions. Following a review of the academic and industry literature, interviews were conducted with representatives from across the food sector on the island of Ireland (Republic of Ireland and Northern Ireland). Based on the analysis, the following findings emerge in relation to the impact of the pandemic on food supply chains across the island of Ireland.

Food supply chains on the island of Ireland experienced an unprecedented and unforeseen disruption because of the global pandemic. When initial reports of a respiratory disease outbreak emerged from China, Republic of Ireland and Northern Ireland based food companies, even those with a global presence, did not expect the scale of the impact of Covid-19. The initial assumption was that the outbreak would be similar to those seen previously in South-East Asia, such as SARS in 2003.

The severity and impact of the public health restrictions introduced across the world had both positive and negative impacts for food producers on the island of Ireland. Food producers with customers in the food service sector incurred sudden and significant loss in demand, while those with customers in the retail grocery sector saw significant increase in demand.

The food sector exhibited “bullwhip effect” behaviour caused by the sudden drop in demand from food service, the effect of which rippled up through the supply chain. For food producers, including farmers, it was very difficult to quickly adjust capacity levels, as many capacity planning decisions are made with a medium to long-term horizon.

It was noted that larger multi-national firms tended to have greater levels of financial reserves to withstand the loss in sales. This also provided them with the ability to procure and hold additional levels of inventory of raw materials or work in process.

Trade associations in the Republic of Ireland and Northern Ireland played a critical role for their members. Firstly, they provided a forum for general information sharing between members. Multi-national members were able to provide market intelligence and experience to locally based members.

They also provided a strong lobbying voice to governments in relation to the impact of the pandemic and developing government supports for sectors. The combined expertise of members was also beneficial in developing operational protocols for members.

There were high levels of innovation seen across the sector, among micro and small/medium enterprises. Many of these firms would have low levels of financial reserves and they experienced loss of key customers due to the closure of the food service sector. The financial supports put in place by the governments in both jurisdictions provided critical relief for companies in the agri-food sector, particularly those heavily impacted by the sudden loss in food service demand.

At the time the data was collected, industry representatives expressed the following uncertainties about the future:

- What will steady-state demand look like across Business-to-Business retail, Business-to-Business food service and Business-to-Consumer segments?
- What aspects of consumer behaviour which was adopted during the pandemic will continue and what aspects will return to pre-pandemic patterns?
- Will the pandemic accelerate the trend towards plant-based diets?
- How will the issue of food price inflation¹, driven by rising food commodity prices, develop?

¹ “What the soaring cost of breakfast may signal for global food price inflation”, Financial Times, 28th May 2021, <https://www.ft.com/content/007bdoao-f149-427d-937c-ec5b0ef4374d>

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1 Introduction to the report

This report collates the known impacts the current SARS-Cov-2 (Covid-19) pandemic is having, and has already had, on the food chain on the island of Ireland (Iol). An overview of the impact of Covid-19 on the global food industry, including on food security and safety is provided in Chapter 2 where industry specific responses to the challenges of Covid-19 are described.

Chapter 3 – Covid-19 and Food Supply Chains – provides a summary of the academic literature on the impact of Covid-19 on global food supply chains. Due to the relatively long lead-time between the commencement of an academic study, paper writing and subsequent publication in an academic journal, the literature in this area is quite limited. Several the leading academic journals in the supply chain domain have issued calls for submission in “Covid-19 Special Issues”, which are due for publication in late 2021 and early 2022. The impact of the Covid-19 pandemic on food supply chains in the Republic of Ireland (RoI), Northern Ireland (NI), Great Britain (GB), United States (US) and Europe is also discussed, as well as the impact on specific agri-food sectors, such as beef and dairy.

The research methodology and approach are described in Chapter 4 – Research Findings, in which primary data was collected through semi-structured interviews with key informants across the Iol, from firms who are located in food supply chains, including upstream primary providers, processors, downstream wholesalers and end customers, as well as other stakeholders in food ecosystems. Interviews were carried out between early March and early June 2021. In addition, secondary data was gathered from publicly available sources, including those from relevant government departments, semi-state companies, trade associations, company websites and media reports.

The findings from the primary and secondary data collection processes are provided in Chapter 4. These findings are presented sector by sector, and include dairy, beef, poultry, seafood, food distribution/retail grocery, small and medium enterprises, transport and logistics and trade associations.

Chapter 5 provides an analysis of the findings. The vulnerabilities of food supply chains on the Iol because of the Covid-19 pandemic are analysed using seven factors, based on a previously validated academic framework. Using the same framework, the capabilities developed by these food supply chains to enhance their resilience are analysed across fourteen factors.

The conclusions from the study are presented in Chapter 6. In addition, there are several uncertainties for the future listed which were described by the industry representatives during the data collection phase.

Finally, key terms that have been used since the pandemic began - “supply chain risk” and “supply chain resilience” – are explored in Appendix 3. This analysis provided the basis for the development of the interview protocol for the primary data collection process.

2 Impact of the Covid-19 pandemic on the global food industry

This section provides an overview of the impact of the Covid-19 on the food industry globally, using secondary data sources.

Impact of the Covid-19 pandemic on the global food industry

The Covid-19 pandemic not only presented challenges for healthcare systems, but it also revealed the vulnerability of food supply chains to an unprecedented shock and disruption. The pandemic crisis increased our understanding of the exposure of food supply chains to unprecedented shocks and emergencies, especially in terms of food access (rather than food shortages)², changes in consumer behaviour, small-scale production, and flexible food supply chain design³. In addition, local micro agri-food production also had to deal with increased challenges, including shocks in supply or demand and delays or interruption in logistics operations due to the lockdown measures and the need to identify alternative sales channels⁴.

Despite the pandemic crisis, unlike many other supply chains which experienced supply side disruptions, agri-food supply chains have generally experienced demand side disruptions and have therefore been able to maintain their core operations to some degree, providing essential food supply within and across countries. However, the overnight closure of restaurant and other food service industries due to “stay at home” public health restrictions resulted in an immediate drop in demand in these sectors, with changes in consumers’ purchasing and consumption patterns then emerging. The nature of agri-food production requires planning to be made months or even years in advance before the expected output is delivered to customers. For instance, crop planting and animal breeding decisions for 2020 were made before the Covid crisis unfolded, leaving upstream actors in food supply chains, such as farmers, with little flexibility to adjust the production volume to adapt to the rapid

2 Christophe Béné, ‘Resilience of Local Food Systems and Links to Food Security – A Review of Some Important Concepts in the Context of COVID-19 and Other Shocks’, *Food Security*, 12.4 (2020), 805–22 <<https://doi.org/10.1007/s12571-020-01076-1>>.

3 Charis M. Galanakis, ‘The Food Systems in the Era of the Coronavirus (COVID-19) Pandemic Crisis’, *Foods*, 9.4 (2020), 523 <<https://doi.org/10.3390/foods9040523>>.

4 Matteo Vittuari and others, ‘Envisioning the Future of European Food Systems: Approaches and Research Priorities After COVID-19’, *Frontiers in Sustainable Food Systems*, 5 (2021) <<https://doi.org/10.3389/fsufs.2021.642787>>.

change in customer demand and purchasing habits⁵. This situation demonstrates the importance of flexible supply chain design that allows members to quickly identify new sources of supply and markets when the existing ones are disrupted⁶.

Unlike many other types of supply chain disruption in the past, the Covid-19 crisis has caused an unprecedented stress across entire food supply chains. Whereas prior disruptions (e.g., weather related, or product recalls due to contamination) tend to initially impact on just one area of a supply chain, Covid-19 simultaneously impacted supply chains from end-to-end: harvesting, processing, logistics and final demand fulfilment. The magnitude of the impact varied across food sectors, with products experiencing disruption at different points of the supply chain. Upstream operations of the food supply chain such as farm production and harvesting had trouble in obtaining some input factors, especially labour. Labour intensive farming activities suffered more, as restrictions on travel related to public health regulations impacted the availability of seasonal migrant workers for planting and harvesting activities especially in the fruit and vegetable sector. Food processing units faced capacity challenges due to social distancing requirements, the scarcity of workers and forced closures (e.g., Covid-19 outbreaks have occurred in meat processing plants in many countries). There was a knock-on impact of travel restrictions on freight and logistics providers, with the greatest impact on products requiring air freight, such as seafood shipments from Europe and North America to Asia⁷. Global air cargo capacity in May 2020 was 26% lower than its usual capacity, with highest decrease (80%) in cargo travel between Europe and Latin America. In Europe, though there was an initial decline of 40-50% in truck freight, it recovered shortly afterwards. The difficulties associated with transportation was of particular concern for products with a short shelf-life such as fruits and vegetables.

Industry specific responses to the challenges of the Covid-19 pandemic

As the Covid-19 pandemic exposed weaknesses in food supply chains, it is important to understand how the members of supply chains responded to the disruption. Here, Bassett et al. (2021)⁸ studied

⁵ '2020 - Teagasc Publish Analysis of Farm Income Impacts of COVID-19 - Teagasc | Agriculture and Food Development Authority' <<https://www.teagasc.ie/news--events/news/2020/farm-income-impacts-of-co.php>> [accessed 15 April 2021].

⁶ Koen Deconinck, Ellie Avery, and Lee Ann Jackson, 'Food Supply Chains and Covid-19: Impacts and Policy Lessons', *EuroChoices*, 19.3 (2020), 34-39 <<https://doi.org/10.1111/1746-692X.12297>>.

⁷ David C. Love, Edward H. Allison, Frank Asche, Ben Belton, Richard S. Cottrell, Halley E. Froehlich, Jessica A. Gephart, Christina C. Hicks, David C. Little, Elizabeth M. Nussbaumer, Patricia Pinto da Silva, Florence Poulain, Angel Rubio, Joshua S. Stoll, Michael F. Tlusty, Andrew L. Thorne-Lyman, Max Troell, Wenbo Zhang, (2021) "Emerging COVID-19 impacts, responses, and lessons for building resilience in the seafood system", *Global Food Security*, Volume 28, <https://doi.org/10.1016/j.gfs.2021.100494> .

⁸ Bassett, H.R., Lau, J., Giordano, C., Suri, S.K., Advani, S., Sharan, S., 2021. Preliminary lessons from COVID-19 disruptions of small-scale fishery supply chains. *World Dev.* 143, 105473. <https://doi.org/10.1016/j.worlddev.2021.105473>

seven small-scale fishery supply chain cases from specific regions in four countries (Peru, Indonesia, India and US) to identify how the actors adaptively responded to the disruption and to identify the obstacles to risk mitigation efforts. Their study revealed that, as a response to the disruption, firms changed their attention to local and regional distribution systems, improved flexibility in their operations and took advantage of technology. Travel restrictions, decrease in spending power among customers and disruption to the existing logistics facilities were the challenges faced in reaching domestic customers.

Belton et al., (2021)⁹ conducted a survey of 768 respondents from Asia and Africa to study the impact and adaptive response of the aquatic food supply chain in these regions. According to their survey, firms adapted to the impact of Covid-19 by decreasing production costs, adopting alternative sourcing and employment, expanding business activities, taking advantage of social capital, borrowing, and lowering food consumption. In another study conducted on the meat supply chain by Hobbs (2021)¹⁰, it is suggested that increased adoption of automation and digitalization of supply chain activities will occur to cope with the disruption caused by the pandemic. In an analysis of strategies to overcome the impact of Covid-19 pandemic, Chitrakar et al. (2021)¹¹ reviewed the technological interventions to address the crisis. They discussed smart technologies for food processing to reduce human-to-human and human-to-food contact as well as possible virus decontamination technologies.

In relation to supply chain resilience, Ali et al. (2021)¹² explored reactive strategies for food SMEs to improve their resilience to deal with the Covid-19 crisis. They proposed a reactive time/cost matrix to help decision makers in SMEs to execute strategies during a disruption. Coluccia et al. (2021)¹³ studied the resilience levels of the Italian agri-food supply chains to the impact of the pandemic by examining its impact on commodity prices. They proposed an assessment tool to develop strategies for the entire agri-food supply chain by ensuring resilience across the sector in the case of unprecedented events. To demonstrate the resilience of the French organic dairy supply chain to the impact of the pandemic, Perrin and Martin (2021)¹⁴ conducted an empirical study using online surveys and interviews

⁹ Belton, B., Rosen, L., Middleton, L., Ghazali, S., Mamun, A.-A., Shieh, J., Noronha, H.S., Dhar, G., Ilyas, M., Price, C., Nasr-Allah, A., Elsira, I., Baliarsingh, B.K., Padiyar, A., Rajendran, S., Mohan, A.B.C., Babu, R., Akester, M.J., Phyto, E.E., Soe, K.M., Olaniyi, A., Siriwardena, S.N., Bostock, J., Little, D.C., Phillips, M., Thilsted, S.H., 2021. COVID-19 impacts and adaptations in Asia and Africa's aquatic food value chains. *Mar. Policy* 129, 104523. <https://doi.org/10.1016/j.marpol.2021.104523>

¹⁰ Hobbs, J.E., 2021. The Covid-19 pandemic and meat supply chains. *Meat Sci.* 108459. <https://doi.org/10.1016/j.meatsci.2021.108459>

¹¹ Chitrakar, B., Zhang, M., Bhandari, B., 2021. Improvement strategies of food supply chain through novel food processing technologies during COVID-19 pandemic. *Food Control* 125, 108010. <https://doi.org/10.1016/j.foodcont.2021.108010>

¹² Ali, M.H., Suleiman, N., Khalid, N., Tan, K.H., Tseng, M.-L., Kumar, M., 2021. Supply chain resilience reactive strategies for food SMEs in coping to COVID-19 crisis. *Trends Food Sci. Technol.* 109, 94–102. <https://doi.org/10.1016/j.tifs.2021.01.021>

¹³ Coluccia, B., Agnusdei, G.P., Miglietta, P.P., De Leo, F., 2021. Effects of COVID-19 on the Italian agri-food supply and value chains. *Food Control* 123, 107839. <https://doi.org/10.1016/j.foodcont.2020.107839>

¹⁴ Perrin, A., Martin, G., 2021. Resilience of French organic dairy cattle farms and supply chains to the Covid-19 pandemic. *Agric. Syst.* 190, 103082. <https://doi.org/10.1016/j.agsy.2021.103082>

with supply chain actors. According to this study, the inherent buffers and adaptive capacities of these supply chains promoted resilience in supply chain operations, enabling them to satisfy customer demand. Coopmans et al. (2021)¹⁵ studied the impact of Covid-19 on food supply chains in northern Belgium and the resilience measures adopted by that agri-food sector. Their study revealed that the ability of the Flemish food supply chain to provide food was not significantly compromised and the resilience of the food supply chain system can be attributed to flexibility, diversity, self-rearrangement, and openness.

The Covid-19 pandemic, food security and safety

Focusing on food safety issues, Rizou et al. (2020)¹⁶ reviewed the potential spread of the Covid-19 virus through food supply chain activities. This study emphasized the need for the awareness of the spread of the virus through unhygienic environments, food systems and people along the supply chain and suggested possible measures to prevent such a spread. Djekic et al. (2021)¹⁷ carried out a survey with respondents from multiple countries, to examine the response of firms regarding food safety and to identify the attributes related to food safety during the pandemic crisis. The study identified that staff awareness and hygiene measures were the main factors influencing the food safety. In another study, Brooks et al. (2021)¹⁸ discussed challenges of food fraud detection and prevention in the wake of the Covid-19 pandemic and Brexit.

The combined effect of the health crisis and an economic slow-down due to Covid-19 resulted in a serious threat to food security, especially in poorer and developing countries. Arouna et al., (2020)¹⁹ studied the impact of Covid-19 on rice supply chains in West Africa, where rice plays a significant role in the food security of the region. They also proposed short, medium and long-term policy recommendations for government to enhance the resilience of the value chain to improve the food

¹⁵ Coopmans, I., Bijttebier, J., Marchand, F., Mathijs, E., Messely, L., Rogge, E., Sanders, A., Wauters, E., 2021. COVID-19 impacts on Flemish food supply chains and lessons for agri-food system resilience. *Agric. Syst.* 190, 103136. <https://doi.org/10.1016/j.agsy.2021.103136>

¹⁶ Rizou, M., Galanakis, I.M., Aldawoud, T.M.S., Galanakis, C.M., 2020. Safety of foods, food supply chain and environment within the COVID-19 pandemic. *Trends Food Sci. Technol.* 102, 293–299. <https://doi.org/10.1016/j.tifs.2020.06.00>

¹⁷ Djekic, I., Nikolić, A., Uzunović, M., Marijke, A., Liu, A., Han, J., Brnčić, M., Knežević, N., Papademas, P., Lemoniati, K., Witte, F., Terjung, N., Papageorgiou, M., Zinoviadou, K.G., Dalle Zotte, A., Pellattiero, E., Sołowiej, B.G., Guiné, R.P.F., Correia, P., Sirbu, A., Vasilescu, L., Semenova, A.A., Kuznetsova, O.A., Vrabič Brodnjak, U., Pateiro, M., Lorenzo, J.M., Getya, A., Kodak, T., Tomasevic, I., 2021. Covid-19 pandemic effects on food safety - Multi-country survey study. *Food Control* 122, 107800. <https://doi.org/10.1016/j.foodcont.2020.107800>

¹⁸ Brooks, C., Parr, L., Smith, J.M., Buchanan, D., Snioch, D., Hebishy, E., 2021. A Review of Food Fraud and Food Authenticity across the Food Supply Chain, with an Examination of the Impact of the COVID-19 Pandemic and Brexit on Food Industry. *Food Control* 108171. <https://doi.org/10.1016/j.foodcont.2021.108171>

¹⁹ Arouna, A., Soullier, G., Mendez del Villar, P., Demont, M., 2020. Policy options for mitigating impacts of COVID-19 on domestic rice value chains and food security in West Africa. *Glob. Food Secur.* 26, 100405. <https://doi.org/10.1016/j.gfs.2020.100405>

security in the region. Rasul (2021)²⁰ examined the impact of the twin challenges of Covid-19 and climate change on food security and sustainability in the South Asia region. Their study highlighted importance of understanding the relationship between these global issues and integrated measures for addressing interconnected crises. Priyadarshini and Abhilash (2021)²¹ studied the impact of the pandemic on food security in India and explored government initiatives and recommendations to deal with them.

The impact of the Covid-19 pandemic on consumer behaviour

On the downstream side of the supply chain, Covid-19 caused drastic changes in consumer demand. As the Covid-19 crisis increased in severity in spring 2020, customer demand at dine-in restaurants collapsed due to the enforced closure of restaurants and other food service outlets (Figure 2.1). This resulted in an unprecedented surge in retail demand for certain food items. In France, during the initial peak of the crisis (spring 2020), weekly retail sales of frozen food items went up by 63% (compared to 2019) and similarly, in Germany, the retail sales of packaged food increased by 56% year-on-year. After this initial spike, demand for fresh, packaged and frozen food at retailers continued to be 15-20% higher than normal. Figure 2.2 illustrates the percentage change year-on-year in United States food sales. There was a sudden increase in retail food sales in March 2020, but which reduced from April onwards. Restaurant reservations collapsed and stayed at this level from March 2020 to May 2020 (time period for the available data). However, the increase in “food-at-home” sales do not make up for the drop in “food away from home”. Restaurants generally sell higher priced food compared to supermarkets, so even if the same number of people who cancel a restaurant reservation, then go to a supermarket, it is unlikely that they will spend the same amount at the supermarket. Overall, it is difficult to transfer restaurant sales directly to supermarket sales.

