A system dynamics model for managing corruption risks in dairy supply chains

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Abstract
We identify corruption risks in the dairy supply chain to be a research gap. We explore how corruption modifies supply chain risk factors and performance in the dairy sector, and find mitigation strategies to safeguard dairy supply chains against risk due to corruption. In this paper, we critically review literature on dairy supply chain risks and corruption risks in the supply chain. Then we propose research methodology, modelling ideas and preliminary system dynamic models to lay the foundation for further studies.

Keywords: Dairy supply chain risks, corruption, causal loop diagram, stock flow diagram, risk management

1 Introduction

Various risks exist among the different links in a supply chain. To mitigate risks, companies should integrate internal functions and connect them with suppliers, channel members and end customers (Giunipero and Eltantawy, 2004).

The competitive market for dairy products requires companies to optimise profits from the stages of production and sales (Guan and Philpott, 2011). The global dairy market is presently weak with milk oversupply, driving international milk prices down (Hunt and Tajitsu, 2015). Although there is some recovery in the prices, it will be hindered because of excess stocks. A stronger momentum in the industry may not be expected until the second quarter of the year 2016 (Rabobank, 2015).

Quality problem of dairy products can threaten consumer health. Constant good quality contributes to brand reputation. Therefore quality and safety issues are significant for the dairy supply chain. The dairy quality risk can bring disastrous loss and affect the whole supply chain. For example, the 2008 adulterated milk scandal in China not only seriously impacted relevant companies, but also lead to health problems (even life problems) for many young children.

Various risks including corruption can be found in the dairy supply chain. In this research, we will review this supply chain and its risks. Research methodology will be introduced. We aim to analyse how corruption modifies dairy supply chain risk factors and performance. As a first step, we propose our modelling ideas for further studies. There are three objectives in this research paper:

1. Identifying dairy supply chain risk factors and risk impact.
2. Understanding how corruption modifies dairy supply chain performance through modifying supply chain risk factors.
3. Constructing the preliminary system dynamics model to lay the foundation for the final model.

This paper is organised in five sections. Section 2 presents current research on dairy supply chain risks and corruption in this industry; the research gap has been mentioned

in the summary. Section 3 introduces the methodology used in this research. The following section describes the problem to be studied and formulates preliminary system dynamics models. The last section concludes this paper by summarising the major points and proposing further research.

2 Literature review

2.1 Dairy supply chain

Supply chain is a network of connected and interdependent organisations working together, mutually and cooperatively, to control, manage and improve the flow of material and information from suppliers to end users (Aitken, 1998). In the agri-food supply chain, activities exist among entities including suppliers, producers, processors, exporters and buyers. (Gereffi and Lee, 2009) depict some agri-food value chains containing dairy products. Enlightened by (Gereffi and Lee, 2009), (Junqueira, 2010) adapts their value chain structures and proposes a basic agri-food value chain (see Figure 1).

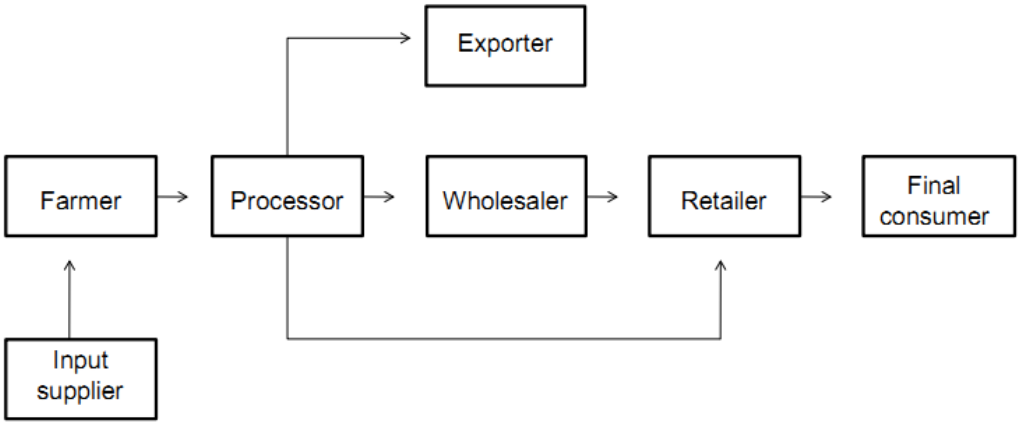


Figure 1 Basic agri-food value chain (Junqueira, 2010)

(Douphrate *et al.*, 2013) identify the distinctive features of dairy production, including liquid state of milk (high-cost transportation, perishability, subject to adulteration), dairy producers' socioeconomic position, cooperatives' strong position and dairy cattle's converter function. Understanding the dairy supply chain is needed before analysing its risks.

(Junqueira, 2010) proposes a dairy value chain structure consisting of four stages which are input suppliers, milk production, processing and marketing. Input suppliers represent supplies to farmers including feed, veterinary services, etc. Milk production means the operators who produce milk, and this includes dairy farmers, corporate farmers and smallholders. Processing refers to companies which process the delivered milk. The forms of companies are co-operatives, multinational/national companies and small dairy companies. Marketing expresses the way dairy products are sold, including export, supermarkets, small retailers, etc. This value chain structure illustrates the conversion process through these links and the entities involved.

According to (Schlecht and Spiller, 2009), vertical coordination refers to how the relationships between producers and processors are formed. For food supply chains, vertical coordination is among the most controversial topics. (Dries *et al.*, 2009) analyse the modern dairy supply chains' transition and globalisation. Foreign investment emerges in the dairy products' process and retail stage. Supply chain restructuring uses vertical coordination between the farmer level and processor level, and provides more suitable

products than those under old structures. Different from previous studies, they collect much wider survey data by conducting cross-country analysis in Central and Eastern European countries. Vertical coordination is found important for small dairy farms because it can address major weaknesses and enhance the competitiveness of the whole supply chain. (Chen, Zhang, and Delaurentis, 2014) consider the vertical control issue in food supply chains. They employ exploratory case study research in the Chinese dairy industry, and find that China's adulterated milk incident in 2008 is due to the poor vertical control strategy. However, there are also scholars arguing that forming stronger vertical coordination is not very likely. (Schlecht and Spiller, 2009) suggest that agricultural producers, regardless of industry difference, prefer entrepreneurial freedom and independence. They mention another reason which is identified by (Spiller, 2009), that is, dairy farmers' high specific knowledge.

