Food Systems Dynamics

Research Findings Brief
September 2021

H2020 VALUMICS Project
Framework for risk and resilience in food value chains

Objectives

Development of a framework for risk and resilience in food value chains.

Using an agent-based hybrid simulation approach, analyse the resilience of food supply chains in the face of unforeseen disruptions.

In this work, we consider the case of the Norwegian Atlantic salmon aquaculture supply chain.

Industry stakeholders

Based on case study interviews with representatives from a range of actors in the salmon supply chain, indications are that the Norwegian salmon supply chain is susceptible to upstream (supply side) risks and disruptions.

Introduction

The focus of VALUMICS project task 4.6 was to develop a framework for risk and resilience in food value chains, thereby enabling value chain actors to analyse these risks and to develop appropriate strategies to increase resilience.

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 industrialisation of the agri-food sector has changed perspectives of farming from an idyllic rural life-style to a highly competitive agribusiness sector with a supply chain mindset. Owing to these inherent characteristics of agri-food supply chains, the decision making environment is highly uncertain. On the upstream side, an agri-food supply chain is faced with uncertainty caused by weather, varying input costs, raw material availability etc. On the other hand, the downstream side of an agri-food supply chain is confronted with demand volatility and is highly sensitive to price fluctuations. Therefore, incorporating these and other uncertainties is critical for managerial decision-making in agri-business supply chain planning at operational, tactical, and strategic levels.

The globalization of operations and growing interconnectedness among nodes in agri-food supply chains have led to high levels of inter-dependency and increased complexity. Supply chains that have generated high levels of efficiency through lean operations during stable business conditions become vulnerable to disruption risks. Evolving customer preferences in relation to food consumption and sustainability present additional risks and opportunities for food value chain actors, as well as an area of focus for policy makers interested in the resilience of food systems.

Concept of resilience

Conventional risk management tools, which depend heavily on historical data, become ineffective when disruptions are unanticipated. Systems that face predictable risks can adapt and increase resilience though mitigation. Since resilience is a multi-disciplinary concept, several definitions of this phenomenon are available in diverse fields of scientific literature. However, for the purpose of the VALUMICS project, we use the definition of resilience developed considering food supply chain systems by Tendall et al (2015):[1]

"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''

Where:

- "Sufficient" means quantity and nutritional quality.
- "Appropriate" incorporates cultural, technical and nutritional aspects.
- "Accessible" means physically and economically available.

[1] 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.

Supply side risks

Examples cited by food value chain actors are e.g., contamination in feed, or the impact of a ban by the European Food Safety Authority (EFSA) on feed imports from South America to Europe.

Disruptions are often thought of as those solely arising from suppliers or production problems, whether caused by natural disasters, quality defects, financial or other reasons. However, as indicated in the salmon case, the most recent serious disruption experienced was due to a policy change by EFSA which had implications on the availability and price of feed material.

Methodology

While the autonomous and interacting nature of the various supply chain actors such as suppliers, producers and customers are modeled using the agent-based approach, the processes within each member are captured using discrete-event simulation.

- "Various and even unforeseen disturbances" means unexpected shocks (external or internal) which can occur within the food value chain (e.g. contamination, supplier bankruptcy, natural disaster, sabotage) and slower ongoing change (e.g. changes in policy, consumer tastes etc). The nature of disturbances in food value chains can be internal or external, cyclical or structural, sudden or gradual; they can consist of natural, political, social, or economic shocks.

Agent-Oriented Simulation Framework

The development of the simulation framework in this task follows a multi-method approach. Multi-method refers to an approach that combines two or more mainstream simulation methods, and has seen increased adoption recently as a way to model complex supply chain systems. The issue examined in this task has multiple elements, therefore the use of the multi-method approach makes it possible to capture all of them in a single framework. The overall modelling framework is outlined in Figure 1.

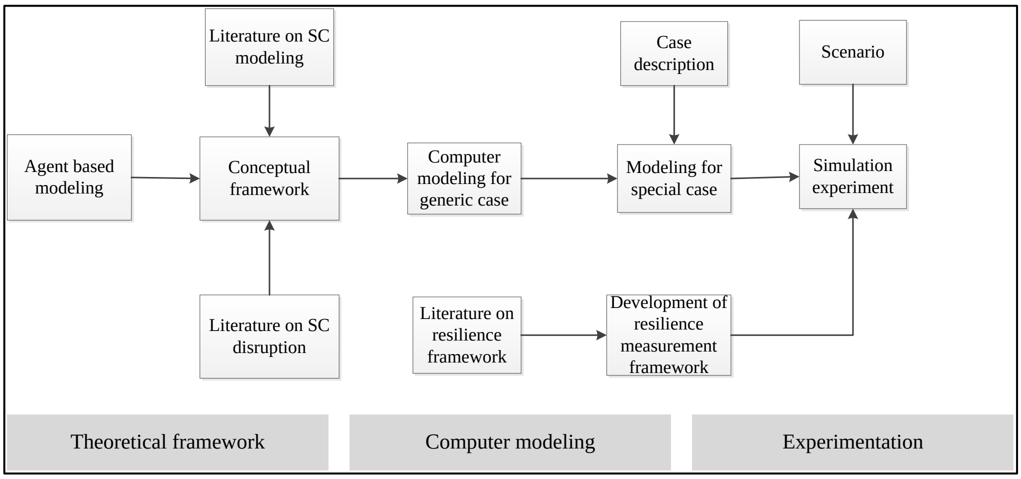

Figure 1. The overall modeling framework

With specific focus on the Norwegian salmon supply chain, the interaction between various actors such as feed suppliers and producers is modelled using an agent-based framework (ABM). Meanwhile, the various processes occuring within each supply chain member is modelled using a discrete event simulation (DES) approach. This hybrid simulation approach (Figure 2) enables insights to be obtained into the behaviour of the complex system.