²⁰ Rasul, G., 2021. Twin challenges of COVID-19 pandemic and climate change for agriculture and food security in South Asia. *Environ. Chall.* 2, 100027. <https://doi.org/10.1016/j.envc.2021.100027>

²¹ Priyadarshini, P., Abhilash, P.C., 2021. Agri-food systems in India: Concerns and policy recommendations for building resilience in post COVID-19 pandemic times. *Glob. Food Secur.* 29, 100537. <https://doi.org/10.1016/j.gfs.2021.100537>

Figure 2.1: Percentage change in reservations at restaurants compared to the previous year²²

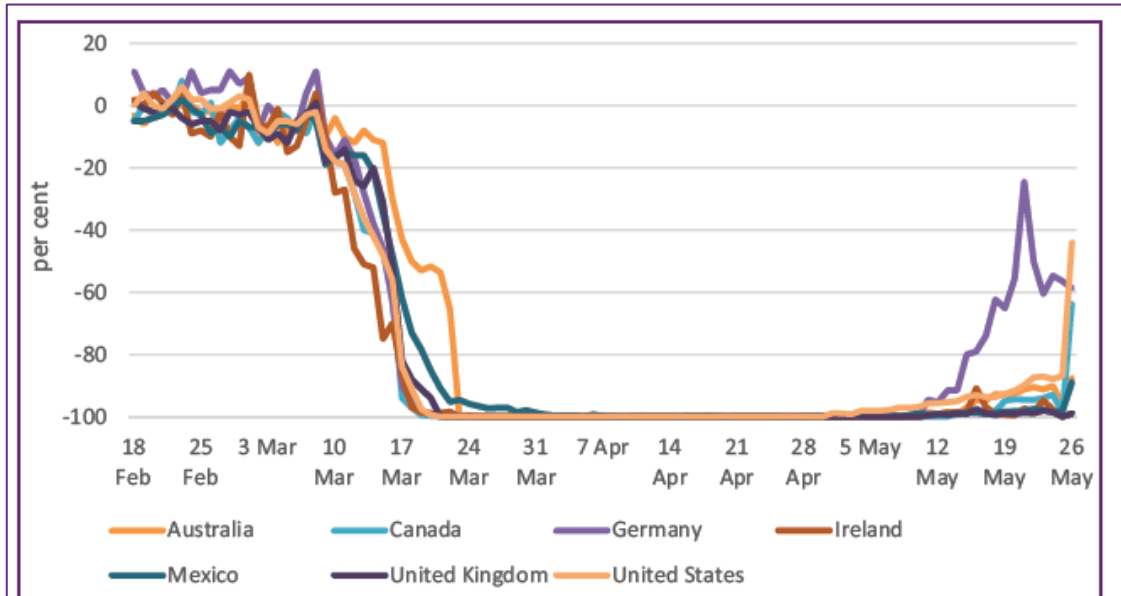
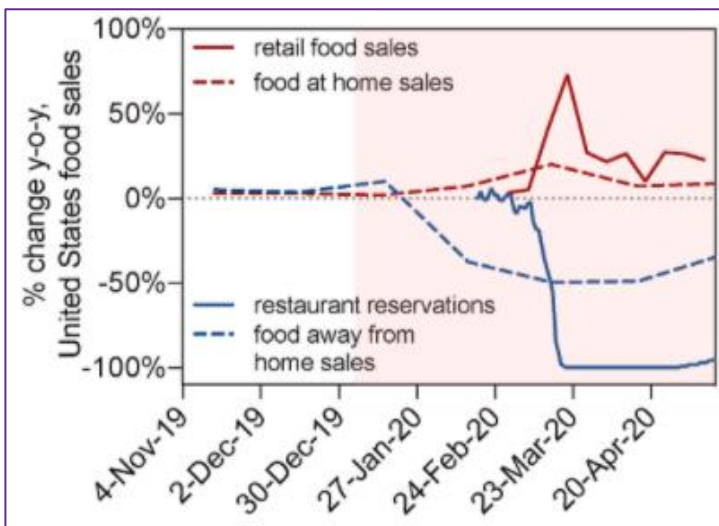


Figure 2.2: Percentage change year-on-year food sales (United States)²³



²² Deconinck, K., Avery, E. and Jackson, L.A., 2020. Food Supply Chains and Covid-19: Impacts and Policy Lessons. *EuroChoices*, 19(3), pp.34-39. <https://doi.org/10.1111/1746-692X.12297>

²³ David C. Love, Edward H. Allison, Frank Asche, Ben Belton, Richard S. Cottrell, Halley E. Froehlich, Jessica A. Gephart, Christina C. Hicks, David C. Little, Elizabeth M. Nussbaumer, Patricia Pinto da Silva, Florence Poulain, Angel Rubio, Joshua S. Stoll, Michael F. Tlusty, Andrew L. Thorne-Lyman, Max Troell, Wenbo Zhang, (2021) "Emerging COVID-19 impacts, responses, and lessons for building resilience in the seafood system", *Global Food Security*, Volume 28, <https://doi.org/10.1016/j.gfs.2021.100494> .

3 Covid-19 and food supply chains

This section examines the available academic literature to date on the impact of Covid-19 on food supply chains. Due to the relatively lead-time between the writing of an academic paper and its publication in an academic journal (often 1.5-2 years), the academic literature on the impact of Covid-19 on food supply chains in developed countries is relatively small. It should be noted that several the leading academic journals in the domain of operations and supply chain management are currently preparing “Special Issues” on the topic of Covid-19, which are due for publication in late 2021. It is not yet known how many of these papers will focus on food supply chains. The following paragraphs summarise the findings from academic studies across the world on the impact of Covid-19 on food supply chains. A comprehensive description of supply chain risk and the concept of resilience is provided in Appendix 3.

Analysing the impact of the Covid-19 pandemic on food supply chains

There is a relatively small body of literature that pursued a quantitative modeling approach to analyze the impact of Covid-19 on food supply chains. Perdana et al. (2020)²⁴ developed an optimization model for managing the impact of Covid-19 in a food supply chain network through regional food hubs (RHF) facing uncertainty. The study introduced RFH as a mitigation strategy to better link the producers in rural areas with the customers in urban areas. The study identified the locations and capacity of RHF in the food supply network that would minimize the logistics cost.

With the help of econometric modeling, Malone et al. (2021)²⁵ examined the initial impact of Covid-19 on the US egg supply chain caused by the changes in consumption patterns from closure of restaurants and the food service sector to food-at-home. Their study revealed that while the pandemic caused a significant rise in retail and farm gate prices for table eggs, the price of eggs used in food service sector dropped by 67%.

²⁴ Perdana, T., Chaerani, D., Achmad, A.L.H., Hermiatin, F.R., 2020. Scenarios for handling the impact of COVID-19 based on food supply network through regional food hubs under uncertainty. *Heliyon* 6, e05128. <https://doi.org/10.1016/j.heliyon.2020.e05128>

²⁵ Malone, T., Schaefer, K.A., Lusk, J.L., 2021. Unscrambling U.S. egg supply chains amid COVID-19. *Food Policy* 102046. <https://doi.org/10.1016/j.foodpol.2021.102046>

Kumar et al., (2021)²⁶ employed a fuzzy-best worst methodology (F-BWM) to study risk mitigation strategies for perishable food supply chains during the pandemic crisis. According to their findings, collaborative management efforts, proactive planning for risk mitigation and financial sustainability are the leading risk mitigation measures.

Impact of the Covid-19 pandemic on specific food supply chains worldwide

Nchanji et al. (2021)²⁷ studied the impact of Covid-19 on “common beans” supply chain activities such as production, distribution and consumption in sub-Saharan Africa. This survey-based study gathered data from the various actors in the supply chain from nine countries in Central, Eastern and Southern parts of Africa. The study revealed that restrictions imposed by governments to control the spread of the pandemic negatively impacted the cost and accessibility of farm inputs and on labour, distribution and consumption of beans.

In order to investigate the early impact of the pandemic, Nordhagen et al., (2021)²⁸ collected data from 367 micro, small and medium-sized agri-food enterprises (MSMEs) in 17 African and Asian countries. This study found that the impact of the pandemic and associated pandemic prevention measures resulted in the reduction of sales and limited access to inputs and financing as well as on staffing. In addition, changes in production volume, production shutdowns and production prices were also observed.

In an effort to study the impact on aquatic food production and small scale fisheries in Bangladesh, Sunny et al. (2021)²⁹, conducted an empirical study based on secondary data and primary field research. According to their results, labour crisis, transportation issues, reduced consumer demand, increased commodity prices and the weak value chain were the main drivers of large-scale negative impacts on the aquatic supply chain.

²⁶ Kumar, A., Mangla, S.K., Kumar, P., Song, M., 2021. Mitigate risks in perishable food supply chains: Learning from COVID-19. *Technol. Forecast. Soc. Change* 166, 120643. <https://doi.org/10.1016/j.techfore.2021.120643>

²⁷ Nchanji, E.B., Lutomia, C.K., Chirwa, R., Templer, N., Rubyogo, J.C., Onyango, P., 2021. Immediate impacts of COVID-19 pandemic on bean value chain in selected countries in sub-Saharan Africa. *Agric. Syst.* 188, 103034. <https://doi.org/10.1016/j.agry.2020.103034>

²⁸ Nordhagen, S., Igbeka, U., Rowlands, H., Shine, R.S., Heneghan, E., Tench, J., 2021. COVID-19 and small enterprises in the food supply chain: Early impacts and implications for longer-term food system resilience in low- and middle-income countries. *World Dev.* 141, 105405. <https://doi.org/10.1016/j.worlddev.2021.105405>

²⁹ Sunny, A.R., Sazzad, S.A., Prodhan, S.H., Ashrafuzzaman, Md., Datta, G.C., Sarker, A.K., Rahman, M., Mithun, M.H., 2021. Assessing impacts of COVID-19 on aquatic food system and small-scale fisheries in Bangladesh. *Mar. Policy* 126, 104422. <https://doi.org/10.1016/j.marpol.2021.104422>

To study the short and long-term impact of Covid-19 on agri-food supply chains in the United States and Canada, Weersink et al. (2021)³⁰ examined six commodity supply chains. They observed that “just-in-time” practices with less reserved capacity in food supply chains was one of the main reasons for the initial disruption. In the longer term, they predict that in addition to structural changes in the supply chain, increased flexibility through product diversification and consolidation of companies could be expected.

Ilesanmi et al. (2021)³¹ examined the impact of Covid-19 on food losses in the agricultural supply chains in Nigeria and proposed measures to reduce the effect of the pandemic. Better stakeholder engagement, improved logistics operations and implementation of social protections systems were proposed as counter measures to mitigate the pandemic crisis. In a related study, Khan et al., (2021)³² explored the impact of the pandemic on disruption to food supply chains in Asian countries. Their study showed that the impact of pandemic restrictions on the food supply chains led to higher levels of undernourishment.

In addition to studying the socioeconomic implications of the pandemic, Barman et al. (2021)³³ examined the general impact of lockdowns on agri-businesses and associated supply chains. They found that lockdowns impacted the availability of labour, led to delays in farming activities, production and transportation, as well as causing changes in consumer behaviour.

Impact of the Covid-19 pandemic on the island of Ireland food supply chain

The agri-food sector plays a key role in economic activity in both the Republic of Ireland (ROI) and Northern Ireland (NI). In ROI, the sector accounts for 7.1% of total employment and €14.5 billion in exports, which is 9.5% of all ROI merchandising exports. The main commodities are dairy, beef, sheep, pig and tillage. Similarly, agriculture is one of Northern Ireland’s most important industries. The most recent annual statistics from NI Department of Agriculture, Environment and Rural Affairs (DAERA) indicate that the total output from the sector was £5.2 billion. Of this, 51% was exported to Great Britain, 23% was consumed in Northern Ireland, 15% went to ROI, 9% exported to other EU countries and 3%

³⁰ Weersink, A., von Massow, M., Bannon, N., Ifft, J., Maples, J., McEwan, K., McKendree, M.G.S., Nicholson, C., Novakovic, A., Rangarajan, A., Richards, T., Rickard, B., Rude, J., Schipanski, M., Schnitkey, G., Schulz, L., Schuurman, D., Schwartzkopf-Genswein, K., Stephenson, M., Thompson, J., Wood, K., 2021. COVID-19 and the agri-food system in the United States and Canada. *Agric. Syst.* 188, 103039. <https://doi.org/10.1016/j.agsy.2020.103039>

³¹ Ilesanmi, F.F., Ilesanmi, O.S., Afolabi, A.A., 2021. The effects of the COVID-19 pandemic on food losses in the agricultural value chains in Africa: The Nigerian case study. *Public Health Pract.* 2, 100087. <https://doi.org/10.1016/j.puhip.2021.100087>

³² 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. *Socioecon. Plann. Sci.* 101033. <https://doi.org/10.1016/j.seps.2021.101033>

³³ Barman, A., Das, R., De, P.K., 2021. Impact of COVID-19 in food supply chain: Disruptions and recovery strategy. *Curr. Res. Behav. Sci.* 2, 100017. <https://doi.org/10.1016/j.crbeha.2021.100017>

exported to the rest of the world. NI products are principally dairy, pork, beef and poultry. Of the 15% that was exported to ROI, a large portion of that is dairy, which is subsequently processed into cheese or butter for export to Great Britain.

Though the Covid-19 restrictions had limited impact on farm production across the Iol (Northern Ireland and Republic of Ireland), there has been a similar downwards trend in the demand for food items in the food service sector (Hotel, Restaurant and Catering “HoReCa”) in both jurisdictions^{34,35}. This collapse in demand has not been fully compensated by a shift towards household food consumption (eat-at-home). This fall in consumer demand had a ripple effect back up through the food supply chain - a phenomenon called the “bullwhip effect”³⁶. Equally, the sudden increase in demand at retail supermarkets also had a ripple effect through the food system. The challenge with sudden increases or decreases in customer demand means that actors further up the supply chain do not have sufficient production capacity or products to meet the sudden increase in demand, or else are left with excess capacity or products when there is a sudden decrease in demand.

The estimated loss of income in 2020 throughout the primary agricultural sector in ROI ranges from 0.7 billion euro to 1.6 billion euro³⁷. While similar data for NI was not readily available, the NI Department of Agriculture, Environment and Rural Affairs indicated “*some agricultural and horticultural businesses have incurred financial losses as a result of short-term market disturbance due to the COVID-19 pandemic*”³⁸. Data from the Ulster Farmers Union (UFU) illustrates the impact of Covid on the various sectors³⁹ which are included in the relevant sections later in this report.

In ROI, the decline was attributed to the associated pandemic restrictions in the main destination markets for beef and the ongoing difficulties to get access to markets in mainland China. Exports to the UK, which represents 44% of primary ROI beef export, were impacted by the decline in demand due to the closure of the food service industry. For the same reason, along with the change in consumer eating habits, beef consumption in the EU declined by 2% in 2020. ROI beef exports to China (which had initially gained access to the Chinese market in 2018), was interrupted in May 2020 due to Covid related import restrictions imposed by the Chinese government. With respect to percentage change in

³⁴ Hospitality Sector and the Wider Economy in NI: Key estimated initial impacts of COVID-19 and related government responses, Northern Ireland Assembly Research and Information Service Briefing Note, 10th November 2020, <http://www.niassembly.gov.uk/globalassets/documents/raise/publications/2017-2022/2020/communities/6820.pdf>

³⁵ Year-over-year daily change in seated restaurant diners due to the coronavirus (COVID-19) pandemic in Ireland from February 24, 2020 to August 24, 2021, <https://www.statista.com/statistics/1105125/coronavirus-restaurant-visitation-impact-ireland/>

³⁶ Lee, H.L., Padmanabhan, V. and Whang, S., 1997. The bullwhip effect in supply chains. *Sloan management review*, 38, pp.93-102. <https://sloanreview.mit.edu/article/the-bullwhip-effect-in-supply-chains/>

³⁷ McConalogue, *Export Performance and Prospects 2021*, 13 January 2021 <https://www.bordbia.ie/industry/news/press-releases/export-performance-and-prospects-2021>.

³⁸ <https://www.daera-ni.gov.uk/articles/Coronavirus-Income-Support-Scheme>

³⁹ Ulster Farmers Union (UFU) Response to Covid-19 and Food Supply, https://content17.co.uk/media/99/files/EFRA_UFU_Response_1.pdf

income, the beef sector is estimated to be hardest hit within the agriculture sector. Latest reports suggest the value of primary beef exports suffered a 2% decrease to 1.9 billion euro in 2020.

It is estimated that 35-40% of NI beef sales are food service and catering. The closure of the food service sector in Europe and the Great Britain (GB) resulted in a significant oversupply as processors export nearly 90% of their beef production. Industry reports suggest that there was around 60% loss of market in the EU. As a result, inventory levels were higher than usual which exposed the UK domestic beef market to this oversupply. Orders for cuts of sirloin, fillet and ribs in particular as well as mince that were destined for hotels, restaurants, conference centres and other events were cancelled or postponed³⁹.

After experiencing growth in 2019, ROI poultry sector exports fell by 2% in value in 2020 to 152 million euro, although the volume increased by 4%. Covid-19 caused a significant negative impact on poultry export prices and the sector was affected by 14% decline in the exports to UK, which was somewhat balanced by a 16% increase in the trade in other international markets.

The poultry sector in NI saw both positive and negative impacts, with the collapse in food service demand but increase in retail sales. There was also a medium-term impact, with the reduction in demand for hatching eggs from firms in GB who raise chicks for the food service sector. This has resulted in NI breeding farms ceasing production for up to three months.

Covid-19 impacted the international dairy market. Prior to the pandemic crisis, ROI farmers exported 92% of all the product produced and three quarter of ROI dairy items were exported to the 15 countries most severely affected by Covid-19. While similar statistics were unavailable for NI, dairy exports to ROI and Rest of EU account for 60% of NI dairy turnover⁴⁰. However, both the ROI and NI dairy sectors were able to maintain production capacity and output during the pandemic crisis⁴¹.

The ROI seafood sector was also impacted due to loss of demand from the food service industry and the loss of major export markets. High value cut fish is purchased predominantly by the food service sector. In 2020 the value of primary ROI seafood exports decreased by 10% to 443 million euro. This is because of the disruption in exports in the shellfish category which is usually destined for foodservice outlets in key EU27 markets and in Asia. While the aquaculture sector is a small, niche market in NI, mainly producing mussels, oysters, salmon and trout, it encountered similar issues to ROI, but the magnitude of the impact is unavailable⁴².

⁴⁰ <https://www.nisra.gov.uk/sites/nisra.gov.uk/files/publications/Overview-of-NI-Trade-April-2020.pdf>

⁴¹ <https://www.daera-ni.gov.uk/publications/milk-price-and-production-statistics-2000-onwards>

⁴² <https://www.daera-ni.gov.uk/news/poots-announces-ps360k-support-aquaculture-sector>

The ROI drinks industry has been impacted due to closure of pubs, hospitality and tourism businesses both nationally and internationally. Overall, alcohol exports have decreased by 19% in 2020 to 1.3 billion euro. The decrease in export in this sector can be primarily attributed to reduction in the value of whiskey (-€205m), cream liqueurs(-€53m) and beer (-€51m). Similar data was not readily available for NI.

Since the start of pandemic crisis, it has been observed that consumers in ROI and NI have been buying local products in a large amount with leading brands seeing growth of almost 20%, with 44% of the 100 top-selling take-home grocery brands in ROI during 2020 being produced in ROI⁴³. While there was a similar trend in NI, corresponding data were not available.

Impact of the Covid-19 pandemic on the food supply chain in Great Britain

Unlike ROI and NI, who are both net exporters of food, the Great Britain food supply chain is characterized by high dependence on imports, consisting half of the food consumed within the country and 84% of the fresh fruits⁴⁴. It is heavily depended on European Union (EU) countries such as Spain for vegetables and Italy for packaged goods such as canned tomatoes and pasta.

There was a significant disruption on entire food supply chains across the country due to the dependence on highly complex and just-in-time supply chains. Owing to the Covid-19 pandemic mitigation efforts taken by the UK government, such as lockdown and closure of restaurants and other food service sector outlets, supermarkets ran short of certain food items (Figure 3.1) and food banks experienced double the demand compared to 2019.

The results of a UK government survey conducted across a range of organizations in the UK food supply chain identified three ways the pandemic impacted the food system.

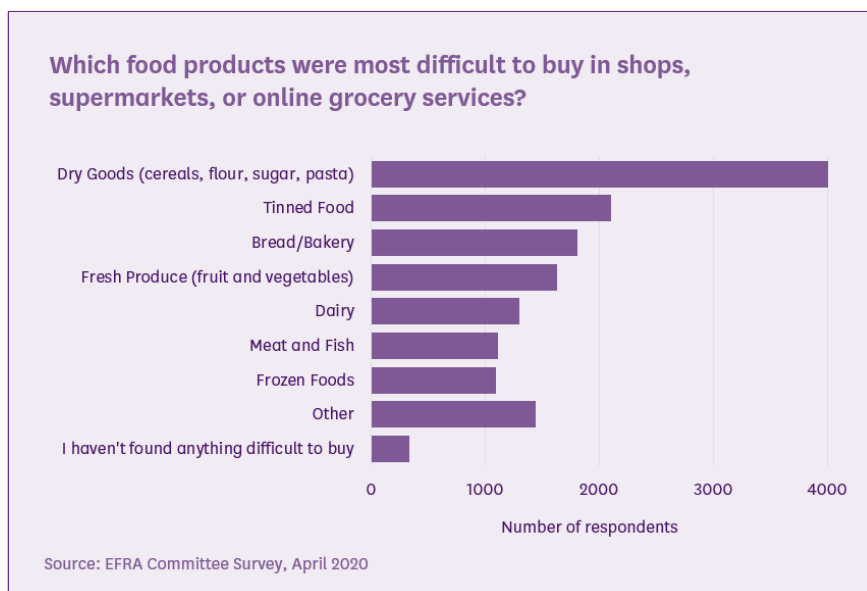
1. **Difficulty predicting demand for essential food items:** When the pandemic hit, changes in eating habits resulted in eating all meals at home. Consequently, retail grocery outlets experienced record sales. However, many buyers encountered empty shelves, especially for tinned and dry food items. Figure 3.1 illustrates the results of a public survey conducted by the Environment, Food and Rural Affairs Committee (EFRA) (a cross-party group of MPs appointed by the UK House of Commons to scrutinize the UK Department of Environment, Food and Rural Affairs). There were 5,500 respondents to the survey, which asked members of the public to indicate which food products they found most difficult to purchase, either in

⁴³ Conor Pope, 'Irish Consumers Turn to Irish Food Products during Covid Crisis', *The Irish Times* <<https://www.irishtimes.com/business/agribusiness-and-food/irish-consumers-turn-to-irish-food-products-during-covid-crisis-1.4506540>> .