(Junqueira, 2010) admits that every section in the dairy supply chain is important, but the link between dairy farmers and milk processors is of critical importance.

2.2 Dairy supply chain risks

Risk is always connected with uncertainty and surprise. Risk is most commonly regarded as 'the variation in the distribution of possible outcomes, their likelihoods, and their subjective values' in classical decision theory (March and Shapira, 1987). (Mitchell, 1995) uses a formula to describe risk, combining probability with the importance of the loss. The formula is as follows:

$Risk_n = P(Loss_n) * I(Loss_n)$, ('n' refers to different events)

(Jüttner, Peck, and Christopher, 2003) consider supply chain risk as 'the possibility and effect of a mismatch between supply and demand' in a simple term in their research. (Jüttner, 2005) emphasises that supply chain risk exists not only in the boundaries of the firm itself, but also the boundary spanning flows.

Supply chain risk management is still at the developing stage, but various literature can be found describing risk sources and management strategies. Literature on supply chain risk management in the dairy sector is limited (Nasir, Quaddus, and Shamsuddoha, 2014). (Zubair and Mufti, 2015) suggest that risk identification and risk assessment in the dairy sector still need investigation.

The safety and risk issues of food products are attracting increasing concern. Because of the perishability of dairy products, (Pant, Prakash, and Farooquie, 2015) propose a framework to manage transparency and traceability in dairy supply chains. They aim to manage food quality and safety risks, and improve the effectiveness of dairy supply chain management as well. (Enderwick, 2009) analyses the melamine contamination in the Chinese dairy industry, and focuses on the effective management of quality risks in this industry. He asserts that effective governance structures and effective management of environmental conditions are key to minimise the quality risk. (Ma, Han, and Lai, 2013) also pay attention to dairy safety risk. They identify risk indicators of food safety in dairy supply chains, calculate the weights of different risk indicators, and assess the risk level of dairy safety.

There are various risks including quality and safety risks exist in the dairy supply chain. Table 1 lists many risk sources from literature. (Daud, Putro, and Basri, 2015) express that most risk sources are derived from the upstream of the milk supply chain, especially smallholder farmers. In this table, some of the risk sources are focused on the farm level.

Table 1 Dairy supply chain risks

Milk price variations, lack of hygienic conditions and meat price variability	(Akcaoz, Kizilay, and Ozcatalbas, 2009)
High risks (low milching cattle, illiteracy of the milk producers, etc.), medium risks (high cost of fodder and medicines, delivery risks, etc.) and low risks (seasonal fluctuations in production, process/control/quality risks, etc.)	(Mishra and Shekhar, 2011)
Demand side risk (forecast, demand fluctuation, etc.), supply side risk (quality risk, changes in technology/design, etc.), logistic side risk (storage, transportation issues, etc.), external risk (natural disasters, legal, economic downturn, etc.) and informational risks (improper planning, access to key information, distorted information, etc.)	(Zubair and Mufti, 2015)
Quality of the milking animal, feed availability, milk handling practices, milk bulking practices and milk transportation	(Daud *et al.*, 2015)
Production risks (notifiable/non-notifiable cattle diseases, drought, flood), market risks (milk spoilage, etc.) and enabling environment risks (abrupt regulation, human disease, etc.)	(The World Bank, 2011)
Financial risk, technological risk, human resource risk, absence of fixed government policy, political risk, mismanagement and unethical behaviour of employees, natural risk, hazard risk, input risk, poor infrastructural facilities and unethical behaviour of middlemen	(Nasir *et al.*, 2014)
Production risk, price risk, input risk, systematic risks and idiosyncratic risks	(Ramaswami, Ravi, and Chopra, 2004)
Production risk, institutional risk, animal disease, input/output market risk, milk contamination risk and personal risk	(Zhou, Nanseki, and Takeuchi, 2012)

(Mishra and Shekhar, 2011) study the impact of risks and uncertainties on the dairy supply chain in India. The dairy food supply chain (shown in Figure 2) is illustrated for one federation with 7 major stakeholders.

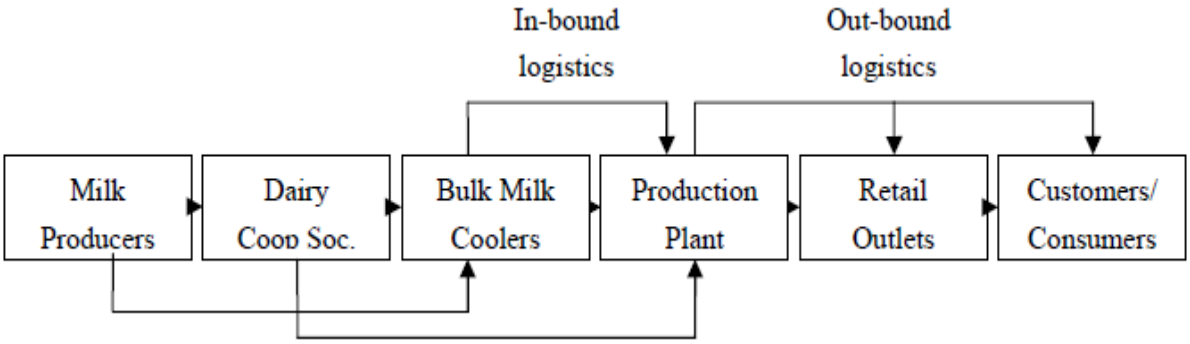


Figure 2 Dairy food supply chain (Mishra and Shekhar, 2011)

Various risks have been identified within different stages of this supply chain. As the supply chain is integrated, risks in one stage may impact other stages. (Mishra and Shekhar, 2011) detect fourteen risks within the supply chain, and analyse the probability, severity and impact of these risks. Based on the description of impact of risks on the supply chain, we obtain the causal loop diagram (see Figure 3). This does not show all

the relationships among variables in the dairy supply chain. The main objective of this diagram is to clearly present causes and effects based in part on their literal narratives. In this diagram, some relationships are with conditions. First, “Production – Production cost”, this negative relationship exists only when milk per day is less than 60 litres. Second, “Milk producers illiteracy – Production cost” and “Milk producers illiteracy – Produce quality”, these two relationships sometimes exist. Third, “Quality of milk – Brand switching”, the situation may happen that customers cannot survive with the federation and need to switch to competitors’ brand. Last, “Customer satisfaction – Market share”, this relationship may exist according to (Mishra and Shekhar, 2011).