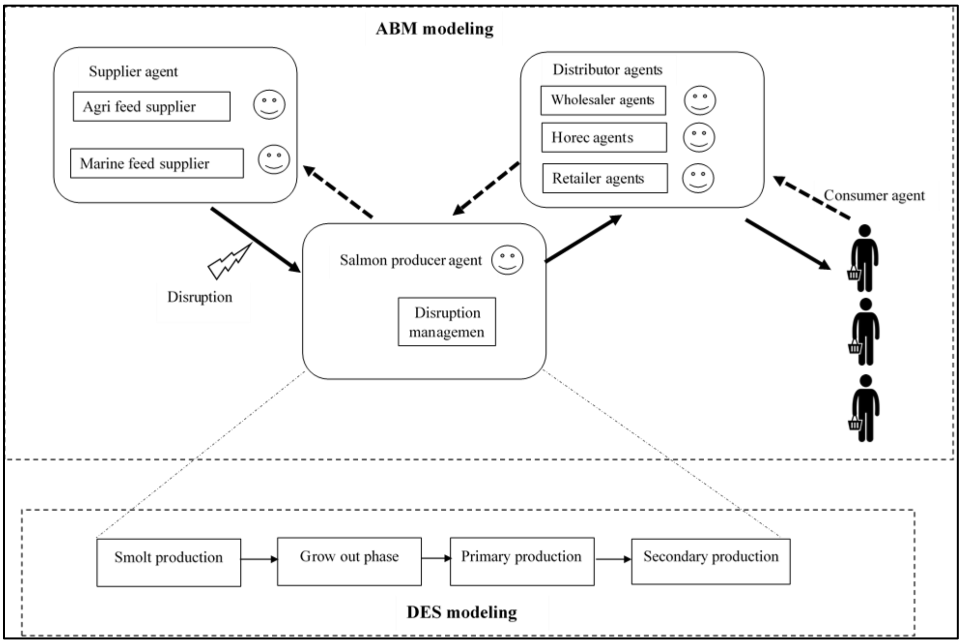

Figure 2. The hybrid simulation model of salmon supply chain

Resilience modelling

Agent Based Modelling is a powerful way to model the preferences and actions of heterogeneous members of a supply chain via autonomous agents, combined with the ability of DES (Discrete Event Simulation) to model the queueing behavior of internal production processes.

The resilience of a supply chain to a series of disruptions can be assessed and the impact of a range of approaches to increase resilience can be evaluated.

Impact of supply disruption captured

Through an agent-based modelling approach, a virtual representation of a real-world scenario was developed, capturing the impact of a disruption in a complex food supply chain system that emerges due to interventions by decision makers in the chain.

Findings

The base-line performance of the supply chain under normal operations was established. The impact of a supply disruption, such as the EU ban on ethoxyquin in fish meal was assessed (Figure 3). Further experimental scenarios were developed to assess the impact of a range of proactive and reactive actions to deal with such a disruption. These included increasing the length of time from announcement to implementation of the ban on ethoxyquin in feed, increased safety stocks of feed at the salmon producer, reducing the proportion of feed sourced from outside Europe prior to the ban.

Figure 3. Simulation Results

Conclusion

The results of this task illustrate the use of simulation modelling to increase the understanding of food system interactions. This enables both supply chain personnel within the system and food system regulators to assess the impact of policy-led interventions and other types of disruptions on the whole chain. The research also highlights the vulnerabilities in the chain as well as the approaches to increase the overall resilience of the chain.

Key sources for further information

To discuss the research presented in this brief, please email Vincent Hargaden (vincent.hargaden@ucd.ie)

Thomas Vempiliyath, Vincent Hargaden (2020). Risk & Resilience in Food Value Chains. VALUMICS project "Understanding Food Value Chains and Network Dynamics" funded by European Union's Horizon 2020 research and innovation programme GA No 727243. Deliverable D4.6, University College Dublin, Ireland, 48 pages.

Publications

[1] Vempiliyath, T.; Thakur, M.; Hargaden, V. 2021. Development of a Hybrid Simulation Framework for the Production Planning Process in the Atlantic Salmon Supply Chain. Agriculture, 11, 907. https://doi.org/10.3390/agriculture11100907

[2] Vempiliyath, T., Hargaden, V. and Thakur, M. 2020. Hybrid Simulation to Analyse the Resilience of Food Supply Chains. Proceedings of the 2020vIISE Annual Conference. L. Cromarty, R. Shirwaiker, P. Wang (eds). pp. 748-753.

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