⁴⁴ UK Department of Environment.

shops or online. This survey was conducted in the very early stages of the pandemic. The government responded to the situation by relaxing competition laws⁴⁵ so that the companies across food supply chains could collaborate with each other, for example by synchronizing opening hours, sharing delivery vans etc., to meet the unprecedented challenge. While the UK government asked people to stay at home, the authorities also spread awareness messages discouraging consumers from panic buying in supermarkets.

Figure 3.1: Impact of Covid-19 on UK food systems⁴⁶



2. **Unaffordability of food:** Food banks and food aid providers started reporting food shortage in their stock levels in early March 2020. During the first few weeks of the pandemic crisis, these organization, like downstream consumers, experienced shortage in food supply from upstream suppliers due to lack of food donations and rationing schemes adopted by these suppliers. An organization associated with food banks reported an 81% increase in demand and an increase of 122% in the number of students receiving food through food banks as compared to the same period in the previous year. It was estimated that 5.9 million adults in the UK experienced food poverty during the period from August 2020 to February 2021. The

⁴⁵ The Competition Act 1998 (Groceries) (Coronavirus) (Public Policy Exclusion) Order 2020 <https://www.legislation.gov.uk/ukSI/2020/369/made/data.pdf>

⁴⁶ What Effect Did the Coronavirus Pandemic Have on Food? <https://houseofcommons.shorthandstories.com/EFRA-covid19-food-supply/>.

UK government's attempt to develop a substitute system for its schools' free meals programme when pupils were forced to engage in remote learning from home ran into problems because it failed to include convenience stores and discount retailers from the beginning. During the third lockdown which started in January 2021, the government adopted 'food parcel first approach' for providing free school meals to pupils not attending in school. However, when serious concerns regarding the quality of food parcels were raised, a national voucher program was reinstated.

3. **Long term impact on food service industry and hospitality business and the associated supply chain:** When the pubs, bars and restaurants were closed as part of the public health restrictions, upstream suppliers lost their sources of revenue immediately. According to a UK government report⁴⁷, some farmers tried to redistribute the food items originally meant for hospitality businesses to supermarkets and food bank organizations, but it did not materialize due to operational difficulties. As a result, British farmers lost over £41 million in July 2020 alone. During the pandemic crisis, the loss in revenue in the hospitality sector and its suppliers is estimated to be over £72 billion. It is estimated that potato growers had 200,000 tonnes of potatoes in stock as result of the closure of the restaurant sector alone. It was observed that upstream companies of the hospitality supply chain had not received the same government support as those in the downstream side.

Monopoly of retailers

The closure of the hospitality sector and other food service sector markets resulted in food retailers acquiring a monopoly in the provision of food to the customers. This was further aggravated by the UK government's intervention to relax competition law, which prevented unequal sharing of the disruption risks across the supply chain members. Retail operations reneged on commitments towards upstream supply chain partners by failing to source indigenous products. For example, when there has a huge increase in demand for minced beef, retailers like Asda and Sainsbury attempted to secure minced meat from Poland to meet the demand. Sainsbury's decision to provide more shelf space for New Zealand lamb and ROI beef instead of promoting UK beef demonstrated their lack of commitment towards UK supply chains. Certain retailers, such as Morrisons, Aldi and Waitrose did attempt to promote British meat products by having in-store promotions⁴⁸.

⁴⁷ UK parliament committee, *Written Evidence Submitted by the Tenant Farmers Association (COV0132)* <https://committees.parliament.uk/writtenevidence/4153/pdf/> .

⁴⁸ Tenant Farmers Association, *Written Evidence Submitted by the Tenant Farmers Association (COV0132)*.

Labour issues

According to a study on the impact of Covid on the UK fresh food supply chain, the public health restrictions to mitigate the spread of Covid-19 resulted in a decrease in production output by typically 30% because of social distancing protocols (fewer numbers of workers allowed in a production line), travel restrictions (fewer foreign workers able to attend work) and absenteeism (due to Covid related illness or isolation). Additional costs were incurred due to recruiting, training, obtaining PPE and cleaning activities.

Impact of the Covid-19 pandemic on European food supply chains

The EU food supply chain system consist of a complex web of inter-connected sectors that brings food to consumers. In 2019, about 23 million farms were engaged in the production of 300 million tons of cereal grain, around 23 million tons of pig meat and 140 million tons of raw cow's milk. In 2019, EU trade in food and drink accounted for 8% of all exports and 6% of all imports in the bloc⁴⁹. By employing millions of people, the European food supply chain system aims to achieve the objectives set by the EU's common agriculture policy (CAP) implemented by Treaty on the Function of the European Union (TFEU).

Disruption in logistics and transportation services

Logistics activities for food and agriculture were affected by the Covid measures taken by individual EU countries. These measures included border closures or reintroduction of border checks with temporary suspension of the Schengen rules on free travel across the countries and local confinement zones with limited access. These measures resulted in interruptions in transportation routes, delays and long queues at border checkpoints and limited access to certain markets (e.g., central Italy where that country's largest wholesale fruit and vegetable markets operates). Travel restrictions adversely affected global trade outside the EU. Due to the slow-down in global trade, shortages of items such as refrigerated containers for food transportation were experienced⁵⁰. EU countries also experienced difficulties in exporting to third-country markets such as China due to local import restrictions.

⁴⁹ ROSSI Rachele, 'Protecting the EU Agri-Food Supply Chain in the Face of COVID-19' Briefing April 2020. [https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/649360/EPRS_BRI\(2020\)649360_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/649360/EPRS_BRI(2020)649360_EN.pdf)

⁵⁰ "Container shipping costs have surged in recent months", The Economist, Friday 7th May 2021, <https://www.economist.com/graphic-detail/2021/02/11/container-shipping-costs-have-surged-in-recent-months>

Scarcity of seasonal workers

The threat of scarcity of seasonal agricultural workers in 2020 was a major cause of concern⁵¹, as it was forecasted to severely interrupt production and processing activities. Travel restrictions and quarantine rules prevented workers from traveling between countries. Many EU agricultural firms are highly dependent on migrant seasonal workers, primarily from eastern Europe, who are hired by labour-intensive western European based companies. This is a particular challenge for the fresh fruits and vegetables sector where produce needs to be harvested and processed promptly. In addition, there were significant public health concerns around the living conditions for these workers, who tend to live in crowded, poor sanitary conditions and therefore, they present a higher risk of spreading infection.

However, when compared to migrant seasonal labourers, workers within each country affected by the pandemic continued to work. National authorities who imposed restrictions on free movement declared the food sector as essential and thus not liable to these restrictions. Based on one estimate in Italy, despite the Covid-19 safety protocols, 854,000 harvest workers and over 1.4 million workers engaged logistics and distribution operations were able to carry on their work.

Lack of seasonal migration not only impacted the destination countries through loss of labour capacity, but also for the countries of origin of these workers. Seasonal migration for employment plays a significant role in the life of certain countries populations. For example, in the Republic of Moldova, remittances from overseas workers contribute to 16% of its GDP. According to the OECD, the pandemic led to a fall of 20% in income across these regions⁵².

Impact on consumers

In the case of consumers, the pandemic crisis affected household incomes, food purchasing trends and preferences. In the early stages of the pandemic crisis, consumers tended to purchase more frozen and preserved food items, such as sugar, oil, tinned tomatoes and flour. Due to the public health restrictions, closure of food service outlets and working from home, consumers also engaged more in bulk purchases, e-commerce, home deliveries, takeaways and ready-made meals. The demand for food from supermarkets and retail stores increased due to the closure of indoor and outdoor markets, food stalls and restaurants. Expecting unfair pricing behaviour, authorities in several

⁵¹ Liz Alderman, Melissa Eddy, and Amie Tsang, 'Migrant Farmworkers Whose Harvests Feed Europe Are Blocked at Borders', *The New York Times*, 27 March 2020, <https://www.nytimes.com/2020/03/27/business/coronavirus-farm-labor-europe.html>.

⁵² "Impact on migrants' labour market outcomes", OECD Policy Responses to Covid-19, <https://www.oecd.org/coronavirus/policy-responses/what-is-the-impact-of-the-covid-19-pandemic-on-immigrants-and-their-children-e7cbb7de/>

countries including Bosnia and Herzegovina, Serbia and Ukraine, temporarily froze the price of certain food items⁵³. Since many supermarket retailers obtain supplies through contractual agreements with their suppliers, many farmers and micro-producers were unable to sell their produce when their regular outlets like restaurants and farmers markets were closed as they were not part of the approved supplier lists of supermarket retailers. This led to innovative and entrepreneurial behaviour by these farmers and micro-producers, enabled by relatively easy access to e-commerce technology, website design, independent delivery service providers and cheap marketing via social media platforms.

Impact on global food supply chains: Case of US food supply chain

Growers

Farmers were left with fewer distribution options as their traditional buyers such as restaurants, schools, and other food service industries were closed. Growers found it difficult to adapt to changes in their supply chain and to change their distribution processes. For example, due to packaging requirements growers could not sell directly retail customers since their requirements were very different compared to those growers' traditional buyers. Moreover, growers also had to follow strict packaging protocols imposed by the FDA and USDA if they wished to supply foodbanks. Crops planted in advance were either left to rot, ploughed back into the fields or composted. Similarly, unpurchased milk was dumped⁵⁴. In the case of the livestock supply chain, due to reduced processing plant capacity and lack of storage capacity for excess animals, some farmers were forced to euthanized animals such as hogs and laying hens⁵⁵.

Processors

Due to its labour-intensive nature, meat processing and packing plants became hotspot for coronavirus outbreaks. Though processors were also affected by the change in customer demand, many plants were closed by public health authorities due to the spread of the virus between workers in these plants⁵⁶.

⁵³ <https://www.covid19healthsystem.org/countries/bosniaandherzegovina/livinghit.aspx?Section=1.2%20Physical%20distancing&Type=Section>

⁵⁴ 'U.S. Dairy Farmers Dump Milk as Pandemic Opens Food Markets', *World Economic Forum* <https://www.weforum.org/agenda/2020/04/dairy-milk-pandemic-supply-chains-coronavirus-covid19-pandemic/>.

⁵⁵ Hayes, D.J., Schulz, L.L., Hart, C.E. and Jacobs, K.L., 2021. A descriptive analysis of the COVID-19 impacts on US pork, turkey, and egg markets. *Agribusiness*, 37(1), pp.122-141.

⁵⁶ Marunadan Malayali, *Inside America's Food Supply Chain Under Covid-19* | *Forbes*, 2020 <https://www.youtube.com/watch?v=YOJ31n6RUaA>

Workers in meat processing plants became very susceptible to infection because a meat processing plant environment facilitated the spread of the virus. Cool temperatures, recirculation of air, proximity of workers to each other within the plant, physical exertion and high ambient noise levels leading to workers shouting (and therefore exhaling to a greater extent) are thought to be some of the contributing factors. In addition, lack of paid sick leave and poor social security payments led workers to continue attending work when infected or when they should have been in isolation due to close contact with an infected person.

Packaging

Many food processing companies rely heavily on overseas suppliers for supplies of support material, such as packaging. With Covid-19 closures of production plants and shipment delays, the supply of these materials was severely impacted. As consumers prioritized health and safety, public health authorities introduced guidelines related to adoption of single-use packaging. Many cities and states banned the use of reusable bags and cups as a measure to prevent the spread of the virus. This had a knock-on impact on the environmental sustainability initiatives that had been evident in the sector in recent years.

Transportation

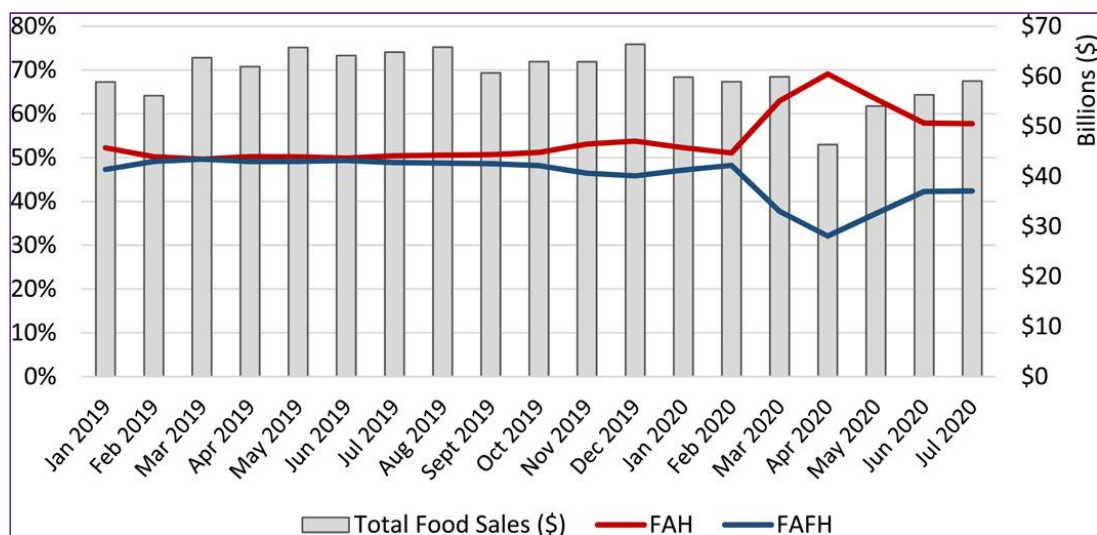
The ground transportation (trucking) industry in the US has been under increasing pressure in recent years, with industry reports suggesting a shortage of over 60,000 drivers even before the pandemic struck⁵⁷. The pandemic has seen this shortage exacerbated, coupled with increased demand for transportation services due to the significant increase in e-commerce sales. To keep the links between facilities in supply chains moving, including in food sectors, the US Department of Transport declared truck drivers and associated workers as essential critical infrastructure workers.

⁵⁷ American Trucking Association “Truck Driver Shortage Analysis 2019” <https://www.trucking.org/sites/default/files/2020-01/ATAs%20Driver%20Shortage%20Report%202019%20with%20cover.pdf>

Consumers

Over the last number of years, food expenditure by US consumers has been equally divided between eating at home and outside the home (figure 3.2). However, when the crisis hit, these consumption patterns suddenly changed, straining the supermarket/retailer sector supply chain. Over the three-month period February-April 2020, expenditure on “Food at Home” jumped from 50% to 70%, with a corresponding drop in “Food Far from Home” from 50% to 30% (Figure 3.2). The closure of restaurants, schools and workplaces, coupled with travel restrictions, resulted in increased consumption of food at home, for which many supermarket retail outlets found challenging. Besides the shift in customer demand from food service to supermarket/retail outlets, consumption of plant-based food is also increased. Customers also adopted plant-based protein food for a healthier diet during pandemic due shortages of beef and other meat products. For example, refrigerated plant-based meat was the fastest growing plant-based food category during the mid-March 2020 coronavirus panic buying peak in the United States. Refrigerated plant-based meat grew by 241 percent compared to the previous year and maintained a growth of 113 percent over the subsequent four weeks⁵⁸.

Figure 3.2: Changes in US consumption pattern FAH (food at home) and FAFH (food away from home)⁵⁹



⁵⁸ <https://www.statista.com/statistics/1120804/coronavirus-plant-based-food-retail-sales-growth-us/>

⁵⁹ Hayes, D.J., Schulz, L.L., Hart, C.E. and Jacobs, K.L., 2021. A descriptive analysis of the COVID-19 impacts on US pork, turkey, and egg markets. *Agribusiness*, 37(1), pp.122-141.

Sector specific impacts of the Covid-19 pandemic worldwide

Meat sector

Despite some of disruptions to processing plants due to the spread of the virus, operations generally did not completely cease. However, there were some difficulties in international trade, especially exports to Italy⁶⁰. Italy is one of the main markets for livestock and beef for some EU countries.

According to the Food and Agriculture Organisation (FAO), the United Nations Meat Price Index dropped by 2% in February 2020 compared with January 2020. This was attributed to the reduction in Chinese imports due to handling delays at seaports. The sheep market was severely impacted leading to build up of stocks in exporting countries. The poultry sector suffered due to reduced demand from Asia. The demand for pig meat, while initially impacted, subsequently improved, but the scarcity of supply in Europe led to increase in prices.

Dairy sector

In the Slovenian dairy sector, which exports around 30% of its raw milk to Italy, there were difficulties reported in supplying milk to Italy due to the severity of the lockdown imposed in that country. This led to a particular challenge for Slovenian dairy processors, who do not have sufficient domestic processing capacity for all the milk supplied by Slovenian dairy farmers. In Croatia, demand for milk is heavily influenced by the tourism sector, so there was a knock-on effect due to the lack of international travel in 2020 and 2021.

Wine sector

It is reported that more than one third of wineries have suffered from cancelled orders, in particular from customers in China. In addition to the losses in the Chinese market, the pandemic coincided with tariffs levied on wine imports into the US, another main market for EU producers, due to the ongoing US-EU trade war related to subsidies provided to Airbus in Europe, with whom the US aircraft manufacturer Boeing competes on a global basis.

Oilseed sector

The vegetable oil sector was severely affected, with many producers impacted by the reduction in handling capacity at Chinese ports. The price of palm oil also dropped due higher than anticipated production in Malaysia, a temporary drop in Indian demand and concerns over slowdown in demand

⁶⁰ Rachele Rossi and Members' Research Service, *EU Trade and Transport of Live Animals*, 1 February 2020.

because of the continuing pandemic crisis. It is reported that soy, rapeseed and sunflower prices also suffered from Covid-19 crisis and higher than anticipated stocks in the US.

Fruits and vegetables sector

In Spain, the sector reported a significant increase in retail demand, but there has been a major fall in the demand from hotel and other food service industries, which accounts for 10% of total demand. Demand for certain fruits, such as citrus fruits, increased. This was due to consumers wishing to increase their daily intake of vitamin C to improve their immune systems. However, despite the higher demand in the fruits and vegetables sector, especially from China for citrus fruits, there were capacity bottlenecks encountered in logistics.

The lockdown measures temporarily disrupted the raw material supply for farmers, for example, crop planters in Kyrgyzstan and Tajikistan reported shortages in the availability of seed and fertilizers. Similarly, livestock farmers faced difficulties in importing feed, medicine, and veterinary products. They have also seen an increase in the price for input materials, partially due to the cost of Covid-19 safety protocols⁶¹.

⁶¹ 'The Impact of COVID-19 on Food and Agriculture in Europe and Central Asia and FAO's Response', 2020 <http://www.fao.org/3/ne001en/ne001en.pdf>.

4 Research findings

Methodology

The methodology employed in this study comprised primary data collection through semi-structured interviews with representatives from across the food sector on the IoI. In addition, secondary data collection was carried out using publicly available information in government and semi-state bodies publications in both jurisdictions, food association reports, company websites and media reports.

The interview protocol was developed using the Supply Chain Vulnerability Factors (Table A3.1), Supply Chain Capability Factors (Table A3.3) and the Supply Chain Disruption Profile (Figure A3.3). Details of the interview protocols used for food companies and trade associations are provided in Appendix 1 and Appendix 2.

Semi-structured interviews were conducted between February and June 2021. Interviews were carried out online (via Zoom, or other virtual communication software), or by telephone. In total, 13 interviews were completed. Six companies did not respond to a request for interview. Interviewees represented a wide range of food sectors, company sizes, semi-state companies and trade associations across the IoI. All interviewees held senior positions in their organisations and had oversight of supply chain activities, such as director of supply chain operations in food processing firms, CEO/Managing Director of trade associations, Chairperson of professional bodies. All interviewees agreed to participate in the study on condition of anonymity. Therefore, no specific company or individual is identified in the findings. Where companies are mentioned, this is based on publicly available secondary data. The findings from the semi-structured interviews are presented on a sectoral basis.