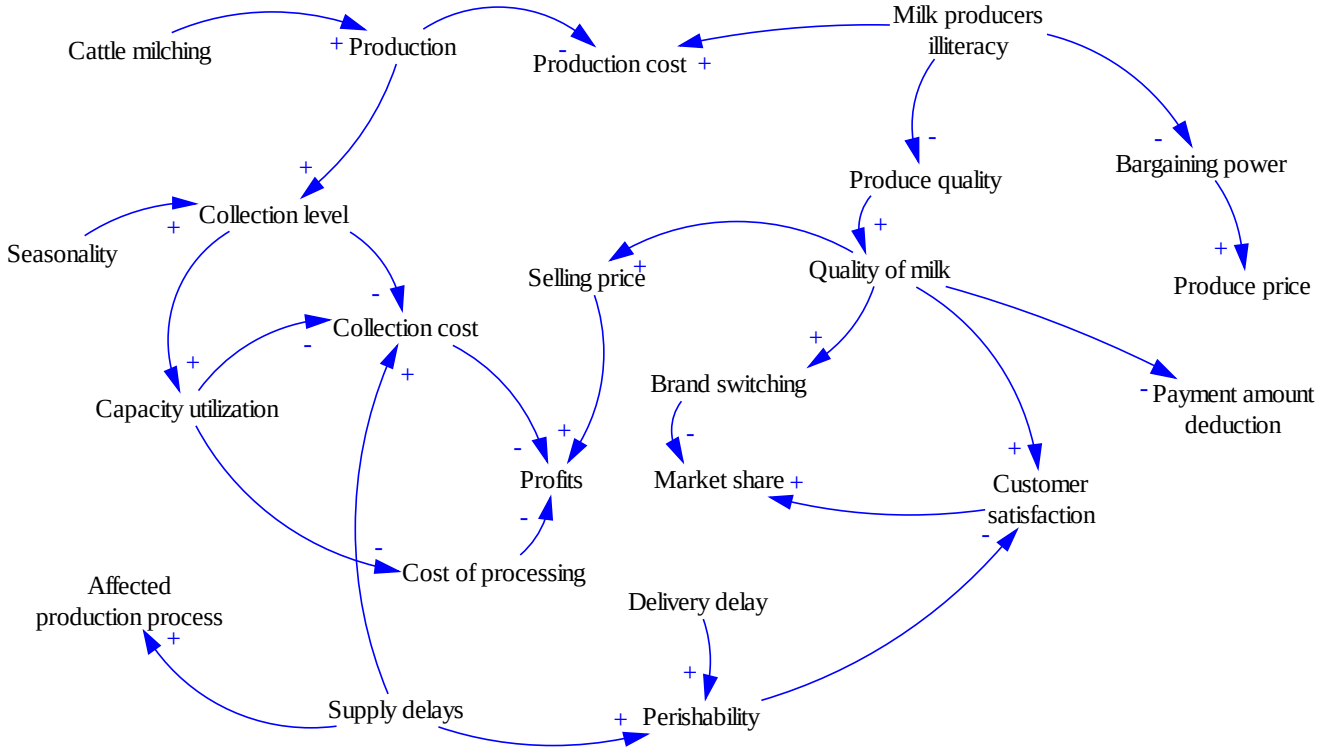


Figure 3 Supply chain risks in dairy industry

2.3 Corruption in the dairy supply chains

(Enderwick, 2009) suggests that widespread corruption is one of the causes of possible quality deterioration. He discusses the Chinese dairy industry case, and mentions that it is challenging for businesses based in the least corrupt economies (e.g., Fonterra from New Zealand) to operate in economies with extensive corruption. In China, it is regarded as quite common for milk collection agents to take the greatest opportunity to falsify raw milk. (Nasir *et al.*, 2014) identify corruption as a risk variable in the dairy industry. In their context, corruption refers to mixing water with milk. One interviewee mentions the link between limited income level of employees and corruption in their behaviour. When talking about the risk factor, “Government policy and support”, the interviewee describes the passive corruption in dealing with unfair situations and gaining easy loan.

2.4 Summary

In this section, a literature review has been conducted about the dairy supply chain structure and the risks and corruption in the supply chain.

As mentioned before, literature in dairy supply chain risk management is limited. We identify corruption risks in the supply chain to be a research gap. We intend to identify

supply chain risk factors and risks in the dairy sector, and then explore how corruption modifies those risk factors and dairy supply chain performance. This paper proposes a research methodology and illustrates our preliminary ideas for further research.

3 Methodology

Figure 4 is the framework for this research, which has been proposed in our previous study (Liu and Arthanari, 2014). This framework will be applied in the dairy supply chain context.

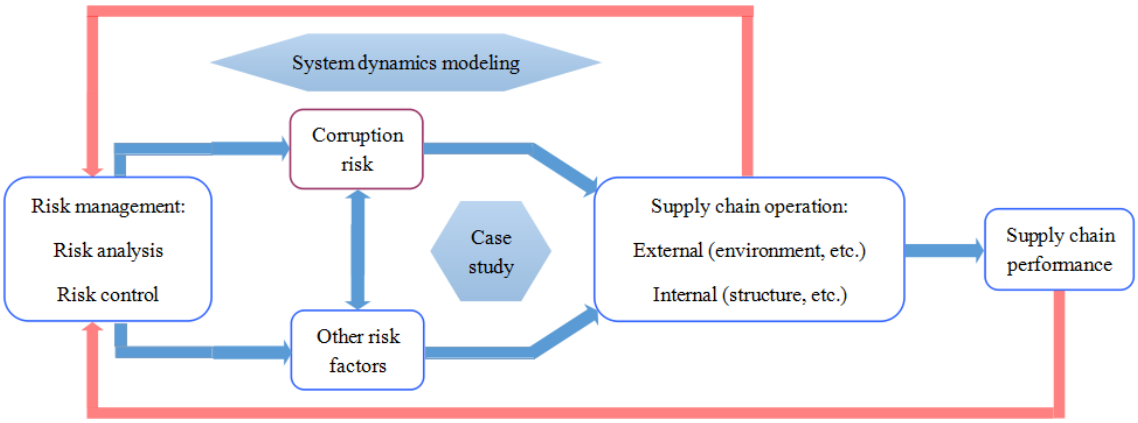


Figure 4 A conceptual framework of managing corruption risk in a supply chain (Liu and Arthanari, 2014)

We will employ two research methods, which are case study research and system dynamics modelling.