Dairy

The nature of milk production on the IoI is that the dairy herd is principally grass fed. This provides a unique selling point for dairy exports which are labelled “pasture/grass fed”. The most significant change in the milk production sector in recent years was the elimination of quotas by the European Union in 2015. Quotas had been introduced in 1984. Between 1984 and 2015, the average volume of milk produced in ROI was 5 billion litres per annum⁶², while in NI the volume of milk in 2000 (earliest

⁶² Bord Bia Dairy Sector Profile <https://www.bordbia.ie/industry/irish-sector-profiles/dairy-sector-profile/>

data available) was 1.6 billion litres, increasing to 2.3 billion litres in 2015⁶³. The abolition of quotas led to significant investment by dairy farmers to increase the size of herds and by dairy processors to increase production capacity. The result was the annual volume of milk produced in ROI increased to 8 billion litres and in NI to 2.44 billion litres in 2020.

Milk production across the Iol is seasonal, with production ramping up to a peak in May each year (Figures 4.1 and 4.2). Dairy processors indicated that the majority of supply chain risk analysis carried out in the sector tends to focus on the ability of processors to collect and process the peak volume of milk.

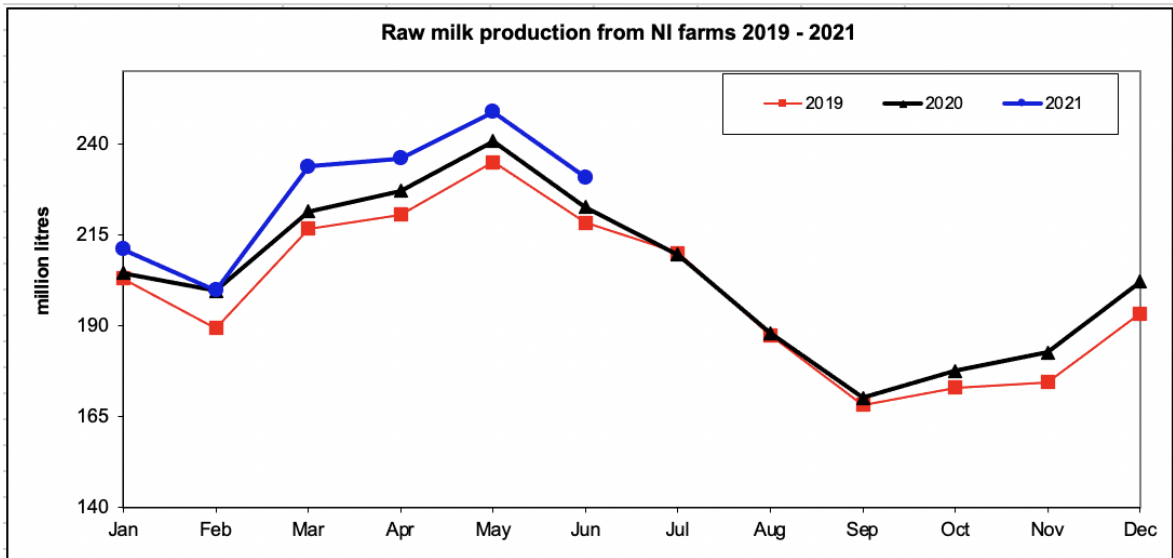
Historically, the structure of both the ROI and NI dairy sectors were based on the farmer owned co-operative movement. While many co-operatives are now public limited companies, the sector continues to operate on a supply driven (push) production basis across both jurisdictions. This means that if a dairy farmer has milk, it must be collected by the processor, and then it is up to the processor to manage the supply-demand-capacity challenges that this may present. Dairy processing is an all-Island activity, with milk collection from Northern Ireland farms being processed at plants in Republic of Ireland and vice versa. This is particularly evident in Lakeland Dairies cross-border operations. In addition, primary milk processing for some companies occurs in one jurisdiction, followed by secondary processing in another jurisdiction (e.g., Kerry Group has primary processing in the Republic of Ireland and some secondary processing in Northern Ireland). Of the total value of food and live animal exports from NI to ROI (£983m in 2019), dairy products comprised £395m.

⁶³ Northern Ireland Milk Price and Production Statistics 2000 onwards, <https://www.daera-ni.gov.uk/publications/milk-price-and-production-statistics-2000-onwards>

Figure 4.1: Republic of Ireland domestic milk statistics (in millions of litres)⁶⁴



Figure 4.2: Northern Ireland milk statistics (in millions of litres)⁶⁵



⁶⁴ Irish Central Statistics Office Milk Statistics December 2020.
<https://www.cso.ie/en/releasesandpublications/er/ms/milkstatisticsdecember2020/>

⁶⁵ <https://www.daera-ni.gov.uk/publications/milk-price-and-production-statistics-2000-onwards>

ROI Central Statistics Office (CSO) data for 2019 and 2020 raw milk intake show that despite the pandemic, milk intake increased by 3.8% to 8.292 billion litres and butter production increased by 4.7% to 262,600 tonnes. Similar data for Northern Ireland farms shows that there has been a year-on-year increase since 2019 in the volume of milk produced (and therefore processed). Despite the pandemic, there was no interruption to the supply of raw milk on the IOL. Dairy processors indicated that the timing of the outbreak of the pandemic (March 2020) and the uncertainty around the length and severity of restrictions presented serious concerns among dairy farmers and processors, as this occurred just two months before peak milk production (early May 2020).

As well as being designated “critical service providers”, processors in both jurisdictions acted quickly to put in place the necessary protocols which alleviated any concerns that milk would not be collected from farms or processed at plants. For example, in its March 2020 newsletter, Lakeland Dairies indicated that its emergency response team met every day since the end of February 2020⁶⁶, as well as publishing its protocols for farmers, milk tanker hauliers, suppliers and agriculture supply stores⁶⁷. Other dairy processors also put similar standard operating procedures in place (e.g., Aurivo⁶⁸). Two dairy companies in NI (Pritchitt’s and Dale Farm) contributed to the development of best practice guidelines for the Northern Ireland Food Industry⁶⁹.

The price paid to farmers for milk in ROI was stable throughout 2020. Unlike the situation seen in the US, no dumping of milk occurred in Ireland during the pandemic⁷⁰. Northern Ireland exports 80% of the milk produced, so is exposed to both exchange rate and market volatility. Data for the early part of the pandemic (March-June 2020) from the Ulster Farmers Union highlighted a number of issues in relation to drop in market prices and rise in input costs⁷¹.

Milk collection from farms is generally carried out by third party hauliers, whereby the tankers are owned by dairy processors, but the drivers are employed by the haulage companies. Since the start of the pandemic, dairy processors have put a number of protocols in place to reduce access by third party employees (e.g., drivers) to their plants (e.g., placing portable toilets outside for drivers) to minimise the possibility of the spread of infection and to have back up drivers available in the event regular drivers were required to isolate.

⁶⁶ Lakeland Dairies “Farm Notes” March 2020

https://www.lakeland.ie/images/uploads/website/March_2020_Farm_Notes_ROI_FINAL.pdf

⁶⁷ <https://www.lakeland.ie/news/lakeland-dairies-milk-collection-protocols-for-farmers-hauliers>

⁶⁸ <https://www.aurivo.ie/wp-content/uploads/2020/03/COVID-19-Milk-Suppliers-with-suspect-or-confirmed-COVID-19.pdf>

⁶⁹ Northern Ireland Food Industry Guidance: Best Practice Covid-19. <https://nifda.co.uk/wp-content/uploads/2020/12/NIFDA-Best-Practice-Covid-19-v3-final-DEC20.pdf>

⁷⁰ <https://www.dairyreporter.com/Article/2020/04/06/US-dairy-farmers-dumping-milk-due-to-coronavirus-situation>

⁷¹ Covid-19 and Food Supply Inquiry: Ulster Farmers Union Response

https://content17.co.uk/media/99/files/EFRA_UFU_Response_1.pdf

Dairy processing plants tend to be highly automated unit operations with high levels of cleanliness in place, requiring few personnel, thereby enabling implementation of social distancing and other workplace Covid-19 regulations without impacting on production throughput. While administrative staff were able to work from home, factory floor and laboratory staff were required to be on site (regulations require samples of incoming milk to be tested by on-site laboratories). Measures put in place to reduce the risk of reduced production throughput due to enforced employee absences included cross-training of production facing employees to provide maximum flexibility. In addition, agreements were put in place in some companies with employees agreeing to work extra shifts if required, thereby ensuring continuity of production while other employees were absent.

While the primary input to dairy plants is raw milk collected from farms across the island, many processors' bills-of-materials have other ingredients which are obtained from non-farm suppliers (e.g., vegetable oils, casein, etc.). A number of these suppliers are based outside the IoI. Dairy processors across the IoI tend to operate lean supply chains, so would not have large volumes of buffer stocks in place. Therefore, in the early stage of the pandemic, all dairy processors purchased buffer stocks of these type of third-party ingredients to reduce the risk of stock-outs. It was acknowledged by industry representatives that as many of the dairy processors in both ROI and NI are large companies, they had the financial resources to engage in that type of risk mitigation. A number of companies also held stocks of "work in progress", whereby raw milk went through a number of initial processing steps but was not converted into final products for a period of time until the uncertainty around customer demand was reduced.

Given the relatively small number of dairy processors on the IoI, even prior to Covid-19, the sector has been characterised by a high degree of collaboration and with informal arrangements in place between processors. For instance, if production capacity issues arise at one processor, milk can be re-routed to another processor's site. This practice continued throughout the pandemic and was a particularly important contingency if one processor's capacity was reduced due to employees being unable to attend work.

Exports of ROI dairy products to 140 markets around the world were worth €5bn in 2020, which is the largest ROI sector by value⁷². Priority dairy markets are in Asia and Africa. In fact, in one key African market (Nigeria), demand for ROI dairy product increased during the pandemic due to the immune boosting nature of the products. This global footprint of the sector provided it, through Bord Bia (Irish Food Board) with significant market intelligence capabilities, particularly in the early stage of the pandemic (January and February 2020). Northern Ireland accounts for 15% of the UK's dairy

⁷² Bord Bia Dairy Markets Seminar, April 2021.

production⁷³, with 80% of milk exported, primarily to Republic of Ireland, rest of UK and EU. One issue faced by NI farmers was a drop in milk prices by 10% in the early period of the pandemic.

In recent years, the ROI and NI dairy sectors have been diversifying their product portfolios, with a move away from low margin skim-milk powder, to higher value products. For example, Carbery successfully developed a new mozzarella cheese product, and despite a short pandemic induced delay, commissioned its new Co. Cork production facility in late 2020⁷⁴.

Despite the challenging trading environment in 2020, with a combination of the pandemic, the EU-US trade war (following a World Trade Organisation ruling on the Boeing-Airbus subsidy dispute, which led to tariffs being temporarily imposed on EU dairy imports to US) and the pending UK departure of the UK from the EU, Ornu's operating profit increased by 69%, its Kerrygold brand experienced 13% volume growth and it sold over 10 million packs of butter and cheese per week⁷⁵. Ornu, formerly Bord Baine/The Irish Dairy Board, is a co-operative which is responsible for the global distribution, sales and marketing of a number of consumer dairy brands under the Kerrygold brand. Products from a number of ROI dairy processing sites are shipped directly to Ornu for onward distribution and sales⁷⁶. A subsequent EU-US trade agreement saw those earlier tariffs being suspended⁷⁷, enabling full access to €400m worth of butter, cheese and liqueurs to the US market, where they command a strong price based on consumer demand for quality products⁷⁸.

At an individual company level, performance was generally strong across the sector. There were some exceptions, particularly for companies with high exposure to the food service sector. For instance, Lakeland Dairies, which operates in both ROI and NI, reported a decrease in revenue of 24% (€57m) from food service in 2020 when compared to 2019. However, some of this decrease was offset by the growth in its retail grocery market revenues in 2020 (€145.9m in 2020, compared to €139.7m in 2019). Dale Farm, which is Northern Ireland's largest dairy co-operative, had a fall in profits of 15% due to the impact of the pandemic on its food service business⁷⁹. In contrast, Carbery reported an increase in revenue of 5.8%, driven in particular by strong retail demand (up 13% year-on-year) for its high quality cheddar cheese⁸⁰. Overall, retail demand was strong for dairy products, particularly items such as yoghurt and cheese. Some of this demand was attributed by industry representatives due to

⁷³ <https://www.investni.com/invest-in-northern-ireland/food-and-drink>

⁷⁴ https://www.carbery.com/wp-content/uploads/2020_ceo_report_for_web.pdf

⁷⁵ <https://www.ornua.com/kerrygold-sales-up-13-with-over-10-million-packets-sold-weekly/>

⁷⁶ Interview with Ornu CEO John Jordan on Newstalk "Down to Business" with Bobby Kerr, 24th April 2021.

⁷⁷ <https://trade.ec.europa.eu/doclib/press/index.cfm?id=2250>

⁷⁸ Boost for Irish Food Exports from EU-US Trade Agreement <https://www.ifa.ie/farm-sectors/boost-for-irish-food-exports-from-eu-us-trade-agreement/>

⁷⁹ <https://www.belfasttelegraph.co.uk/business/northern-ireland/dale-farm-reports-fall-in-sales-and-profits-as-coronavirus-hits-farmers-39446912.html>

⁸⁰ <https://www.carbery.com/carbery-annual-report-2020/>

consumers being focused on value, nutrition and health. Others indicated that parents who were attempting to combine work commitments while their children were also at home needed to have good value, healthy and “child-pleasing” snacks such as cheese and yoghurt readily available.

Beef

“The closure of the food service sector across Europe has hit Ireland disproportionately as we are an export country. While there has been an increase in retail sales across Europe, much of this is taken up by domestic suppliers who have surplus product due to food service closures in their country...We are facing massive challenges across all sectors, but the beef market is now in turmoil” (Irish Farmers Association President Tim Cullinan)⁸¹.

In terms of gross output, the beef and dairy sectors are the two largest in the agri-food sector in ROI, with Ireland’s cattle herd being the fifth largest in the EU. The ROI herd represents 8% of the total EU bovine livestock⁸². The value of exports in the sector is approximately €2 billion per annum. The beef and sheep sector (data jointly reported for these two sectors) also makes a major contribution to the NI economy in monetary terms, with gross turnover of the NI beef and sheep meat processing sector was just over £1.39 billion⁸³. The pandemic had limited impact on ROI and NI farm production in 2020 as many of the production decisions had been made by farmers prior to the pandemic outbreak.

The beef processing sector in both jurisdictions was heavily impacted by the pandemic, through the closure of the food service sector in key markets as well as the spread of the virus among meat processing plant employees. There are 3 features of these plants which are considered to explain high levels of Covid-19 outbreak; low ambient temperature/high relative humidity, close proximity of workforce and demographic profile of workforce⁸⁴.

The initial closure of the ROI and UK foodservice sector in spring 2020 had an immediate impact on ROI and NI beef processors supplying this sector. While there was no disruption to animal supply, a number of processors temporarily ceased production as there was no downstream demand from food service clients. Others were faced with higher levels of inventory to the sudden loss in sales. The uncertainty around when food service would re-open contributed to this decision due to the maximum time allowed by their customers between processing of beef and its use by a customer.

⁸¹ <https://www.ifa.ie/farm-sectors/ifa-makes-detailed-submission-for-covid19-supports-with-beef-market-in-turmoil/>

⁸² Department of Agriculture, Food and the Marine, Annual Review and Outlook for 2020.

⁸³ Covid-19 and Food Supply Inquiry: Ulster Farmers Union Response
https://content17.co.uk/media/99/files/EFRA_UFU_Response_1.pdf

⁸⁴ Investigation into a Series of Outbreaks of COVID-19 in Meat Processing Plants in Ireland, 2020, Outbreaks of COVID-19 in Meat Plants Ireland, 2020 | Final Report V1.1 27/07/2020, <https://assets.gov.ie>

With the reopening of elements of foodservice (e.g., dine at home, drive through fast food restaurants), production recommenced. Processors who had business-to-business retail customers benefited from the increase in retail demand. Retail consumers were observed to have a focus on value, particularly those consumers whose income had been negatively impacted by the pandemic, while other consumers with disposable income purchased premium cuts of meat.

A second impact of the pandemic was on the requirement to redesign beef production processes to reduce the likelihood of spread of the disease among workers. Social distancing requirements within facilities with a fixed floor area meant fewer operators per production line, which reduced throughput. In addition, increasing the gap between production shift changeovers to prevent workers mixing reduced the total production time available.

While the sectors in ROI and NI were impacted negatively by loss in food service demand, retail demand increased as well as demand for premium products. As was seen in other food sectors, consumers were unable to spend their disposable income on eating out but were willing to spend this on premium eat-at-home products, whether purchased in retail grocery stores or from restaurants offering take-away options.

Poultry

According to The Irish Farmers Association Poultry Council Report (December 2020)⁸⁵, Bord Bia have reported that overall retail sales of Quality Assured ROI poultry meat were up 14% year on year. This is due to a number of factors, including the normal annual increase of 2-3% that chicken in particular has seen over the past 5 years. Northern Ireland processors also saw increase in retail sales, but loss in food service sales. The Covid situation has seen a general move away from the food service sector which usually procured a high volume of imported chicken and increase in the sales of Bord Bia Quality Assured Irish chicken on the retail shelves in 2020. Interestingly, Ireland is only 50% self-sufficient in chicken fillets and demand is increasing due to the popularity of chicken meat with the ROI consumer. The industry has grown to meet this demand but planned expansion in the ROI broiler sector was halted during the pandemic due to Covid level-5 building restrictions. In addition, there it was reported that there was a backlog of planning applications in the Environmental Protection Agency and there was up to 15 poultry building sites awaiting a commencement order from both Monaghan and Cavan County Councils. 15 broiler sheds have the capacity to produce 4.7 million broilers annually, equivalent to 9,500 tonnes of chicken meat.

⁸⁵ <https://www.ifa.ie/policy-areas/poultry-council-report-december-2020/>

There was no interruption to production at the three ROI poultry processing plants (Manor Farm in Co Cavan, Western Brand in Co Mayo and Shannonvale in Co Cork)¹¹⁴. With the streamlined and constant throughput nature of the broiler production system, processors acted quickly once the threat of Covid-19 emerged, in order to protect their staff and the throughput of product to the final consumer. Over 100 million birds are processed annually in these three plants. Due to the high compliance with the measures put in place, no worker in these three plants has tested positive for Covid-19 (as of September 2020). Extra shifts through the night and into the weekends allowed production levels to be maintained, and workers to keep the recommended distance from fellow workers. PPE and proper guidance by employers to all staff in the poultry sector prevented any hotspots of infection from becoming an issue⁸⁶.

Moy Park is Northern Ireland's largest private sector business and one of the UK's top 15 food companies⁸⁷, with three processing sites at Ballymena, Dungannon and Craigavon, employing 5,500 people across its operations. In July 2020, it reported a very small Covid outbreak in its Ballymena site. In a press interview with Ulster Business in early August 2021, a director of the company indicated that 2020 was a very strong trading year, with profits slightly up and the comment that fresh chicken, as a popular form of protein, has strong customer demand. The company has seen recovery in the food service sector following relaxation of public health restrictions and that the increase in retail demand seen during 2020 is reducing slightly⁸⁸.

The Ulster Farmers Union outlined a further knock-on impact of the loss of sales in the food service sector for poultry producers. This was the reduction in demand for hatching eggs in Great Britain (by approximately 20% of NI hatching egg production)⁸⁹. The result was that breeding farms in NI were taken out of production for a period of time (up to 3 months), with a significant financial impact on farmers.

Egg production

Following 14 confirmed outbreaks of Low Pathogenic Avian Influenza (LPAI), in the Co Monaghan region, approximately 550,000 laying hens were culled in the period March-May 2020. This resulted in a shortfall of eggs on the ROI market, which also coincided with an increase in retail demand due to the "stay-at-home" requirement from the Covid-19 pandemic, creating a major challenge for the

⁸⁶ <https://www.ifa.ie/policy-areas/poultry-council-report-september-2020/>

⁸⁷ <https://moypark.com/>

⁸⁸ <https://www.belfasttelegraph.co.uk/business/ulsterbusiness/top-100/top-100-strong-trading-year-for-moy-park-as-it-heads-up-business-list-for-10th-year-in-a-row-40713886.html>

⁸⁹ <https://www.ufuni.org/news/covid-19-support-scheme-for-pig-and-poultry-sectors-opens-today>

sector. This resulted in main egg packers importing Northern Irish eggs to cover the shortfall of ROI eggs. Northern Ireland eggs which meet the Lion Standard were temporarily approved to be sold in Bord Bia Quality assured packs from ROI packers, in to ensure availability in retail markets. By October 2020, the restocking of the flock had been completed⁹⁰. Another challenge experienced in the egg sector was the lack of egg packaging. There are only 3 providers of egg boxed in Europe, one of which based in Denmark had to temporarily cease production due to a Covid-19 outbreak⁹¹. A concern was also raised in Northern Ireland in relation to the impact of local councils not collecting domestic recycling waste for a period of time. Components of such recycling waste are used as inputs to certain forms of packaging, including egg packaging⁹².

Seafood

The ROI Seafood sector operates under the European Union quota regime, with quotas determined in December each year by the EU Council of Ministers. These quotas are then fixed in legislation, which places limits on different types of fish which may be caught by in EU waters and by EU vessels in certain non-EU waters⁹³.

Seafood representatives indicated that prior to Covid, the principal supply chain risk would have been the impact of weather/storms on the ability of the fishing fleet to catch and land fish. Unlike other countries (e.g., Norway), the majority of ROI fish is trawler caught, rather than farmed. Farmed fish (e.g., salmon) has much more stable supply/production volumes compared to trawler fishing.

The ROI trawler fish supply chain is quite short, with supply and demand very closely coupled and highly supply dependent. There was a high level of concern in March and April 2020 that the sector would collapse, particularly due to the closure of the food service sector and the uncertainty around the length of public health restrictions. The Irish government introduced a “Covid-19 Voluntary Tie-up Scheme”⁹⁴, which was designed to support the fixed costs incurred by vessel owners while tied up in port and to complement the pandemic unemployment payment (PUP) wage supports. Industry representatives indicated that these government supports provided the sector with some “breathing

⁹⁰ <https://www.ifa.ie/policy-areas/poultry-council-report-october-2020/>

⁹¹ <https://www.reuters.com/article/us-health-coronavirus-economy-breakingvi/breakingviews-chancellor-big-is-beautiful-will-also-be-ugly-idUKKBN22G1U5?edition-redirect=uk>

⁹² Manufacturers 'face problems' if coronavirus halts key recycling in Northern Ireland <https://www.belfasttelegraph.co.uk/business/ulsterbusiness/news/manufacturers-face-problems-if-coronavirus-halts-key-recycling-in-northern-ireland-39097910.html>

⁹³ Sea Fisheries Protection Authority 2021 Quotas <https://www.sfpa.ie/Statistics/Quotas>

⁹⁴ Creed announces Temporary COVID-19 Voluntary Tie-Up Scheme for Parts of the Fishing Fleet

<https://www.gov.ie/en/press-release/6490c1-creed-announces-temporary-covid-19-voluntary-tie-up-scheme-for-parts/>

room” to find new customers in the business-to-business (either processors or retailer) or business-to-consumer (households) sectors.

Similar to the dairy processing sector (and unlike the meat processing sector), the fish processing sector (e.g., for filleting processes) did not encounter serious workforce challenges. As in the dairy processing sector, the demographic of this workforce tends to be rural. Some changes to shift patterns were introduced to reduce the risk of transmission of the virus between employees.

According to the Bord Iascaigh Mhara (Irish Seafood Board) annual report for 2020⁹⁵, the total value of Ireland’s seafood economy in 2020 was just under €1.1 billion. This represented a decrease of 18% when compared to 2019 but was offset somewhat by an increase in retail sales (6%). Domestic consumption fell by 18%, primarily due to the closure of the food service sector. Foodservice markets in Europe and Asia represent major export markets for ROI seafood. These markets experienced lengthy closure in 2020, so exports were down by 8% to €590m, with EU, UK and Africa being the main export markets (€321m, €93m and €75m respectively). While exports to key markets in Europe and Asia fell, opportunities in other global markets emerged with the value of exports to Africa growing by 87% and by 43% to the Middle East driven by increased exports of mackerel. To counteract the loss in food service markets, the sector was able to obtain alternative destinations for its products by supplying the retail market and online sales.

The seafood sector benefited from changing consumer behaviour, with an “eat-at-home” market emerging. Due to the closure of the food service sector, product that would normally have been caught for those customers was now available for the retail sector, when trawlers resumed fishing. The result was independent fishmongers now had access to quality fish at competitive prices. Households who had retained disposable income and might normally eat out once per week were now frequently buying fish from local fishmongers. An online sales channel also emerged, with companies such as KishFish.ie, Gannet Fishmongers (eatmorefish.ie) and Star Seafoods being leading providers in this segment. This was noted as an interesting behavioural change, as consumers would normally prefer to look at fish in-person when buying (similar to the meat sector), rather than doing so “blindly” on-line. It also seemed to mark a shift in consumer attitudes towards fish, which Lorcan O’Cinneide (national secretary of the Irish Fish Processors’ and Exporters Association (IFPEA) and a board member of AIPCEE, the European Union processors’ organization) described in 2016 as a “penitential product”⁹⁶.

⁹⁵ Bord Iascaigh Mhara Publish Annual Business of Seafood Report <https://bim.ie/news-and-events/news/bord-iascaigh-mhara-publish-annual-business-of-seafood-report/>

⁹⁶ Lorcan O’Cinneide Oct 2016 interview with SeafoodSource <https://www.seafoodsource.com/news/supply-trade/q-a-with-the-irish-fish-processors-and-exporters-association-s-lorcan-o-cinneide>

Overall, the ROI seafood industry “*showed great agility during the year and looked to alternatives for its products, switching where possible from supplying hospitality to supplying the retail market and online sales*”⁹⁷.

The Northern Ireland aquaculture sector is a relatively small, niche market, valued at approximately £11 million annually. The main species produced are mussels, oysters, salmon and trout⁹⁸. Similar to ROI, the sector experienced the sudden loss of its domestic and export food service markets and received supports through the NI Department of Agriculture, Environment and Rural Affairs Covid schemes.

Distribution/retail grocery

The ROI retail grocery market is dominated by five main competitors, who at the start of the pandemic (February 2020) between them controlled 88.5% of the market in the Republic of Ireland according to Kantar⁹⁹. Dunnes Stores had the largest share of the market at 23.5%, followed by Tesco (21.5%) and Supervalu (21.4%). What is interesting is how this market share evolved over the early months of the pandemic (February to June 2020). Supervalu gained the number one position, with Dunnes Stores falling to third position with an overall loss of 3% of market share (Figure 4.3). There are a number of factors that can be attributed to this change. The first is that both Supervalu and Tesco had well-established “click and collect” and online ordering/delivery infrastructure in place, whereas Dunnes Stores only had in-store shopping. Due to the stringent public health restrictions and advice in place from mid-March 2020, consumers were reluctant to (or depending on age, advised not to) shop in-store, switching to grocery chains who could provide home delivery or collection services. In addition, Supervalu stores tend to be in smaller towns and villages, with lower footfall, thereby reducing the length of queues outside stores, giving the impression of being less busy, and also enabling customers to visit a store while remaining inside their 2km or 5km radius (even though restrictions allowed people to travel outside their zone for the purpose of grocery shopping). As the Kantar Grocery Market Share data below indicates (Figure 4.4), it was not until October 2020 that Dunnes Stores regained its market share again (tied with Supervalu for first position), which also coincided with the launch of its partnership with Buymie for online shopping and delivery¹⁰⁰.

⁹⁷ Bord Iascaigh Mhara Publish Annual Business of Seafood Report <https://bim.ie/news-and-events/news/bord-iascaigh-mhara-publish-annual-business-of-seafood-report/>

⁹⁸ <https://www.daera-ni.gov.uk/news/poots-announces-ps360k-support-aquaculture-sector>

⁹⁹ <https://www.kantarworldpanel.com/grocery-market-share/ireland/snapshot/14.06.20/23.02.20>

¹⁰⁰ Dunnes Stores launch new groceries home delivery service <https://www.irishtimes.com/business/retail-and-services/dunnes-stores-launch-new-groceries-home-delivery-service-1.4371803>

Figure 4.3: Comparison of Republic of Ireland Grocery Market Share 23rd February 2020 and 14th June 2020⁹⁹

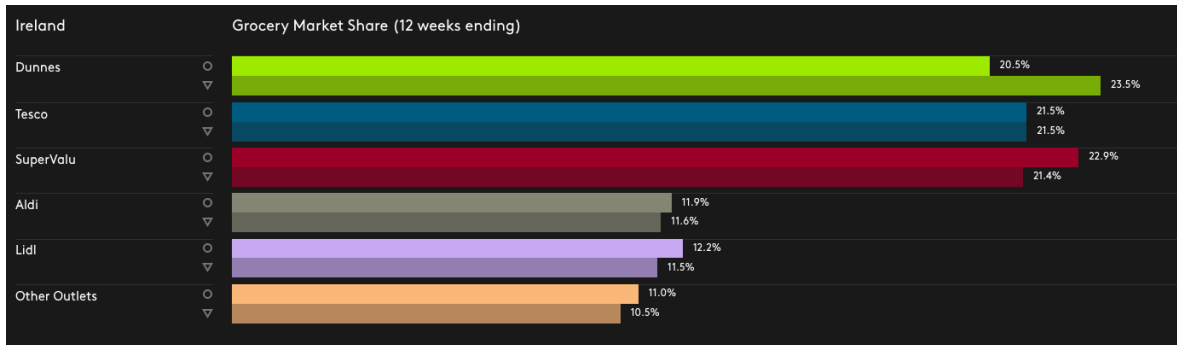
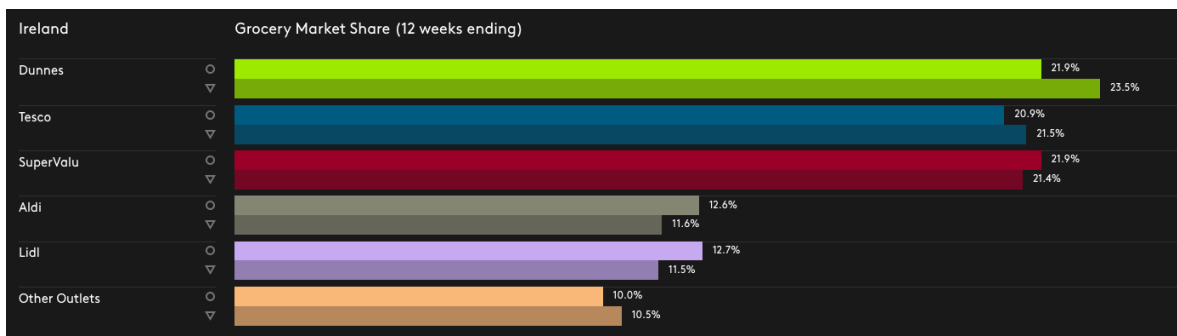


Figure 4.4: Comparison of Republic of Ireland Grocery Market Share 23rd February 2020 and 4th October 2020¹⁰¹



The Northern Ireland grocery market has additional competitors, including Sainsbury and Asda. Overall consumer spending increased by 14.8% from March 2020 to March 2021. Smaller, local supermarkets (Spar, Centra) saw sales values increase 27% year on year, due to customer “shop local” behaviour. Overall, the Kantar reported for Northern Ireland that consumers made 20 fewer trips to grocery stores in 2020, but when they did make trips, they spent more, purchasing on average two extra items per trip (Kantar graphs are not available for Northern Ireland only, as this data is included in Kantar UK reports). Consumers, who may have ordinarily spent their disposable income on eating and drinking in bars and restaurants were still willing to spend this money on luxury food items, with sales of alcohol up by 34%, confectionary up by 19% and savouries by 17% year-on-year¹⁰².

Retailers in Ireland and UK have been engaged in a continuous process of supply chain risk management over the last number of years. Tesco (UK) described how it has “completely reset its

¹⁰¹ <https://www.kantarworldpanel.com/grocery-market-share/ireland/snapshot/04.10.20/23.02.20>

¹⁰² <https://www.irishnews.com/business/2021/03/09/news/spending-at-ni-supermarkets-increased-by-hundreds-of-millions-in-12-months-of-lockdown---kantar-2247978/>

relationships with its suppliers”, which enabled it to get its most popular products onto supermarket shelves during the pandemic¹⁰³. Similarly, ROI based grocery retail organisations have been carrying out detailed risk analysis of their entire supply chains over the last number of years, principally in preparation for the UK departure from the EU in December 2020. Furthermore, it was indicated that Storm Emma in late February/early March 2018, which saw widespread snowfalls and freezing temperatures across Ireland, provided very valuable lessons in the vulnerability and resilience of supermarket supply chains across the IoI to unforeseen shocks and lean supply chain design (many grocery chains operate on a lean/just-in-time basis, often with as little as 1-3 days of inventory). A key lesson was the importance of ensuring high levels of product availability. This prevents the perceptions of food shortages and then subsequent panic buying behaviour by customers (e.g., panic buying of bread during Storm Emma). In the early stages of the pandemic (March-April 2020), retailers placed considerable emphasis on ensuring there was high levels of product availability, thereby reducing the risk of empty shelves, the perception of shortages and the knock-on impact of panic buying behaviour by customers.

The move to working from home and closure of foodservice outlets led to some changes in buying patterns by consumers at the grocery level, with demand for staple products such as flour¹⁰⁴, pasta, tinned tomatoes increasing significantly. This created challenges for supermarket supply chains to obtain the necessary volumes of products to satisfy customer demand, given that, for example, there is a single mass producer of flour on the IoI. While there are a number of small flour mill operators on the IoI, the volume available there was not sufficient to meet the overall demand required. There was some initial concern around the availability of imported fresh fruits and vegetables due to the possible inability of farmers to hire migrant seasonal workers, there was limited impact on the availability of these products in supermarkets in Ireland.

An overall result of the pandemic has been the dramatic reduction in foodservice activity and a corresponding increase in retail demand. However, from a supplier perspective, the supply chains into these two sectors are quite different. This presented significant challenges for food producers who were previously reliant on foodservice and needed to access retail as a source of revenue. Foodservice tends to buy in bulk unit volumes, with end user packaging being less of a concern. The process of gaining access to a retailer approved supplier list can be difficult, particularly with large multi-national chains, where price and volumes are key criteria for entry. In addition, retail packaging requirements are highly specified, in order to satisfy consumer expectations. As a result, food service

¹⁰³ <https://www.cips.org/supply-management/news/2020/april/tesco-completely-reset-relationships-with-suppliers/>

¹⁰⁴ Demand for Flour on the Rise, <https://www.rte.ie/news/2020/04/17/1132153-flour-increase-coronavirus/>

providers found it difficult to gain access to multi-national retailers but had some success with community-based grocery organisations.

Small and Medium Enterprises

According to Teagasc, there are 300 speciality food producers in ROI, which account for approximately €500m in revenue per annum¹⁰⁵. Of these almost 50 are farmhouse cheese producers. By comparison, the Netherlands, which is the size of Munster, has over 100 cheese producers, and New Zealand has over 2,000 speciality food producers. In addition, there has been significant growth in the number of farmer's markets in ROI over the past decade and these are now estimated to have a total turnover in excess of €10m per annum. In Northern Ireland, there are a number of associations which support food SMEs, including Food NI¹⁰⁶ which uses the "Taste of Ulster" and "Our Food So Good" promotion for high quality food. Comparative economic data on the number and value of the NI food SME sector was not found.

The immediate impact of the public health restrictions imposed in March 2020 due to the pandemic had serious consequences for the Micro and SME food sector across the Iol. Many of these enterprises were reliant on the food service sector as their primary source of revenue. Others were dependent on farmer's markets for their sales channel. In addition, many of these firms have limited financial reserves when compared to large multinational food firms. As the primary focus of micro and small/medium firms is on high quality, small-scale food production, they also tended to lack the knowledge and skills in areas of large-scale packaging design, lack alternative packaging suppliers, digital marketing and e-commerce skills. With the closure of business-to-business food service/hospitality and business-to-consumer food markets, micro and small/medium firms were faced with a challenge of how to gain access to and leverage the increased consumer demand seen by business-to-business retailer and find alternative routes to consumers through online sales, with very little financial reserves to support this.

For firms who did not already have access to business-to-business supermarket retailers, it proved quite difficult to gain access to this sector. The large retail grocery chains tend to operate on highly specific volume, price and packaging requirements. Given the relatively small scale of micro and small/medium firms, it was difficult to satisfy the contractual requirements to gain access to multi-national retailers, but there was some success with community-based stores.

¹⁰⁵ Artisan Food in Ireland <https://www.teagasc.ie/food/research-and-innovation/research-areas/food-industry-development/artisan-food/artisan-food-industry-in-ireland/>

¹⁰⁶ <https://www.nigoodfood.com/about-us/>

ROI industry representatives indicated that the €2,500 business support grant through the Local Enterprise Offices (“Trading Online Voucher Scheme”) was a critical intervention¹⁰⁷. This provided micro enterprises (firms with up to 10 employees were eligible for the grant) with access to training on how to setup a website and to develop digital marketing skills. This enabled small food producers to create an e-commerce presence, whereby customers could order on-line and have produce delivered to their home. The infrastructure available from other non-food firms also helped in this regard. For instance, Shopify (www.shopify.ie) is a global e-commerce infrastructure company focused on enabling firms to develop an e-commerce presence. While customers can place their order through their own firm’s Shopify supported website, further challenges arise in relation to logistics and delivery. One recent ROI start-up company, Cork based SmartRoutes (www.smartroutes.ie), provides delivery route planning software and has experienced significant growth since the start of the pandemic. One of its case studies demonstrates how it helped a confectionary company (Le Pâtissier – www.lepattisier.ie) optimise the route network for its delivery vans¹⁰⁸. In fact, Le Pâtissier provides a very good example of how a small food firm, which was solely dependent on the business-to-business hospitality and catering sector, very quickly established and grew a business-to-consumer online home delivery service for its products, with limited resources.

The impact on the food service sector in Northern Ireland was similar to ROI and the rest of the UK, with up to 80% of businesses ceasing trading from March 2020. Northern Ireland SMEs benefited from supports put in place by the UK government, such as the temporary reduction in VAT from 20% to 5% for a six-month period and the “Eat Out to Help Out” scheme which provided restaurant customers with a 50% discount of up to £10 per person per meal¹⁰⁹

While in-person dining remained closed for much of 2020, many restaurants in ROI and NI established “eat-at-home” services. This provided much needed revenue for restaurants, many of whom are micro or small/medium firms, as well as the small food producers in their supply chains. However, firms still faced challenges in relation to meal design, as what may have been suitable to serve on a plate in a restaurant may not be suitable to pack and transport in a box from the restaurant’s kitchen to a customer’s home. Other small food producers such as Artisan Pantry created “Artisan Food Boxes” for home delivery¹¹⁰.

Industry representatives in ROI and NI indicated that the sector benefited from greater consumer awareness and spending on local products. According to Aodhán Connolly, Director of the Northern

¹⁰⁷ Trading Online Voucher Scheme <https://www.localenterprise.ie/Discover-Business-Supports/Trading-Online-Voucher-Scheme/>

¹⁰⁸ SmartRoutes Le Pâtissier Case Study <https://smartroutes.io/case-studies/food-home-delivery-route-planner>

¹⁰⁹ <https://www.nigoodfood.com/vital-hospitality-sector-needs-merits-our-support-to-ensure-survival-protect-jobs/>

¹¹⁰ Ireland’s Artisan Pantry <https://irelandsartisanpantry.com/>

Ireland Retail Consortium, Northern Ireland retailers (from supermarkets to takeaways) purchase £2.7 billion worth of Northern Ireland produce each year¹¹¹. LoveIrishFood reported that leading ROI brands recorded growth of almost 20% in 2020¹¹². Micro and small/medium firms representatives also saw similar patterns across their products. It is important to highlight that this behaviour was evident across the different socio-economic groups. Two principal consumer groups emerged during the pandemic. One group suffered significant loss of income due to unemployment and were in receipt of the ROI government Pandemic Unemployment Payment (PUP) or the Employment and Support Allowance in Northern Ireland. Those in the other group had their income protected due to the nature of their employment and retained disposable income. Both groups were focused on value and supporting local producers (e.g., fruit and vegetables), while those with disposable income also purchased more premium local products. One industry representative indicated that this focus on supporting local producers had been seen previously during the financial crisis in the late 2000's and early 2010's.

Transportation and logistics

As an island nation, transportation and logistics services are a critical component of food supply chains, to ensure that imported products arrive at distribution centres or processing sites and then onwards to supermarkets, and that products for export can arrive at their destinations on time. Both ROI and NI are net exporters of food, compared to the UK for instance, which is a net importer of food. Due to the relatively low value of individual food items, compared to other exports such as pharmaceuticals, medical devices or computer chips, the majority of food imports and exports are carried out by road and sea. One particular challenge with food is that it may require different forms of transportation, such as ambient, chilled, frozen or in the case of animals, live.

The ROI and NI transport and logistics sectors are characterised by three different categories of firms. Several of the global firms have a presence in both ROI and NI (e.g. DHL, DB Schenker, Kuhne & Nagle). Indigenous transport and logistics firms tend to comprise of two types: large family firms and single truck operators.