3.1 Case study research

(Myers, 2013) regards the purpose of case study research in business and management as 'to use empirical evidence from real people in real organizations to make an original contribution to knowledge'.

Case study research is suitable for our purposes for the following reasons. Firstly, it provides the opportunity to understand the phenomena in real situations. Investigators are able to explore cases in organisations and this enhances the validity of practice through empirical research. Secondly, intensive information will be gained from case study research. The unit of analysis can be studied comprehensively by using data collection methods such as semi-structured interviews. For our research, collected data can provide us with abundant information on supply chain corruption. Thirdly, case studies are more suitable for the stages of exploration, classification and hypothesis development during the knowledge building process, and the investigators need to hold a receptive attitude when exploring (Benbasat, Goldstein, and Mead, 1987). Various factors related to supply chain corruption remain unclear and require exploration for deep understanding. Finally, case study research is useful to answer the 'why' and 'how' questions which deal with operational links to be traced over time instead of with frequency or incidence (Benbasat *et al.*, 1987).

Therefore case study research is utilised to explore different risk factors and corruption risks in the dairy supply chain.

3.2 System dynamics modelling

The system dynamics method has been widely applied in different areas, such as engineering (Dukkipati, 2005; Wolstenholme, 1983), economics (Smith and van Ackere, 2002; Sterman *et al.*, 1983), energy (Bodger and May, 1992; Shin, Shin, and Lee, 2013), environment (Ford, 1999) and so forth. System dynamics was initially applied to supply chain management by (Forrester, 1958). (Angerhofer and Angelides, 2000) then gave a general discussion of system dynamics, and the corresponding application in the field of supply chain management. According to different purposes, they classify related research into three categories: building theories, solving problems and improving modelling approaches.

System dynamics modelling is a suitable approach in the following aspects. a) A good combination with case study research. These two methods can complement each other very well. Case study research contributes to identifying risk factors and corruption risks in the dairy supply chain. System dynamics modelling explores the underlying dynamic relationships among different factors. b) A closed boundary. A supply chain network is a complicated system, with various suppliers and customers. Complex interrelationships exist among entities of the real system. It would be challenging and be hard to take everything into consideration. (Lu, Byrne, and Maani, 2000) review literature on systems boundaries from the perspectives of different disciplines. As to boundaries in system dynamics, they mention the definition proposed by (Forrester, 1968) and his suggestion that a systems boundary should contain the least possible number of components, which are connected with a quantified causality. c) Decision making. We aim at finding measures to safeguard dairy supply chains against corruption risks. System dynamics models can be used because they judge the varying tendency through dynamic simulation, and then relevant decisions can be made (Yang, 2012). In addition, (Mula *et al.*, 2013) propose that system dynamics is most suitable to problems with continuous processes, where feedback information can largely influence system behaviour by generating dynamic changes.

4 Problem and model formulation

4.1 Problem description

This study focuses on the interaction of corruption and supply chain risks within the context of the dairy industry. Risks exist among the various links in the supply chain. As a global problem, corruption increasingly attracts the concern of people. Corruption could bring social, economic and other problems at various levels, and could impact either a person, a company or a country. We conduct interviews with department managers in New Zealand companies. Being in a quite transparent country, people's perception is expected to provide us insights for this research.

Figure 5 demonstrates the model structure, which mainly consists of two parts. The first part is the operations of the dairy supply chain, shown in orange lines. The process includes raw milk production, collection, delivery, processing, dairy products delivery and retail. Materials experience the transformation from raw materials (RM) to final products, and the transfer from supplier (S) to manufacturer (M), retailer (R) and finally customer. Customer demand is forecast for the order decision. The upstream order can be determined based on the downstream order and the inventory as well.

The second part is the description of risks in this dairy supply chain. The interrelationships of different variables are connected, shown in the solid blue lines. The dotted blue lines indicate the supply chain risks that may occur to the normal operation. The variables in this figure are only part of the whole model, and aim at indicating how the model is built

up. Corruption impacts the supply chain performance by modifying the supply chain risk factors. These modification will also be described in the model.

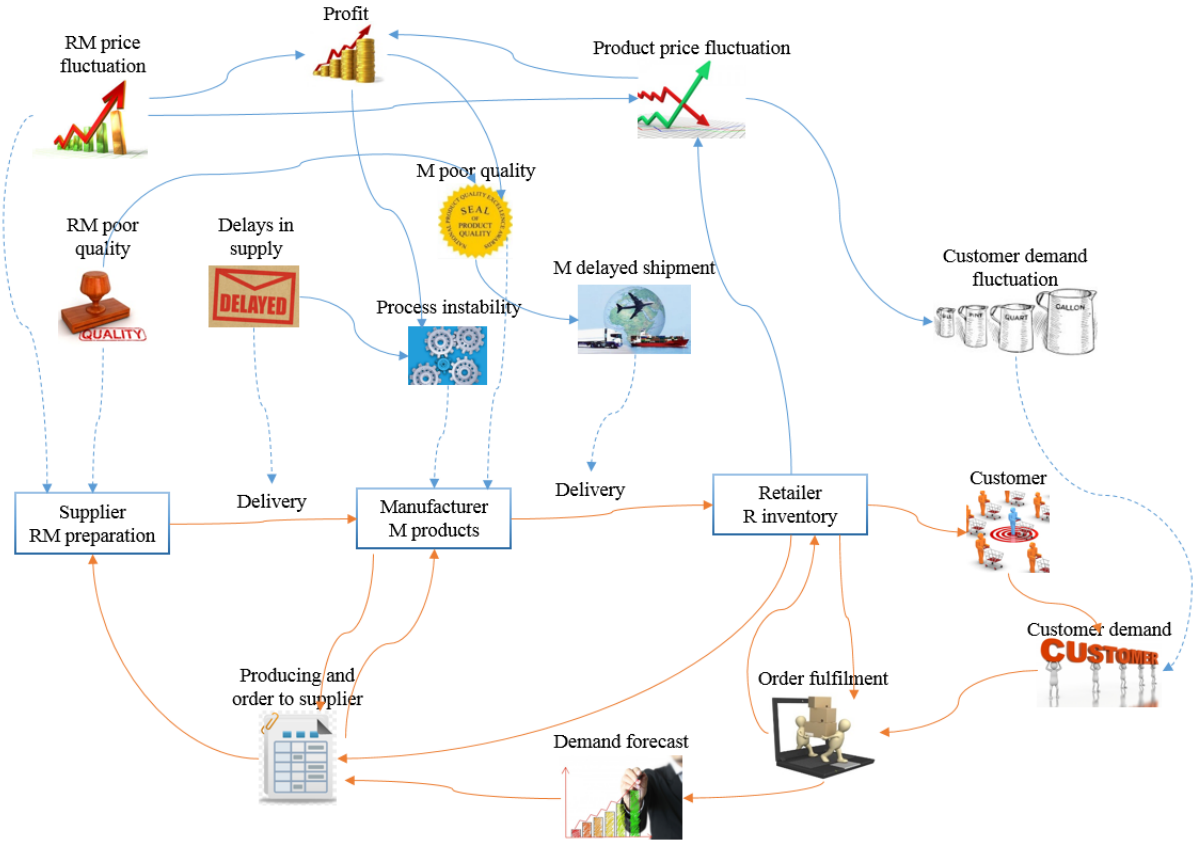


Figure 5 Model structure

4.2 Preliminary modelling ideas

Before constructing the system dynamics model, the basic ideas will be introduced (see Figure 6). Following the logical ideas, the system dynamics model can be built after data collection.

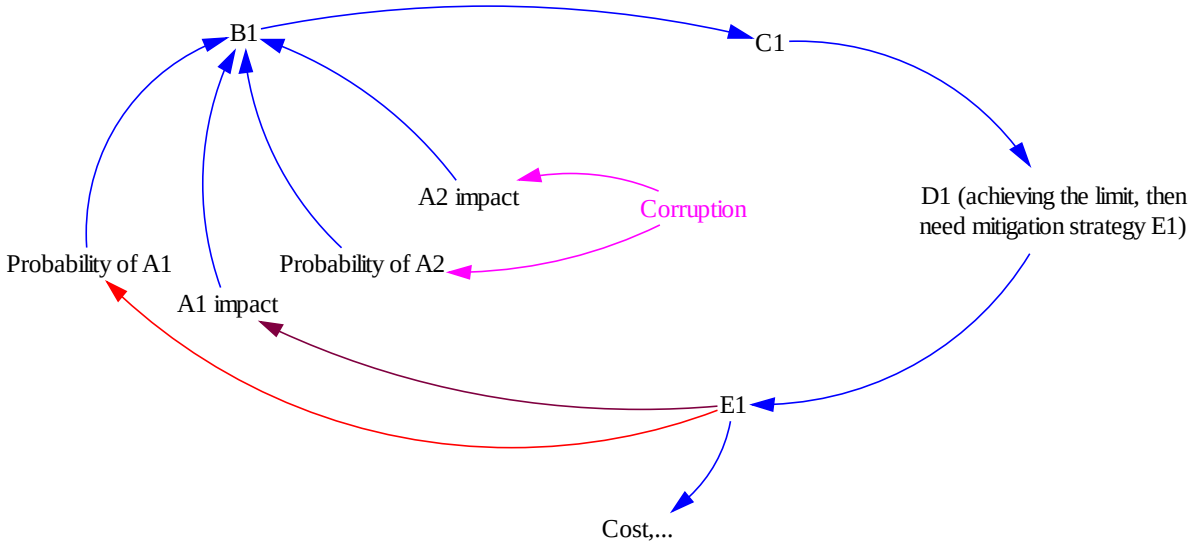


Figure 6 Basic Modelling ideas

A1, A2 --- Potential causes of risk events [e.g., lack of training]
B1 --- Risk events [e.g., human errors]
C1 --- Potential effects of risk events [e.g., damage to delivery]
D1 --- Supply chain performance [e.g., failure to meet the delivery lead time targets]
E1 --- Mitigation strategies (there are two possibilities: 1, minimise the occurrence probability (red) [e.g., strengthen the personnel training]; 2, minimise the impact (purple) [e.g., multiple delivery channels])

Risk factor is regarded as a basis to quantify the risk which is presented to any threat-asset pair (Pai *et al.*, 2003). The authors estimate a risk factor as the expected value of loss that happens to assets because of the threat; they propose calculating risk factor using:

Risk factor = Probability of occurrence of threat * Consequence * Value of Asset

However risk factor is meant to be a factor, instead of a number. For better clarity, we use the term risk factor impact:

Risk factor impact = Probability of occurrence of threat * Consequence * Value of Asset

In our research, this idea has been utilised. Each risk is a combination of risk factor, risk event and loss. For each risk factor, the expected value has been considered. The probability of occurrence, consequence (if the threat occurs, how much the value will change) and the original value of asset should be obtained respectively to calculate the expected value of loss.

In Figure 6, corruption has been highlighted as a modifier. Corruption can modify both the probability of occurrence of risk factor and the risk impact. As to the mitigation strategies, they may bring some side effects, such as raise the probability of occurrence of another risk and increase the cost. Therefore, a systematic model is needed and utilised for analysis.

4.3 Model construction

In this section, we will show the inner structure as to how corruption modifies supply chain risks, using both the causal loop diagram (Figure 7) and stock flow diagram (Figure 8). The variables and their relationships are based on the literature and interview data. The qualitative interview data reinforces the relationships among variables from literature or enlightens new links. The qualitative interview data contributes to the quantitative analysis in the stock flow diagram.