One interesting side effect of the public health restrictions on the ROI in the early stage of the pandemic (March-June 2020), was that there was very little traffic on the roads, and therefore no

¹¹¹ <https://www.daera-ni.gov.uk/news/support-our-food-retailers-and-takeaways>

¹¹² <https://www.loveirishfood.ie/news/irish-times-conor-pope-irish-consumers-turn-irish-food-products-covid-crisis/>

traffic congestion. Food logistics firms, particularly those serving grocery stores, observed that their truck drivers were completing their deliveries from the distribution centres relatively quickly.

A number of measures introduced by the ROI and NI governments and at an EU level were seen as supportive of the transport and logistics sector. For instance, supply chain workers were classed as “essential workers”, which enabled employees to attend work, as well as providing a previously unseen level of recognition for the sector. The EU established “green lanes” at border crossings, thereby ensuring free movement of freight vehicles between countries, along with a commitment that any checks or screening should take no more than 15 minutes¹¹³. There was some concern raised by the Irish Road Haulage Association (IRHA) at the requirement to book a Covid-19 test to enter France. This was later dropped due to the very low positivity rate¹¹⁴. The ROI government introduced a temporary exemption to EU driving and resting time rules (“tachograph rules”) in March 2020 and separate lanes were established for trucks at Garda checkpoints on ROI motorways¹¹⁵. Similar driving and resting time exemptions were obtained by the UK government, which included Northern Ireland¹¹⁶.

As the sector which is critical to the movement of food products into and off the IoI, the logistics and transport sector, like all others in the food industry, has been engaged in significant preparations for the pending departure of the UK from the European Union. Initial analysis of information available on ROI and NI food transport company websites shows that there were more frequent updates in relation to this issue compared to Covid.

Trade associations

Trade associations, semi-state and representative bodies played a key role in supporting and disseminating information across the food sector and sub-sectors throughout the pandemic across the IoI. While large multi-national organisations had the global footprint to acquire market intelligence about the pandemic in a real-time manner, particularly those with operations in Asia, these firms also possess the expertise to develop protocols for employees and the financial resources to purchase and hold buffer stocks to ensure continuity of supply of critical raw materials. For SMEs, the peer-to-peer information sharing through membership of trade associations as well as advisory services provided them with the necessary information to manage their operations as well as

¹¹³ https://ec.europa.eu/commission/presscorner/detail/en/ip_20_510

¹¹⁴ <https://www.irishexaminer.com/business/economy/arid-40238543.html>

¹¹⁵ Temporary relaxation of EU driving and resting time rules due to COVID-19

<https://www.rsa.ie/en/Utility/News/2020/Temporary-relaxation-of-EU-driving-and-resting-time-rules-due-to-COVID-19/>

¹¹⁶ <https://ec.europa.eu/transport/sites/default/files/temporary-relaxation-drivers.pdf>

assisting with access to alternative markets for those heavily reliant on the foodservice sector. Over the last 3-4 years, associations such as Bord Bia, Enterprise Ireland, Irish Business and Employers Confederation (IBEC) and its food related groups such as Food Drink Ireland, the Northern Ireland Food & Drink Association (NIFDA), Food NI, having been advising their respective ROI and NI food firms, both multinational and SME, in assessing supply chain vulnerabilities around the UK departure from EU (e.g., Bord Bia Brexit Readiness Radar¹¹⁷, IBEC¹¹⁸, Enterprise Ireland¹¹⁹, Northern Ireland Food & Drink Association¹²⁰). While these initiatives were focused on a specific issue (UK departure from EU), it was indicated that having put the effort on this, they were found to be highly beneficial in mitigating the full impact of the pandemic on food supply chains.

¹¹⁷ Bord Bia Readiness Radar, <https://www.bordbia.ie/industry/readiness-radar/>

¹¹⁸ IBCE B2B Brexit Business Readiness Event, <https://www.ibec.ie/influencing-for-business/ibec-campaigns/brexit-and-the-future-of-europe/b2b-brexit-business-readiness-event>

¹¹⁹ Enterprise Ireland <https://www.prepareforbrexit.com/all-supports/>

¹²⁰ Brexit: Challenges & Opportunities for Northern Ireland Food & Drink http://nifda.co.uk/wp-content/uploads/2016/11/NIFDA_Brexit_Final_Report.pdf

5 Analysis

Using the Table A3.1 list of seven supply chain vulnerability factors based on a previously validated academic framework (Appendix 3), the Covid-19 pandemic highlighted the following vulnerabilities in food supply chains on the lol:

1. **Turbulence:** ROI and NI food supply chains operate on a global basis, so are exposed to an environment where there are geopolitical disruptions (e.g., EU-US trade war, Brexit), currency fluctuations (euro versus US dollar, UK pound etc). As an EU member, ROI is part of the Common Agriculture Policy (CAP). While “pandemic” is listed as a Turbulence factor, this was not considered as a threat among food supply chains.
2. **Deliberate threats:** while the issue of food fraud is of global concern, it did not emerge as a serious risk among interviewees.
3. **External pressures:** in this category, risks to food supply chains emerge because of changing customer behaviour, such as plant-based diets, and environmental sustainability. The ROI seafood sector operates under EU quotas, while the dairy sector saw the abolition of quotas in 2015.
4. **Resource limits:** primary food producers, such as farmers, tend to have finite capacity to produce. Herd and crop size planning decisions for harvesting or sale in 2020 were made in 2019. Similarly, processors, such as those in the dairy sector, have limited milk processing capacity, with capacity adjustment difficult in the short-term. The impact of the pandemic on human resources was seen across the sector, with reduced production capacity when employees were ill or isolating. The meat processing sector was disproportionately impacted in this regard.
5. **Sensitivity:** this is defined as “the importance of carefully controlled conditions for product and process integrity”. This is a key risk for any company operating in the food sector, with many representatives indicating that analysis of food contamination risk takes higher priority than supply chain risk analysis.
6. **Connectivity:** as a net exporter of food and operating on in a global market, lol food supply chains have high degrees of connectivity, both for raw materials and access to global markets. This increases the level of supply chain risk due to the global nature of their operations.

7. **Supplier/customer disruptions:** The principal impact on Iol food supply chains during the pandemic was caused by customer disruptions. Demand from food service customers dropped drastically, while demand from supermarket retail and consumers increased. Overall, there was limited supplier level disruptions. Some firms encountered challenges in obtaining stocks of packaging. Using Table A3.3 list of supply capability factors, the Covid-19 pandemic demonstrated how food supply chains on the Iol developed capabilities to enhance supply chain resilience.

Using the same previously validated academic framework, the capabilities developed by these food supply chains to enhance their resilience are analysed across fourteen factors Appendix 3, Table A3.2):

1. **Flexibility in sourcing:** Supermarket representatives indicated that both Storm Emma and the pending departure of the UK from the EU forced them to develop multiple sources for products, in particular diversifying their supply based on the UK to mainland Europe. An interesting benefit of mutual recognition in food standards was seen following outbreaks of Low Pathogenic Avian Influenza (LPAI), in the Co Monaghan region, approximately 550,000 laying hens were culled in the period March-May 2020. This resulted in a shortfall of eggs on the ROI market, which also coincided with an increase in retail demand due to the “stay-at-home” requirement from the Covid-19 pandemic, creating a major challenge for the sector. This resulted in main egg packers importing Northern Irish eggs to cover the shortfall of ROI eggs. Northern Ireland eggs which meet the Lion Standard were temporarily approved to be sold in Bord Bia Quality assured packs from ROI packers.
2. **Flexibility:** in Order Fulfilment: similar to flexibility in sourcing, many food companies had developed additional customers in Europe, US, Asia and Africa, to reduce dependence on the UK.
3. **Capacity:** many food firms operate on a lean supply chain basis, so tend to have low levels of redundant capacity. Given the nature of certain food sectors, such as dairy processing, it is very difficult to increase processing capacity in the short-term. To overcome this, there is close cooperation between dairy processors, whereby milk can be re-routed to a competitor plant in the event a processor has capacity issues in their own plant.
4. **Efficiency:** many food producers operate lean supply chains, so are capable of producing outputs with minimum resource requirements.
5. **Visibility:** the role of trade associations and business groups was important during the pandemic, particularly in the early stages, when there was a lot of uncertainty around customer demand and safe-working protocols. These associations and groups, both in the Republic of Ireland and Northern Ireland engaged in business intelligence gathering and information exchange between members.

6. **Adaptability:** is the “ability to modify operations in response to challenges or opportunities”. This is particularly evident from micro and small/medium enterprises. In order to survive financially, firms which had high dependency on food service customers, demonstrated an ability to pivot quickly to online sales and home delivery. Financial supports, such as the local enterprise office training vouchers for online trading, were a critical intervention in this regard.
7. **Anticipation:** this is probably one of the areas where firms did not perform as well, notwithstanding that a global pandemic of this nature had never been experienced before in such as highly mobile, global business environment. There were some individual examples where firms had crisis management teams in place from early February, but for the most part, many did not do so until mid-March 2020. The food distribution and retail supermarket sector had engaged in scenario planning, primarily driven by Storm Emma in 2018 and Brexit.
8. **Recovery:** once the impact of the pandemic was fully evident, many firms and trade associations put crisis management teams in place. Many had communications strategies in place and scenario plans in place in the event of an outbreak among staff. For example, dairy companies developed and published protocols for milk collection and delivery processes. Logistics and transport companies developed processes for safe collection, handling and delivery of goods to minimise human to human contact. Supermarkets placed considerable effort on ensuring shelves were fully stocked in order to avoid the impression that food shortages were occurring, which would then lead to panic buying by consumers.
9. **Dispersion:** at a sector level, export markets are now highly dispersed, with government agencies such as Bord Bia developing markets in Europe, US, Asia and Africa. At an individual company level, the experience varied. Producers who were highly dependent on food service suffered significantly, whereas those who had a more diversified customer based fared better.
10. **Collaboration:** many larger firms have invested in enterprise resource planning (ERP) IT systems in recent years, which facilitates real-time information sharing of demand, forecasts, production plans etc with supply chain members.
11. **Organisation:** as part of firms’ crisis management approaches, issues such as cross-training of employees was carried out, which would enable continuity of production in the event other employees were unable to attend work. Where firms had more than one shift per day, measures were put in place to avoid workers from different shifts interacting with each other, such as increasing the time between a shift finishing and the next one starting.
12. **Market position:** One of the key differentiators for ROI food exports is the focus on environmental sustainability, as evidenced by Bord Bia’s “Origin Green” programme, which conveys a quality brand status to ROI products in export markets. Similarly, Ornua’s Kerrygold brand also provides a unique selling point for ROI dairy products abroad. In the

early stages of the pandemic, when there was some uncertainty around whether the virus could be transmitted through food packaging, the status of ROI food brands helped alleviate any concerns in this regard among international customers. For ROI customers, brands such as “GoodFoodIreland” and in NI “Taste of Ulster” helped assure customers around the quality of food they were purchasing on-line, particularly for meat or fish, which consumers would normally prefer to view in-store before buying.

13. **Security:** this focuses on “defence against deliberate intrusion or attack”. This topic did not come up among interviewees.
14. **Financial strength:** the experience varied across companies. Large multi-national or public liability food companies had the necessary financial reserves to be able to withstand loss of revenue associated with the food service sector and to be able to procure and hold higher than usual levels of buffer stocks of raw materials and work in process. Micro and small/medium enterprises had a very different experience. Many lost key customers (often their sole customers) in the food service sector and had neither the skills or resources to pivot to online sales. Financial support from different schemes, such as the “Tie up Scheme” for the fishing industry, the online trading training voucher for micro firms were seen as important interventions in ROI. Similar schemes were put in place by NI government departments.

6 Conclusions

Based on the analysis, the following key conclusions emerge in relation to the impact of the pandemic on food supply chains across the IoI.

Food supply chains on the IoI experienced an unprecedented disruption because of the global pandemic. While many firms across the island indicated that they engaged in supply chain risk assessment and business continuity planning, none had factored in a global pandemic of this scale. Prior supply chain risk assessment tended to focus on typical supplier induced disruptions (supplier bankruptcy), disruptions to core operations (e.g., factory fire) or delayed shipments due to weather or other transport related risks.

When initial reports of a respiratory disease outbreak emerged from China, ROI/NI based food companies, even those with a global presence, did not expect the scale of the impact of Covid-19. The initial assumption was that the outbreak would be similar to those seen previously in South-East Asia, such as SARS in 2003.

The severity and impact of the public health restrictions introduced across the world had both positive and negative impacts for food producers across the IoI. On the negative side, food producers with customers in the food service sector incurred sudden and significant loss in demand due to the closure of hotels, restaurants and catering. There was some recovery in this when restaurants commenced dine-at-home sales. On the positive side, food producers with customers in the retail grocery sector saw significant increase in demand, driven by increased spending by consumers in supermarkets.

The food sector exhibited “bullwhip effect” behaviour caused by the sudden drop in demand from food service, the effect of which rippled up through the supply chain. Food producers were left with excess stock and unused capacity due to loss of sales. On the other hand, food producers had insufficient capacity and stock-outs due to the sudden increase in demand from the retail supermarket sector. For food producers, including farmers, it is very difficult to quickly adjust capacity levels, as many capacity planning decisions are made with a medium to long-term horizon.

It was noted that larger multi-national firms tended to have greater levels of financial reserves to withstand the loss in sales. This also provided them with the ability to procure and hold additional levels of inventory of raw materials or work in process, which would not normally be done in a lean supply chain context, under which many of the producers operate. Even with financial reserves, some firms experienced challenges in building inventory of items such as packaging (e.g., glass jars).

Supermarket retailers indicated that recent disruptions provided some levels of risk mitigation to the impact of the pandemic. For instance, Storm Emma in spring 2018, demonstrated how susceptible lean supermarket supply chains were to a weather induced disruption and highlighted where weaknesses existed. Many interviewees across the food producing sector on the Iol indicated that preparations for the departure of the UK from the EU have been underway since mid-2016. This has led to producers developing alternative sources of supply and alternative markets for their products. These capabilities contributed to the resilience of food supply chains on the Iol throughout the pandemic.

Trade associations in NI and ROI played a critical role for their members. Firstly, they provided a forum for general information sharing between members. Multi-national members were able to provide market intelligence and experience to locally based members. They also provided a strong lobbying voice to governments in relation to the impact of the pandemic and developing government supports for sectors. The combined expertise of members was also beneficial in developing operational protocols for members.

There were high levels of innovation seen across the sector, in particular among micro and small/medium enterprises. Many of these firms would have low levels of financial reserves and they experienced loss of key customers due to the closure of the food service sector. Sector representatives in ROI indicated that the €2,500 local enterprise office training grant for micro enterprises was a critical intervention, which enabled them to gain e-commerce skills to pivot to online business-to-consumer sales. More generally, the financial supports put in place by the governments in both jurisdictions provided critical relief for companies in the agri-food sector, particularly those heavily impacted by the sudden loss in food service demand.

At the time the data was collected, industry representatives expressed the following uncertainties about the future, as governments announced reductions in public health restrictions:

- What will steady-state demand look like across Business-to-Business retail, Business-to-Business food service and Business-to-Consumer segments?
- What aspects of consumer behaviour adopted during the pandemic, will continue into the future and what aspects will return to pre-pandemic patterns?
- Will the pandemic accelerate the trend towards plant-based diets?
- How will the issue of food price inflation¹²¹, driven by rising food commodity prices, develop?

¹²¹ "What the soaring cost of breakfast may signal for global food price inflation", Financial Times, 28th May 2021, <https://www.ft.com/content/007bdoao-f149-427d-937c-ec5boef4374d>

7 Appendices

Appendix 1: Interview protocol (food companies)

Interview section	Theme	Interview question (Company)
Demographic	Company / Association Name	
	Interviewee Name	
	Company /Association Location	Where is your company located (Republic or Northern Ireland)? Number of employees?
	Company /Association Business	What is the nature of your company's business?
	Interviewee Role	What is your role in the company?
	Supply Chain Structure	In addition to the nature of your business, can you describe your company's supply chain? What comes in from suppliers, what is processed at your sites, what leaves and where does it go? Who are your main customers for the products under your part of the organisation – retail or food service? Domestic versus export?
	All-Island Aspect	Does your company do business in Northern Ireland / Republic of Ireland? Any suppliers, own operations, customers in that jurisdiction?
Establish the baseline	Contingency / Business Continuity Planning	Prior to Covid, what type of contingency or business continuity planning did your company carry out? Would this be typical in your industry?
	Takes SCRAM aspect of "vulnerabilities"	What type of scenarios did you consider? Did these include supply chain disruptions?
		How did you carry out this analysis? Did you use analytical tools (models) or was it primarily based on intuition and experience?
		Was this activity done internally within the company, or did you use any external expertise?
(uses the SCRAM tool components "capabilities" to address "vulnerabilities")	What capabilities did you put in place to address any weaknesses in your supply chains? Prior to Covid, what type of disruptions occurred in your supply chain? What was the impact? How did you manage these?	
Covid warning	Preparation Phase	How early did you start planning for Covid – January, February, March 2020? What signals were you picking up that something serious was happening? For MNCs, did global outposts in Asia/US start reporting issues early?
		As the Covid pandemic spread to Europe in February 2020, but prior to emerging on the Island of Ireland, what scenario planning did your company carry out, if any?
		What measures did you start to put in place in your supply chain?
Covid arrival		How did the impact of Covid really start manifesting itself in your supply chain and where? Suppliers, your own operations, logistics inbound or out, downstream customers?
Covid impact		At what point was your supply chain at its lowest level of performance?

Covid impact		What has been the impact of the various levels of restrictions and Covid protocols on your supply chain over the last year?
Covid recovery		What measures did you have to put in place to repair your supply chain? How effective were these?
Covid reflection		Has the Covid pandemic highlighted previously unknown risks in your supply chain?
		Has the Covid pandemic highlighted gaps in skills or knowledge in your company? If so, where? Did government agencies or state bodies play any advisory or coordinating roles?
		Has the Covid pandemic provided you with new business opportunities, or redefined your business model? Has it speeded up any new ways of doing business? What business strengths did it show to help you cope with pandemic?
		Has the Covid pandemic changed the way you will do business continuity planning in the future? How?

Appendix 2: Interview protocol (trade associations)

Interview section	Theme	Interview question (association)
Demographic	Company / Association Name	
	Interviewee Name	
	Company /Association Location	Where is your association located (Republic or Northern Ireland)?
	Company /Association Business	What is the nature of your association's business?
	Interviewee Role	What is your role in the association?
	Supply Chain Structure	What tends to be the supply chain structures of your members? Sourcing (local vs international), operations (man part of multinationals) and customers (local vs international)
	All-Island Aspect	Do the company members in your association do business in Northern Ireland / Republic of Ireland?
Establish the baseline	Contingency / Business Continuity Planning	What level of business continuity planning was typically carried out among your members prior to Covid? Would you have a role in advising them in relation to this?
	Takes SCRAM aspect of "vulnerabilities"	What type of scenarios and supply chain disruptions would have been included?
		How sophisticated would the risk planning tend to be among members? Analytical modelling or management intuition / experience
		Would your association offer assistance, education or training to members with supply chain risk planning?
(uses the SCRAM tool components "capabilities" to address "vulnerabilities")	What capabilities have members put in place to address weaknesses in their supply chains	
	Prior to Covid, what types of threats would your association would you considered among the most serious (e.g. food fraud, contamination)?	
Covid warning	Preparation phase	Given the global presence of your association, especially in Asia, how early was your association picking up signals that something serious was going to happen? Did your association communicate with members or offer guidance?
		As the Covid pandemic spread to Europe in February 2020, but prior to emerging on the Island of Ireland, what did your association do for members?
		What did you see members starting to do?
Covid arrival		What were the immediate impacts of Covid on members' supply chains?
Covid impact		When do you think was the worst point in the pandemic for members?
Covid impact		How have the various levels of restrictions and protocols impacted on member's supply chains? How have smaller firms coped compared to larger MNCs?
Covid recovery		What have members done to repair their supply chains?
Covid reflection		How has the Covid pandemic highlighted previously unknown risks or vulnerabilities in your sector?
		How has the Covid pandemic highlighted strengths and capabilities in your sector? Do you think smaller companies were more nimble and entrepreneurial to adapt, or did larger companies have an advantage with financial resources to survive?

		Has the pandemic identified gaps in skills or knowledge among members? Does your association have a role in addressing this?
		Has the Covid pandemic provided your members with new business opportunities, or redefined their business models? Has the pandemic provided your association with new opportunities to support your members?
		Has the Covid pandemic changed the way your members will do business continuity planning in the future? What role might your association have with this?
		Long term impact on the food system. Will there be food inflation (commodity prices going up, oil prices going up, labour shortages etc)

Appendix 3: Academic literature review: Supply chain risk & resilience

In this section, a general overview is provided on the concepts of supply chain risk and supply chain resilience. This is based on a review of the academic literature in this area.

Appendix 3.1: Supply chain risk

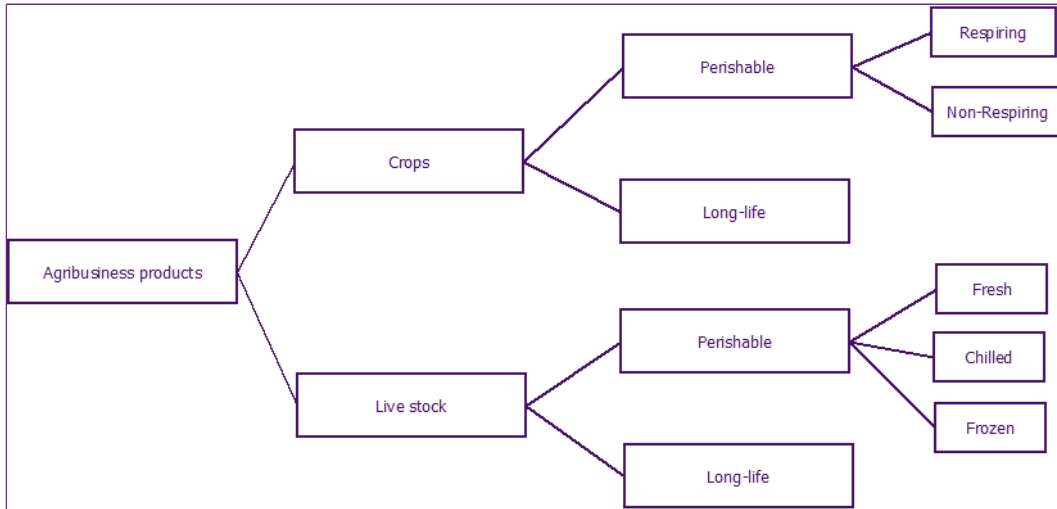
In recent years, the scope of agribusiness research has been extended from focusing solely on farming activities to include more stages and links, therefore taking an end-to-end supply chain perspective. The study of these supply chains provides opportunities to improve the efficiency, business integration, responsiveness and market competitiveness (Higgins et al., 2007)¹²². The industrialisation of the Agri-Food sector has changed perspectives of farming from an idyllic rural lifestyle to a highly competitive agribusiness sector with a supply chain mindset (Martin, 2001)¹²³. Increased global competition and lower commodity prices in recent decades have directed the agri-food sector to identify supply chain efficiency opportunities from other industrial sectors in order to increase profitability and enhance sustainability.

The agri-food supply chain, like any other supply chain, is a network of firms working together on various processes and activities to provide products and services to the market, to satisfy end customers. Figure A3.1 below provides an outline of the types and nature of products in agri-business supply chains.

¹²² Higgins, A., Thorburn, P., Archer, A., Jakku, E., 2007. Opportunities for value chain research in sugar industries. *Agric. Syst.* 94, 611–621

¹²³ Martin, M.A., 2001. The future of the world food system. *Outlook Agric.* 30, 11–19.

Figure A3.1: Types of Products in Agribusiness Supply Chain



An agribusiness supply chain (ASC) comprises all the elements of "farm-to-fork" processes of a particular food product, which includes various phases of supply, production, post-harvesting activities, storage, processing, transportation, distribution and interconnection between these elements (Behzadi et al., 2018)¹²⁴. Therefore, conceptually ASC is similar in many ways to conventional manufacturing supply chains. However, ASC differs from traditional supply chain in three specific aspects, which makes the risk management of ASC more complicated compared to a manufacturing supply chain. These particular aspects are seasonality, supply spikes and perishability or limited shelf-life. To deal with seasonality, advance planning is required as growth and yield can vary depending on seasonal production, while consumption happens all through the year. Moreover, some farmed food products (e.g. wheat, beef, tomatoes) have long supply lead-times, which cannot easily be shortened, as well as relatively fixed supply capacity, which cannot be adjusted in the short-term. In addition, supply spikes make harvesting and post-harvesting activities, such as processing, storage and transportation more challenging. The perishable nature of the products adds time pressure to post-harvesting activities and demands special handling, storage and inventory management techniques. Evolving food technologies, consumer tastes and preferences present challenges for the design and management of existing supply chains and require them to adapt their structure to meet these evolving demands.

Owing to these inherent characteristics of ASC, decision making under uncertainty becomes an essential activity in these supply chains. On the upstream side, the ASC is faced with uncertainty

¹²⁴ Behzadi, G., O'Sullivan, M.J., Olsen, T.L., Zhang, A., 2018. Agribusiness supply chain risk management: A review of quantitative decision models. *Omega* 79, 21–42. <https://doi.org/10.1016/j.omega.2017.07.005>

arising from weather conditions, seasonal variations, capital availability and other farming conditions (Weintraub and Romero, 2006)¹²⁵. On the other hand, the downstream side of the supply chain is confronted with demand volatility and is highly sensitive to economic and financial fluctuations. Therefore, incorporating these uncertainties is highly relevant for managerial decision-making in agri-business supply chain planning at operational, tactical, and strategic levels. In addition, firms are operating increasingly on a global scale. This is manifested by the size of food industry firms, enhanced flow of livestock and food products, worldwide corporation and collaboration between partners (van der Vorst et al., 2009)¹²⁶.

The traditional methods of dealing with supply chain risks is based on the idea of stability as a normal state of business activities (Fiksel et al., 2015)¹²⁷. However, the increase in the globalization of supply chain operations and growing interconnectedness among supply chain partners have led to higher dependency and increased complexity between the firms in the supply chain. Because of this, the supply chains that have generated high levels of efficiency through lean operations during stable business conditions have become highly vulnerable to disruption risks.

Over the past decade, there has been a growing interest in dealing with systemic risks- threats to the systems on which society depends (Leat and Revoredo-Giha, 2013)¹²⁸. The main categories of such risks involve natural disasters, terrorism-related incidents, technological accidents, epidemic outbreaks, contamination, food safety etc. Estimating the scale and frequency with which low probability, high impact disruptions occur presents a major challenge. For example, the scale of the current Covid-19 global pandemic's impact on the supply chains is evolving and seems unprecedented. It has been reported that 94% of the Fortune 1000 companies are experiencing Covid -19 related disruption in their supply chains. At this point, the question is: should Covid-19 be considered a so called isolated 'black swan event', or, considering the high frequency with which large scale disruptive events are occurring globally in recent times, should it be considered as a 'new normal'- a situation supply chains have to be prepared to deal with at any time.

When it comes to dealing with large scale disruption, the often-used term in risk management is supply chain resilience. In the ongoing Covid-19 crisis situation, even the news articles are discussing how resilient the associated supply chain is when a shortage in food supply is encountered due to

¹²⁵ Weintraub, A., Romero, C., 2006. Operations Research Models and the Management of Agricultural and Forestry Resources: A Review and Comparison. *Interfaces* 36, 446–457.

¹²⁶ van der Vorst, J.G.A.J., Tromp, S.-O., Zee, D.-J. van der, 2009. Simulation modelling for food supply chain redesign; integrated decision making on product quality, sustainability and logistics. *Int. J. Prod. Res.* 47, 6611–6631. <https://doi.org/10.1080/00207540802356747>

¹²⁷ Fiksel, J., Polyviou, M., Croxton, K.L., Pettit, T.J., 2015. From Risk to Resilience: Learning to Deal With Disruption. *MIT Sloan Manag. Rev. Camb.* 56, 79–86.

¹²⁸ Leat, P., Revoredo-Giha, C., 2013. Risk and resilience in agri-food supply chains: the case of the ASDA PorkLink supply chain in Scotland. *Supply Chain Manag. Int. J.* 18, 219–231. <https://doi.org/10.1108/13598541311318845>

panic buying. While referring to supply chain resilience, since every firm is connected to one or more supply chains, it is said that a supply chain is as resilient as its weakest link.

The concept of resilience, which calls for proactive risk management measures, has received a great deal of attention from both practitioners and researchers in the recent past due to the frequent occurrence of high impact unpredictable events and apparent inability of current risk management practices to deal with such disruption risks. The focus of many supply chains has been to reduce waste and redundancy through lean management principles, such as just-in-time production and distribution, which makes supply chains more vulnerable to disruption. These practices have eliminated buffer inventory levels in the highly globalized, complex and tightly linked supply chains, thereby removing an ability to absorb shocks when a high impact disruptive event happens. As far as supply chain risk management is concerned, a study conducted by MIT suggested that 60% of managers did not engage in Supply Chain Risk Management (SCRM) planning as they did not believe that it would have a positive impact on the organization (Sáenz and Revilla, 2014)¹²⁹. The ineffectiveness of traditional risk management practice can be attributed to the reliance of such practices on an ability to carry out risk identification and statistical estimation, while many of the threats are unknown and historical data of such events do not exist (Fiksel et al., 2015). To address these issues, the concept of supply chain resilience has received increasing attention by both researchers and practitioners recently.

While there has been a growing interest in supply chain resilience as an essential element of business continuity, along with sustainability of food systems, governments have become more interested in resilience capabilities of the system against shocks in the event of crisis (Scottish Government, 2009)¹³⁰. According to Ambler-Edwards et al. (2009), the evolving UK food system will have to combine the following four features, which are: resilience, sustainability, competitiveness and ability to address customer requirements¹³¹. The government-level interest in resilience has been related to concern with the sustainability of the food system and potential crises, including food scarcity and large scale disruptions (Leat and Revoredo-Giha, 2013).

The risks in a supply chain are said to happen when unexpected events interrupt the flow of material through the supply chain (Waters, 2011)¹³². The definition of risk differs for various firms depending on their objective and the projected outcome. Supply chain risk management involves the identification

¹²⁹ Sáenz, M.J. and Revilla, E., 2014. Creating more resilient supply chains. *MIT Sloan management review*, 55(4), pp.22-24.

¹³⁰ Scottish Government, S.A.H., 2009. Mapping and Analysis of the Resilience of the Food Supply Chain in Scotland https://www.webarchive.org.uk/wayback/archive/20170701074158oe_/http://www.gov.scot/Publications/2009/07/15103034/10

¹³¹ Ambler-Edwards, S., Bailey, K.S., Kiff, A., Lang, T., Lee, R., Marsden, T.K., Simons, D.W., Tibbs, H., 2009. Food futures: rethinking UK strategy. A Chatham House report.

¹³² Waters, D., 2011. Supply chain risk management: vulnerability and resilience in logistics. Kogan Page Publishers.

of all potential threats and associated probability occurrence (Heckmann et al., 2015)¹³³. According to March and Shapira (1987)¹³⁴, supply chain risk is defined “as the changes in the distribution of expected supply chain outcome, their likelihood of occurrence and their subjective worth”. Zsidisin (2003) described the risk relating to the likely occurrence of events and firm's inability to handle the outcome¹³⁵. Similarly, Jüttner et al. (2003) referred to the risk as to the probability of an event leading to a disparity between supply and demand¹³⁶.

The concepts of supply chain vulnerability is also used, being defined as “the propensity of risk sources and risk drivers to outweigh risk mitigation strategies, thus causing losses and adverse supply chain consequences” (Jüttner et al., 2003). Therefore, vulnerability is viewed as a “function of certain supply chain characteristics such as supply chain density, complexity, and node criticality” that influence both the likelihood and degree of impact of supply chain risky events (Wagner and Bode, 2009)¹³⁷. The latter definition indicates the origin of vulnerability and risk. The notion of vulnerability implies the inherent characteristics of a supply chain influencing the unexpected outcomes, while the risk represents external threat (Heckmann et al., 2015). Thus, vulnerability management expects to reduce the probability of being influenced by the risky events and the degree of impact of that event.

Appendix 3.1.1: Classification of supply chain risks

Supply chain risks can be broadly classified into supply-side risk, demand risks, process risks (Tang and Tomlin, 2008) and control risks (Mason-Jones and Towill, 1998)^{138,139}. Supply risks include, for example, risks associated with supply quantity and quality of supply and cost of supply. Process risks normally include variability associated with inhouse operations and inbound and outbound logistics. Similarly, demand risks include variability associated with the customer demand process. On the other hand, controls are the rules and procedures associated with managerial policies to exert control over the process and operations to ensure the smooth flow material and information within the organization/supply chain (Christopher and Peck, 2004). Therefore, improper use of these controls and

¹³³ Heckmann, I., Comes, T., Nickel, S., 2015. A critical review on supply chain risk–Definition, measure and modelling. *Omega* 52, 119–132.

¹³⁴ March, J.G., Shapira, Z., 1987. Managerial perspectives on risk and risk taking. *Manag. Sci.* 33, 1404–1418.

¹³⁵ Zsidisin, G.A., 2003. A grounded definition of supply risk. *J. Purch. Supply Manag.* 9, 217–224.

¹³⁶ Jüttner, U., Maklan, S., 2011. Supply chain resilience in the global financial crisis: an empirical study. *Supply Chain Manag. Int. J.* 16, 246–259. <https://doi.org/10.1108/13598541111139062>

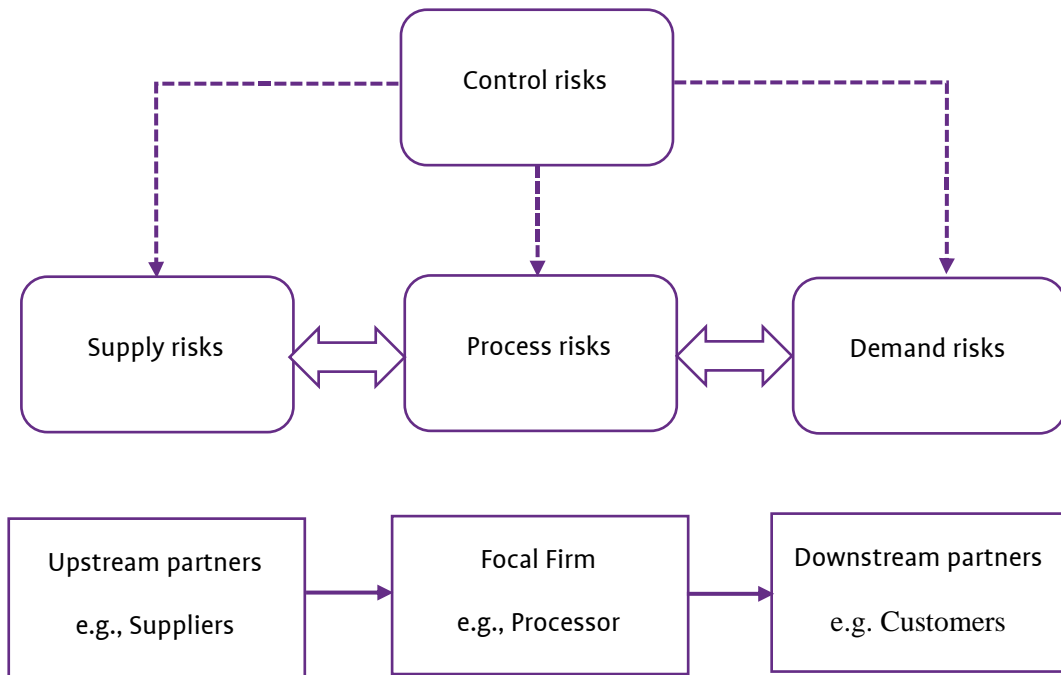
¹³⁷ Wagner, S.M., Bode, C., 2009. Dominant risks and risk management practices in supply chains, in: *Supply Chain Risk*. Springer, pp. 271–290.

¹³⁸ Tang, C., Tomlin, B., 2008. The power of flexibility for mitigating supply chain risks. *Int. J. Prod. Econ.* 116, 12–27. <https://doi.org/10.1016/j.ijpe.2008.07.008>

¹³⁹ Mason-Jones, R., Towill, D.R., 1998. Shrinking the supply chain uncertainty circle. *IOM Control* 24, 17–22.

procedures can result in control risks. These risks are also called system dynamics risk in the literature (Spiegler et al., 2012)¹⁴⁰.

Figure A3.2: Classification of supply chain risks (Christopher & Peck, 2004; Tang and Tomlin 2008)



According to Tang (2006)¹⁴¹, based on the level impact of risky events the risks can be classified into operational risks and disruption risks. Operational risks refer to the inherent uncertainty associated with the supply chain processes such as uncertainty in supply, demand, yield and cost. Disruption risk refers to the major disruption caused by natural or human-made disasters or economic crisis, where the level of impact is significantly higher than the operational risks (Figure A3.2).

In a comprehensive analysis of supply chain risks, Pettit et al (2013) identified seven major vulnerability factors in supply chains. These factors, their definition, and subfactors are shown in Table A3.1.

¹⁴⁰ Spiegler, Virginia L.M., Naim, Mohamed M., Wikner, J., 2012. A control engineering approach to the assessment of supply chain resilience. *Int. J. Prod. Res.* 50, 6162–6187. <https://doi.org/10.1080/00207543.2012.710764>

¹⁴¹ Tang, C.S., 2006. Perspectives in supply chain risk management. *Int. J. Prod. Econ.* 103, 451–488. <https://doi.org/10.1016/j.ijpe.2005.12.006>

Table A3.1: Supply Chain vulnerability factors¹⁴²

Vulnerability factor	Definition	Subfactors
Turbulence	Environment characterized by frequent changes in external factors beyond your control	Natural disasters, Geopolitical disruptions, Unpredictability of demand, Fluctuations in currencies and prices, Technology failures, Pandemic
Deliberate Threats	Intentional attacks aimed at disrupting operations or causing human or financial harm	Theft, Terrorism/sabotage, Labor disputes, Espionage, Special interest groups, Product liability
External Pressures	Influences, not specifically targeting the firm, that create business constraints or barriers	Competitive innovation, Social/Cultural change, Political/Regulatory change, Price pressures, Corporate responsibility, Environmental change
Resource Limits	Constraints on output based on availability of the factors of production	Supplier, Production and Distribution capacity, Raw material and Utilities availability, Human resources
Sensitivity	Importance of carefully controlled conditions for product and process integrity	Complexity, Product purity, Restricted materials, Fragility, Reliability of equipment, Safety hazards, Visibility to stakeholders, Symbolic profile of brand, Concentration of capacity
Connectivity	Degree of interdependence and reliance on outside entities	Scale of network, Reliance upon information, Degree of outsourcing, Import and Export channels, Reliance upon specialty sources
Supplier/Customer Disruptions	Susceptibility of suppliers and customers to external forces or disruptions	Supplier reliability, Customer disruptions

The literature related to agri-business supply chain (ASC) discusses risks and vulnerabilities in various stages of the value chain such as supply cost, yield and price (customer side) variabilities for different agriculture products. Perishability, which is a key characteristic of ASC compared to other supply chains, can influence these risks.

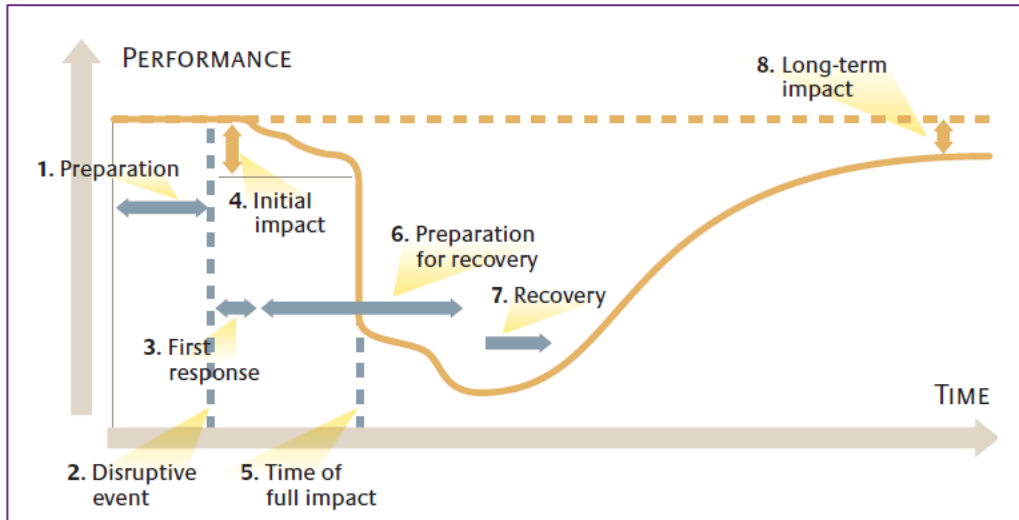
Appendix 3.1.2: Stages of supply chain disruption

The temporal characteristics of a supply chain disruption were first described by Yossi Sheff in 2005 at the MIT Centre for Transportation and Logistics (CTL)¹⁴³. This is illustrated in Figure A3.3. The x-axis represents the time horizon, while some element of firm performance is on the y-axis. This performance can be measured by any relevant metric such as sales, production level, customer service, etc.