Figure 7 presents the causal links among different variables. This diagram consists of three main parts, that is, supply chain operations, supply chain risks and supply chain corruption. The basic structure is the dairy supply chain operations, which describes the transformation of raw milk and other raw materials into dairy products, and the activities involved in the flow between suppliers, manufacturers, retailers and customers. Various supply chain risks exist interrupting the normal operations. In the dairy industry, factors such as product quality, delivery time and process stability may not be stable. They will be affected by different risk factors, and have impact on the supply chain. Corruption may be found in various supply chain links. With information from current research and findings, the researcher conducts interviews with several dairy companies, and gains some knowledge about the impact of corruption.

Although they are useful to show the interrelationships among variables, causal loop diagrams cannot quantify them. (Richardson, 1986) and (Richardson, 1997) point out the shortcomings of the causal loop diagram, which mainly involve its failure to show the

stock/flow distinction. (Sterman, 2000) also mentions that the polarities in the causal loop diagrams usually cannot be clearly interpreted with stocks and flows involved.
Based on the causal loop diagram, we construct the stock flow diagram in Figure 8.

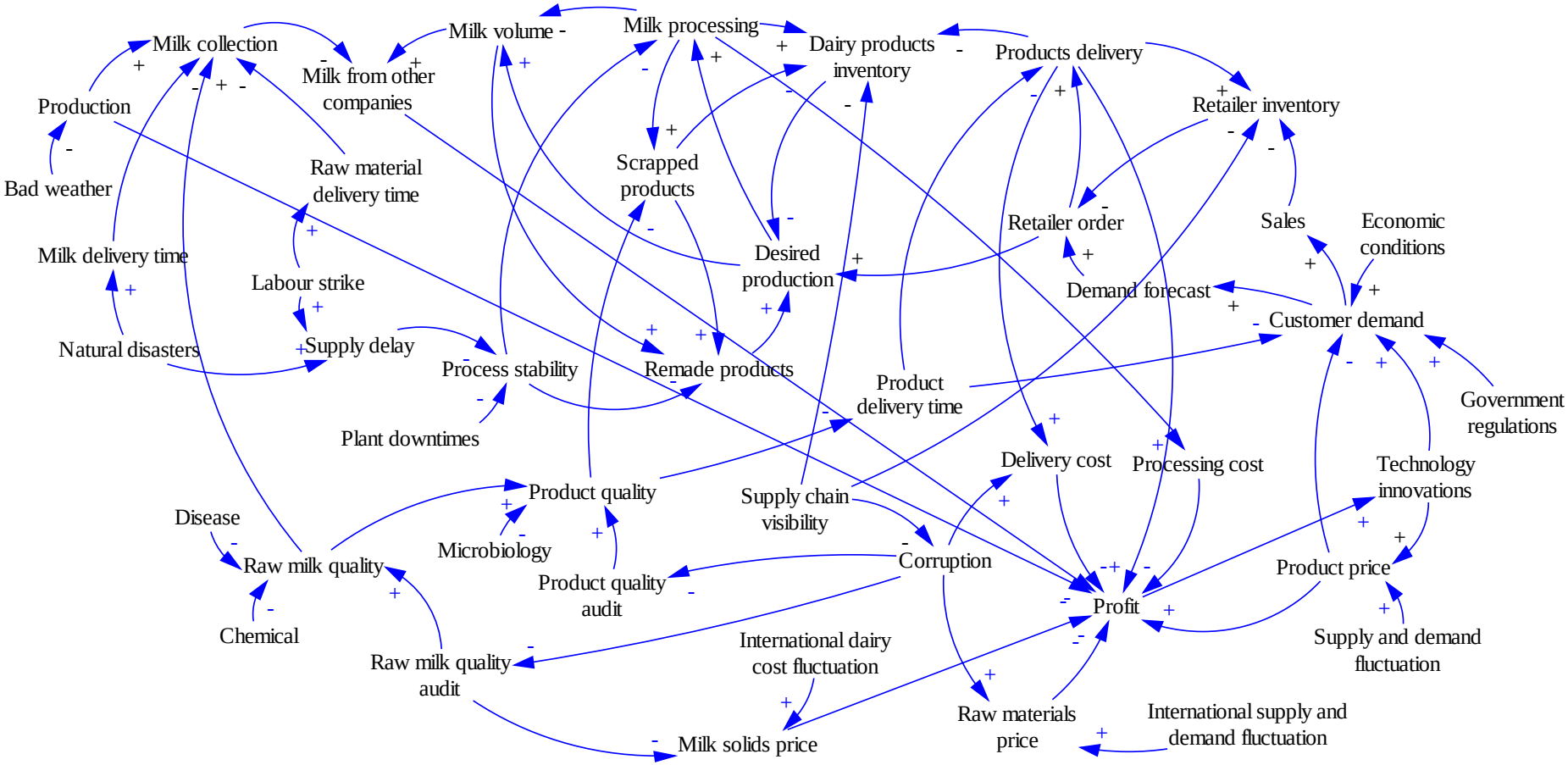


Figure 7 Causal loop diagram

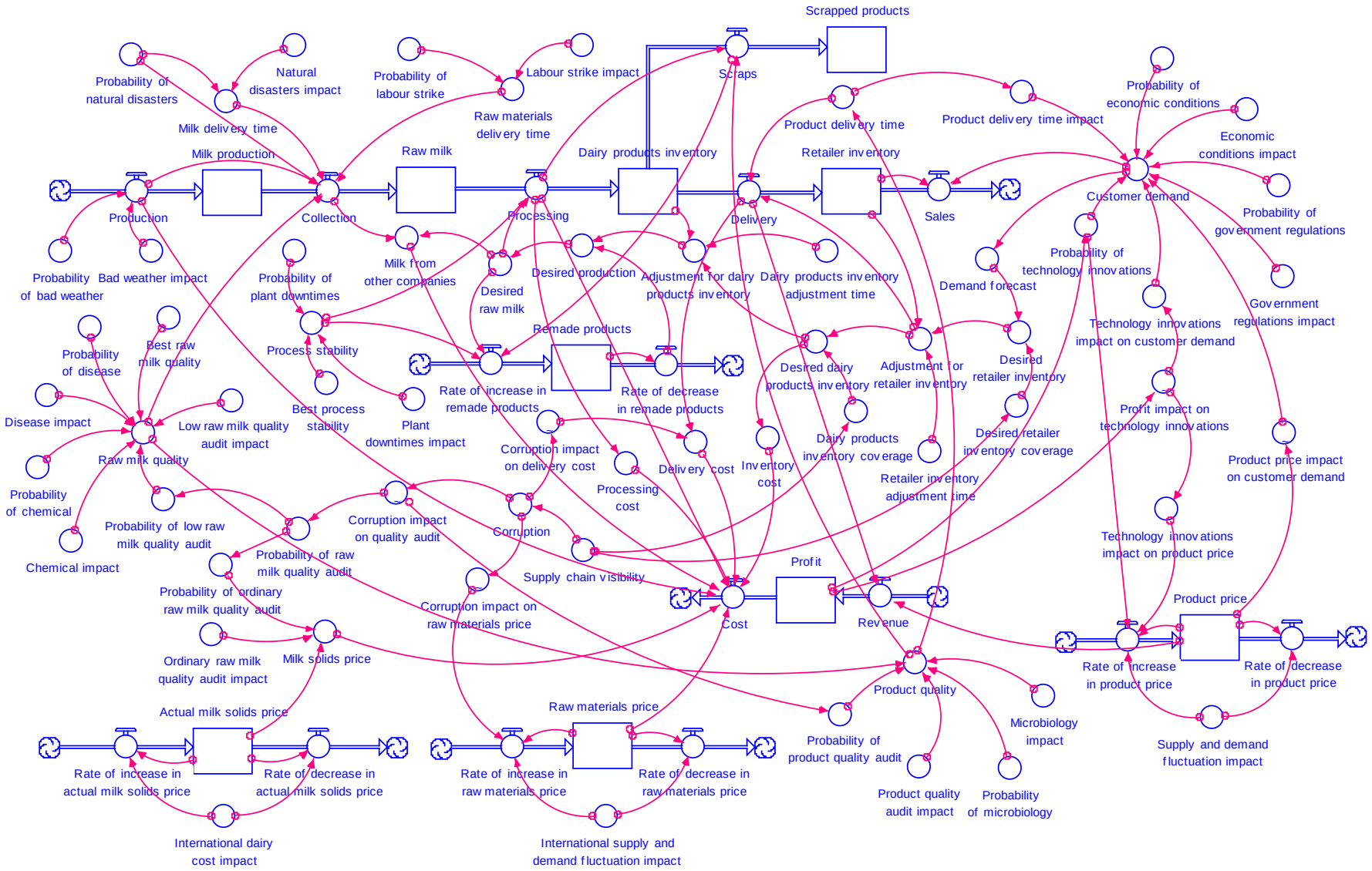


Figure 8 Stock flow diagram

Just as (Sterman, 2000) says, causal loop diagram underlines the feedback structure, while the stock flow diagram pays attention to the underlying physical structure. The stock flow diagram distinguishes the different types of variables. Stocks represent the accumulation process and flows reflect the rate of change in stocks. The following figures explains this stock flow diagram in detail.

Figure 9 shows the process of the dairy supply chain. New Zealand's first cheese company was established in 1871. Since then dairy co-operatives have been part of this country's history (DCANZ, n.d.). Just like other co-operatives in the world, this is an economical way to pool existing resources. According to an interviewee from a NZ co-operative dairy company, they sign the contract with farmers. They will take all the milk from farmers, even when the volume exceeds the actual demand of the company. Under the situation of milk shortage, the dairy company can buy from other companies. Milk collected will be processed into finished products and delivered to meet customer demand. The production and ordering process is enlightened by the ideas of (Sterman, 2000).

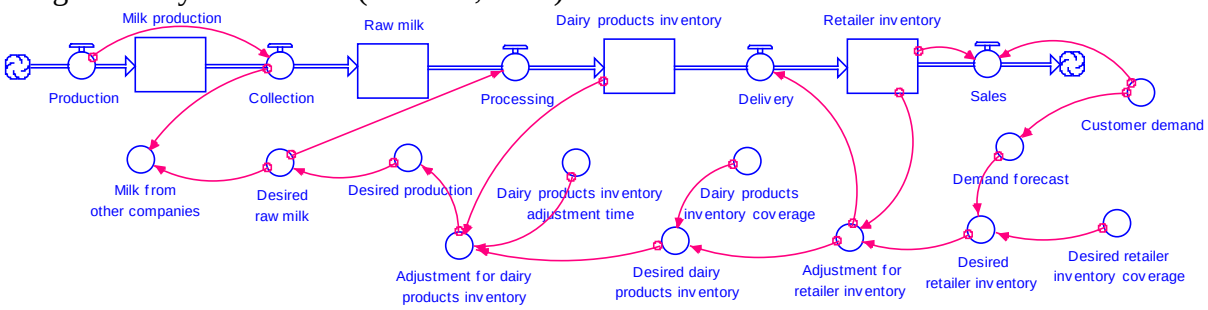
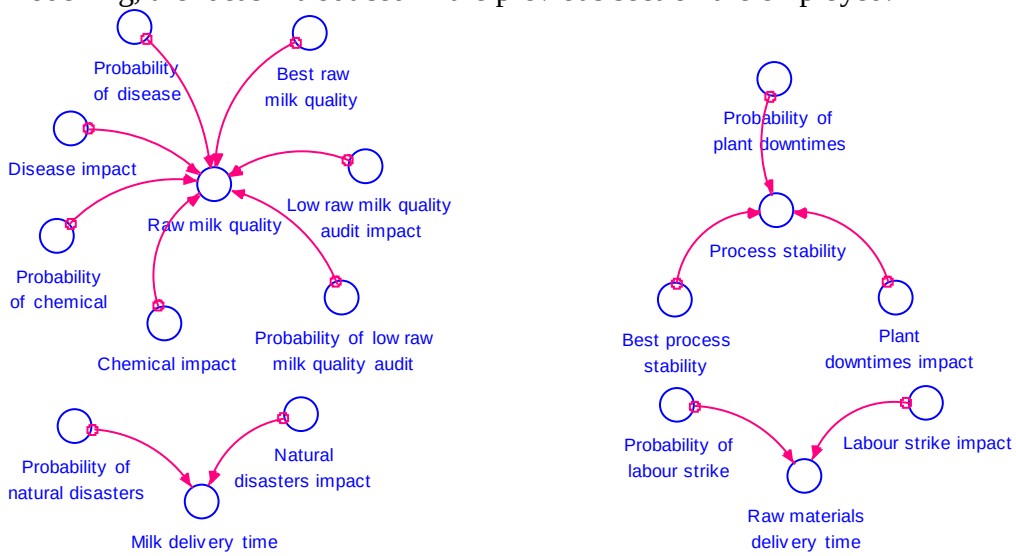


Figure 9 Dairy supply chain operations

Figure 10 presents some dairy supply chain risks. From the relevant literature review, we understand the dairy supply chain risks. However, literature coverage of the risk factors and risk impact is quite limited. On the basis of this understanding, we conducted semi-structured interviews with relevant managers in dairy companies, and gained practical information. We can validate and explore the literature information through the obtained data. For the risk modelling, the ideas introduced in the previous section are employed.



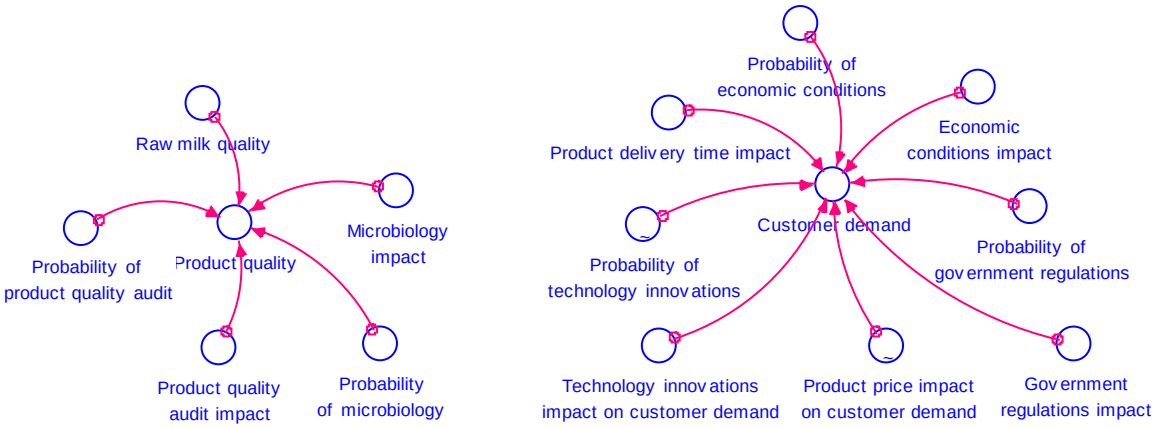


Figure 10 Dairy supply chain risks

Figure 11 indicates how corruption modifies supply chain risk factors. The corruption level ranges from 0 to 10, where 0 stands for the least corruption and 10 for the most corruption. Table functions are utilised to depict how the variables are affected by different corruption levels. With the presence of corruption, some variables will be modified, thus altering the supply chain performance. In Figure 11, we can see that corruption modifies the probability of quality audit, including both raw milk and the dairy product quality audit. The indicator 'Corruption impact on quality audit' is a table function, which shows the different impact values in accordance with different levels of corruption. 'Probability of product quality audit' shows the probability of the situation that the product quality audit is wrong and not the actual result. The impact value indicates how much corruption modifies this probability. This means when corruption exists, the probability would be different from the transparent situation. Similarly, corruption modifies other variables which will be discovered through literature or interviews.

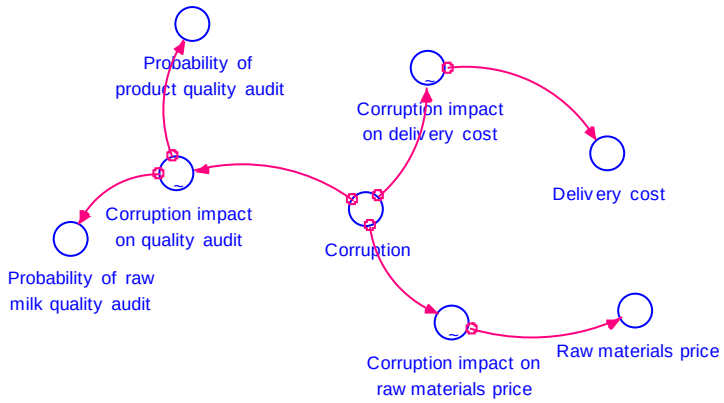


Figure 11 Corruption risks

The above model is constructed based on the literature and on currently collected data. With access to more companies in the dairy industry, data such as supply chain risks and the relationships among different variables will be generalised. Then the causal loop diagram and stock flow diagram will be refined according to the generalised data. The model will then be validated through the extreme condition test and the sensitivity test. After model validation, scenario analysis will be carried out to analyse the complex system. The modification of supply chain risks and the impact on supply chain performance are to be found under different levels of corruption. Leverage shall be discovered to find efficient mitigation strategies which safeguard dairy supply chains against risks due to corruption.

5 Conclusion and further research

In this research, we critically review literature about the dairy supply chain and its risks. Compared with other agri-food products, dairy products have their specific characteristics. The dairy supply chain structure has been analysed. Risks in this supply chain have been identified on the basis of literature and interview information. Corruption may exist in different links of the dairy supply chain, and affect the supply chain performance. Two research methods, case study research and system dynamics modelling, have been introduced and proved their suitability. We present our preliminary ideas to develop system dynamics models.

This is still work in progress. Further research will be focused on refining system dynamics models for simulation. After gaining access to more dairy companies, the investigator will conduct more semi-structured interviews to collect data. The risk factors and corruption risks in dairy supply chain will be established. With more interview data, we will generalise the variables and their interrelationships. The causal loop diagram and the stock flow diagram in our paper will be refined. After model verification, the simulation analysis can be performed. Underlying relationships can illustrate how corruption modifies dairy supply chain risk factors, and how to safeguard dairy supply chains against risk due to corruption.

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