¹⁴² Pettit, T.J., Croxton, K.L. and Fiksel, J., 2013. Ensuring supply chain resilience: development and implementation of an assessment tool. *Journal of business logistics*, 34(1), pp.46-76. <https://doi.org/10.1111/jbl.12009>

¹⁴³ Sheffi, Y., 2005. *The resilient enterprise: overcoming vulnerability for competitive advantage*. MIT Press Books

Figure A3.3: A typical supply chain disruption profile (Sheffi, 2005)



The nature of the disruption and the impact on a firm's performance can be assessed through the following eight steps.

Stage 1. Preparation:

In certain situations, companies can predict the occurrence of a disruption and prepare for this. Warning signals can range from half an hour (e.g., tornado warning) to weeks or even months in the case of labour disputes. In certain instances, such as terrorist attacks, there is no warning.

Stage 2. The disruptive event:

At this stage, the disruptive event strikes the nodes of the supply chain.

Stage 3. First response:

When a disruption takes place, the first response is to attempt to bring the situation under control. Some of the initial activities include reducing the physical damage, saving lives, terminating the affected system and taking measures to prevent the spread of the disruption.

Stage 4. Initial impact:

Firms will experience an initial impact due to the disruption, such as lack of raw materials from a supplier. In certain instances, the firm may be able to continue to produce based on availability of buffer stocks of materials or fulfil customer orders from finished goods inventory. The performance of the supply chain will start to decrease from this stage.

Stage 5. Full impact:

At this stage of disruption, the performance of the supply chain drops significantly (e.g., production ceases due to lack of materials, or in the case of a disruption such as fire, inability to use the production facility). The drive towards lean supply chains has tended to reduce the length of time between the initial impact (stage 4) and full impact (stage 5), so that the full impact is felt sooner due to lack of buffer stocks.

Stage 6. Recovery preparations:

The preparation for recovery can take place when the initial impact occurs through a firm's contingency planning, or even before a disruption take place if it has been predicted with enough accuracy through mitigation. These measures include identifying alternate suppliers, transportation modes, commencing backup production.

Stage 7. Recovery:

At this stage, the firm or the associated supply chain starts to bounce back from the disruption and the performance level begins to improve. The speed at which this occurs is driven by the robustness (or resilience) of the supply chain. To get back to a stable production level companies have to make up for the lost production through higher capacity utilization measures, hiring of employees and sub-contracting.

Stage 8. Long-term impact:

In most of cases, it takes time to return to normal operating conditions. However, if some permanent damage has already happened like loss of customers or major suppliers, it will have a long-lasting impact on the supply chain's performance and will be difficult to return to the original level of performance (Hendricks & Singhal, 2003, 2005)^{144,145}. One issue with this step in the Sheffi (2005) disruption profile is that it assumes the disrupted firm attempts to return to its original steady state level of performance. It does not for instance, capture the situation in which a firm may adapt and redesign its supply chain in such a way to lead to superior performance by using the disruption as an opportunity to develop new products, new services, or serve new customers ("bounce forward").

¹⁴⁴ Hendricks, K.B. and Singhal, V.R., 2003. The effect of supply chain glitches on shareholder wealth. *Journal of Operations Management*, 21(5), pp.501-522.

¹⁴⁵ Hendricks, K.B. and Singhal, V.R., 2005. An empirical analysis of the effect of supply chain disruptions on long-run stock price performance and equity risk of the firm. *Production and Operations management*, 14(1), pp.35-52.

Appendix 3.1.3: Risk mitigation strategies for supply chains

Depending on the type of risks being faced, firms can adopt several risk management strategies. The risk management strategies can be broadly classified into mitigation strategies and contingency strategies. Mitigation strategies are those measures taken before the disruption happens aimed at either to completely avoid the disruption or to reduce the impact of disruption. On the other hand, contingency strategies are those actions which will be taken by a firm in the event of a disruption. Tomlin (2006) classified supply side risk management strategies into three groups: Inventory (stocking strategies against disruption), sourcing (dual or multiple sourcing) and passive acceptance¹⁴⁶. Passive acceptance is considered the default strategy when the cost of contingency and mitigation strategies exceeds the potential loss due to the disruption. On the customer side, demand management is a key disruption management strategy, whereby a firm can shift the demand for a product to a substitutable one when customers desired product is not available due to disruption. According to Tomlin (2009), supplier diversification, contingency sourcing and demand management are the building blocks of a firm's disruption management approach and firms can adopt a combination of these strategies¹⁴⁷. In a study on a perishable product, Tomlin (2009) suggested that buffer inventory might not be a possible option all the time because of the perishability issue. In this situation, supplier diversification is a possible mitigation strategy. However, this widely adopted mitigation strategy may not be attractive in all contexts when firms try to meet other objectives such as quality of supply, rather than optimising based on cost or profit.

From a supply chain point of view, Tang (2006) proposed four basic approaches to manage supply chain risks, which includes supply management, demand management, product management and information management. Supply management aims to ensure sufficient flow material through coordination or collaboration with upstream members. This can be achieved through supply network design, order allocation and contracts. In the same manner, demand management involves influencing the downstream members to change the demand in a way beneficial to the operating conditions of the supply chain. Some of the demand management strategies involve product pricing, shifting demand across time and market. Product management involves modification of process or product to meet supply and demand, which can be achieved through postponement and process sequencing. Through information management supply chain partners can improve coordination and collaboration through sharing private information available to individual supply chain members.

¹⁴⁶ Tomlin, B., 2006. On the Value of Mitigation and Contingency Strategies for Managing Supply Chain Disruption Risks. *Manag. Sci.* 52, 639–657. <https://doi.org/10.1287/mnsc.1060.0515>

¹⁴⁷ Tomlin, B., 2009. Disruption-management strategies for short life-cycle products. *Nav. Res. Logist.* 56, 318–347. <https://doi.org/10.1002/nav.20344>

Supply chain visibility improvement and vendor managed inventory are some of the information management strategies.

According to Lee (2004), agility, adaptability and alignment are the basic building blocks to managing supply chain risks (“Triple A” Supply Chains)¹⁴⁸. Agility implies quick responsiveness to supply or demand, whereas adaptability means the ability to change supply chain design according to market changes. Risk mitigation capability can be improved if the interests of the supply chain partners are aligned, which can be achieved through providing incentives for partners to work toward overall supply chain objectives. Building on this “Triple A” approach, Tang and Tomlin (2008) investigated the importance of flexibility in improving supply chain risk mitigation efforts. They classified the risk management strategies into two categories: i) strategies to reduce the risks associated with supply, process, and demand; ii) strategies to reduce the negative impact of supply, process and demand risks. The strategies in the first category include risk avoidance mechanisms and measures to reduce the likelihood of risky events through approaches like TQM (Total Quality Management). According to Tang and Tomlin (2008), the magnitude of the impact of risky event can be reduced through increasing the flexibility in supply, production and demand processes. The flexibility in supply can be obtained through multiple supplier which helps to switch order quantities across various suppliers. Similarly, flexibility in production process can be increased through flexible manufacturing processes making it possible to shift the production activities across various resources such as plants or machines. Demand risks can be managed through either flexible pricing strategies to switch demand across various products, or through flexible products by employing delayed customization or postponement.

As far as agribusiness supply chains are concerned, conventionally the principle response to risk is diversification, which is usually achieved by adding new resources or expanding the location of resources (Backus *et al.*, 1997)¹⁴⁹. Diversification can also be attained through adopting multiple suppliers, which is a widely addressed diversification strategy found in the related literature. The diversification or dual sourcing strategy has a long history of adoption in supply chain risk management situations and the same is true in the case of agri-food supply chains (Boyabatli *et al.*, 2011)¹⁵⁰. However, it is recommended to not only diversify across suppliers, but also to diversify by geographical region to avoid the situation where a risk could disrupt several suppliers and thereby eliminate any benefit of supplier diversification.

¹⁴⁸ Lee, H.L., 2004. The triple-A supply chain. *Harv. Bus. Rev.* 82, 102–113.

¹⁴⁹ Backus, G., Eidman, V., Dijkhuizen, A., 1997. Farm decision making under risk and uncertainty. *NJAS Wagening. J. Life Sci.* 45, 307–328

¹⁵⁰ Boyabatli, O., Kleindorfer, P.R. and Koontz, S.R., 2011. Integrating long-term and short-term contracting in beef supply chains. *Management Science*, 57(10), pp.1771-1787.

Regarding resilient strategies, Behzadi et al., (2018)¹⁵¹, in an extensive review of quantitative methods for agribusiness supply chain risk management, suggested that compared to robust strategies, resilient strategies are far less studied in the literature. Here, robustness represents an ability to withstand a disruption with a reasonable degree of loss, whereas resilience indicates a system's ability to recover quickly from a disruption. Behzadi et al., (2018) describe the resilient strategies considered so far in the literature as being fairly basic and the key characteristics such as agility and recovery capabilities are not considered.

Appendix 3.2: Supply Chain resilience

The introduction of the concept resilience in the scientific discipline can be traced back to the work of the ecologist C.S. Holling, who characterized the nature of a resilient ecological system in 1974 (Melnyk et al., 2014)¹⁵². Ever since, the notion of resilience has found its application in various disciplines such as engineering, social science, psychology, system thinking, etc., and recently, in supply chain management. In addition, a recent call for papers to a special issue of the Journal of Business Logistics "Participating in the Wider Debate on Resilience", guest editors Wieland and Durach (2018) state that "it is not quite clear yet what resilience means, beyond the simple assumption that it is good to be resilient"¹⁵³. They summarise the long running debate (since 1970's) on the meaning of resilience as both having an engineering perspective (i.e. ability of a system to bounce back to its original state following some type of disturbance), while the ecological perspective regards resilience as an ability to "bounce forward" (i.e. ability to persist/adapt/transform). They also suggest that the literature on resilience in supply chain management has been disconnected from this debate on what resilience is; rather than an equilibrium-focused meaning of resilience, it needs to consider an alternative called evolutionary or socio-ecological resilience. Behzadi, O'Sullivan & Olsen (2020) also state that the concept of resilience has not been fully examined in the literature to date on quantitative aspects of supply chain risk management¹⁵⁴.

The first extensive study on resilience in supply chain management was carried out in the United Kingdom after the transportation disruptions which occurred due to fuel protests in 2001 and the outbreak of Foot and Mouth disease in early 2001. This study emphasized the need to understand the

¹⁵¹ Behzadi, G., O'Sullivan, M.J., Olsen, T.L., Zhang, A., 2018. Agribusiness supply chain risk management: A review of quantitative decision models. *Omega* 79, 21–42. <https://doi.org/10.1016/j.omega.2017.07.005>

¹⁵² Melnyk, S.A., Closs, D.J., Griffis, S.E., Zobel, C.W., Macdonald, J.R., 2014. Understanding supply chain resilience. *Supply Chain Manag. Rev.* 18, 34–41.

¹⁵³ Wieland, A. & Durach, C.F. (2018) Participating in the Wider Debate on Resilience, *Journal of Business Logistics Call for Papers: Special Topic Forum*.

¹⁵⁴ Behzadi, G., O'Sullivan, M.J., Olsen, T.L., (2020) On Metrics for Supply Chain Resilience, *European Journal of Operational Research* (in press), doi: <https://doi.org/10.1016/j.ejor.2020.04.040>

vulnerabilities existing within the supply chain and also underlined the need to understand the subject appropriately (Cranfield University, 2003). Parallel to these studies, researchers at MIT conducted a case study-based approach to study supply chain resilience with a focus on characterizing the vulnerabilities and managerial decisions with respect to flexibility, redundancy, collaboration and security (Sheffi, 2005).

Resilience refers to a system's ability to survive, adapt and grow in the phase of turbulent change. Complex systems such as companies, social systems and ecosystems have known to possess resilience capabilities. Systems are said to evolve through phases of progress, accumulation, crisis and renewal, and even rearrange themselves to reach a more stable and desirable state. Business systems face technological change, regulatory pressure, demand volatility, financial loss and political turmoil, and therefore, industrial growth often happens effortlessly.

The concept of supply chain resilience emerged as a proactive risk management approach, and it significantly differs from the traditional risk management practice. Risk analysis techniques combined with financial models played a significant role in corporate decision-making process (Hertz and Thomas, 1983)¹⁵⁵. In general, risk management involves evaluating all feasible outcomes of a project or a process and assessing potential gains against the likely risk of investment (Carter, 1972)¹⁵⁶. In many situations, the risk is quantified based on historical data and the evaluation of the risk relies on subjective information. For example, in the mid-1990s, the integrated risk management framework called Enterprise Risk Management (ERM) was widely recognized and adopted by large firms. It has been successful by indicating to management how to take a portfolio of risk management strategies after providing detailed information on risks associated with each business activity. Similarly, another risk management tool known as business continuity management (BCM) helped to incorporate crisis management approaches and disaster planning decisions into risk management (Fiksel et al., 2015)¹⁵⁷.

One of the critical steps involved in the conventional risk management process is the risk assessment, which is determining the probability of the occurrence of the risky event and estimation of the impact of the event if it occurs. Therefore, the major deficiency in this approach lies in its inability to capture the low-probability high-impact event such as terrorist attacks, the outbreak of pandemic and natural disasters.

Many believe that building resilience capability into the system can complement the traditional risk management process (Fiksel et al., 2015). The concept of resilience assumes a significant role in

¹⁵⁵ Hertz, D.B., Thomas, H., 1983. Risk analysis and its applications.

¹⁵⁶ Carter, E.E., 1972. What are the risks in risk analysis? Harv. Bus. Rev. HBR, Harvard business review : HBR. - Boston, Mass. : Harvard Business School Publ. Corp., ISSN 0017-8012, ZDB-ID 2382-6. - Vol. 50.1972, 4, p. 72-82 50.

¹⁵⁷ Fiksel, J., Polyviou, M., Croxton, K.L., Pettit, T.J., 2015. From Risk to Resilience: Learning to Deal with Disruption. MIT Sloan Manag. Rev. Camb. 56, 79-86.

current supply chain management thinking (Melnyk et al., 2014). A resilient system does not fail in the face of disruption; rather it learns to adapt and exploit opportunities available during crises. Therefore, supply chain resilience aims to go beyond disruption mitigation and try to achieve a competitive advantage by understanding how to deal with disruption better than its competitors and if possible, move to a new state of stability or normalcy.

Appendix 3.2.1: Definition of resilience

Since resilience is a multi-disciplinary concept, several definitions of this phenomenon are available in diverse fields of scientific literature. However, as this report focuses on the study the food systems from a value chain perspective, we review the related literature for the definition of resilience. Table A3.2 provides a summary of the definitions found literature in the context of supply chain management. These definitions consider various aspects of a resilient system such as adaptive capability, responsiveness, recovery, anticipation, proactive planning and control over the system structure.

Table A3.2: Summary of Supply Chain Resilience Definitions

Reference	Definition
Fiksel (2006); Pettit et al. (2010)	“the capacity for an enterprise to survive, adapt, and grow in
Christopher and Peck (2004)	“The ability of a system to return to its original state or move to
Priya Datta et al. (2007) ¹⁵⁸	
Melnyk et al. (2014)	“The ability of a supply chain to both resist disruptions and
Jüttner and Maklan (2011)	“The apparent ability of some supply chains to recover from
Fiksel et al. (2015)	“the capacity of an enterprise to survive, adapt and grow in the
Roberta Pereira et al. (2014) ¹⁵⁹	“The capability of supply chains to respond quickly to unexpected events so as to restore operations to the previous performance level or even to a new and better one”
Tendall et al (2015) ¹⁶⁰	“Capacity over time of a food system and its units at multiple levels to provide sufficient, appropriate and accessible food to all, in the face of various and even unforeseen disturbances”

Resilience can be assessed at an individual node in the food value chain or at an aggregate level (e.g., while there may be a disruption at one node, there may be minimal impact on the overall value chain ability to deliver sufficient food, whereas a different node encountering a disruption could have a major impact on the ability of the entire value chain to provide food). The concept of robustness is also introduced: the magnitude of a disturbance that can be withstood by a food value chain, without¹⁶¹any impact on the operational performance metrics (Meuwissen et al, 2019). Resilience must also prevent conflicting objectives, i.e. enhancing resilience cannot lead to an undesirable outcome elsewhere (e.g. have a negative impact on sustainability).

¹⁵⁸ Priya Datta, P., Christopher, M., Allen, P., 2007. Agent-based modelling of complex production/distribution systems to improve resilience. *Int. J. Logist. Res. Appl.* 10, 187–203. <https://doi.org/10.1080/13675560701467144>

¹⁵⁹ Roberta Pereira, C., Christopher, M., Lago Da Silva, A., 2014. Achieving supply chain resilience: the role of procurement. *Supply Chain Manag. Int. J.* 19, 626–642. <https://doi.org/10.1108/SCM-09-2013-0346>

¹⁶⁰ Tendall, D.M., Joerin, J., Kopainsky, B., Edwards, P., Shreck, A., Le, Q.B., Krütli, P., Grant, M. and Six, J., 2015. Food system resilience: defining the concept. *Global Food Security*, 6, pp.17-23. <https://doi.org/10.1016/j.gfs.2015.08.001>

¹⁶¹ Meuwissen, M.P., Feindt, P.H., Spiegel, A., Termeer, C.J., Mathijs, E., de Mey, Y., Finger, R., Balmann, A., Wauters, E., Urquhart, J. and Vigani, M., 2019. A framework to assess the resilience of farming systems. *Agricultural Systems*, 176, p.102656.

Appendix 3.2.2: Strategies for developing resilient supply chains

In addition to the supply chain vulnerability factors (Table A3.1), Pettit et al (2013) developed a corresponding set of capability factors, which can be used to assess the current level of resilience of a supply chain and to identify if there are gaps between vulnerabilities and capabilities required. These capabilities are outlined in Table A3.3.

Table A3.3: Supply chain capability factors

Capability factor	Definition	Subfactors
Flexibility in Sourcing	Ability to quickly change inputs or the mode of receiving inputs	Part commonality, Modular product design, Multiple uses, Supplier contract flexibility, Multiple sources
Flexibility in Order Fulfillment	Ability to quickly change outputs or the mode of delivering outputs	Alternate distribution channels, Risk pooling/sharing, Multisourcing, Delayed commitment/Production postponement, Inventory management, Rerouting of requirements
Capacity	Availability of assets to enable sustained production levels	Reserve capacity, Redundancy, Backup energy sources and communications
Efficiency	Capability to produce outputs with minimum resource requirements	Waste elimination, Labor productivity, Asset utilization, Product variability reduction, Failure prevention
Visibility	Knowledge of the status of operating assets and the environment	Business intelligence gathering, Information technology, Product, equipment and people visibility, Information exchange
Adaptability	Ability to modify operations in response to challenges or opportunities	Fast rerouting of requirements, Lead time reduction, Strategic gaming and simulation, Seizing advantage from disruptions, Alternative technology development, Learning from experience
Anticipation	Ability to discern potential future events or situations	Monitoring early warning signals, Forecasting, Deviation and near-miss analysis, Risk management, Business continuity/preparedness planning, Recognition of opportunities
Recovery	Ability to return to normal operational state rapidly	Crisis management, Resource mobilization, Communications strategy, Consequence mitigation
Dispersion	Broad distribution or decentralization of assets	Distributed decision making, Distributed capacity and assets, Decentralization of key resources, Location-specific empowerment, Dispersion of markets
Collaboration	Ability to work effectively with other entities for mutual benefit	Collaborative forecasting, Customer management, Communications, Postponement of orders, Product life cycle management, Risk sharing with partners
Organization	Human resource structures, policies, skills, and culture	Accountability, Creative problem solving, Cross-training, Substitute leadership/empowerment, Learning/benchmarking, Culture of caring
Market Position	Status of a company or its products in specific markets	Product differentiation, Customer loyalty/retention, Market share, Brand equity, Customer relationships, Customer communications
Security	Defense against deliberate intrusion or attack	Layered defenses, Access restrictions, Employee involvement, Collaboration with governments, Cyber-security, Personnel security
Financial Strength	Capacity to absorb fluctuations in cash flow	Insurance, Portfolio diversification, Financial reserves and liquidity, Price margin

The interview protocol for collection of primary data from food sector representatives on the Iol was developed using the Supply Chain Vulnerability Factors (Table A3.1), Supply Chain Capability Factors (Table A3.3) and the Supply Chain Disruption Profile (Figure A3.3). This process is outlined in the next section (Methodology).

safefood

7 Eastgate Avenue, Eastgate, Little Island, Co.Cork, T45 RX01

7 Ascall an Gheata Thoir, An tOiléan Beag, Co. Chorcaí, TT45 RX01

7 Aistyett Avenue, Aistyett, Wee Isle, Co. Cork, T45 RX01

Tel +353 (0)21 230 4100

Fax +353 (0)21 230 4111

Email: info@safefood.net

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 [@safefood_net](https://twitter.com/safefood_net)

 **Helpline**
ROI 1850 404 567 NI 0800 085 1683