Master Thesis

Possible Economic Consequences of a Food Safety Crisis in the Chinese Dairy Chain

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BUSINESS ECONOMICS GROUP

WAGENINGEN UNIVERSITY

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It is a tough but enjoyable time to do the research. I will move on to future study and work with all I learned from the research in Business Economics Group.

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May, 2016

Abstract

The aim of this study is to estimate economic loss of the Chinese dairy industry in case of a possible food safety crisis. A quantified Chinese dairy chain structure is depicted on the basis of relevant statistical data, including producer, processor, retail and consumer stages. In addition, the foreign chain containing imports and exports is also analysed. Based on the crisis scenario that 50% of domestic milk production is contaminated, the estimation of economic loss of the domestic dairy industry is approximately ¥12.39 billion. The analysis of the second crisis scenario that imported milk from a major imported country of origin is contaminated shows an estimated loss of ¥6.16 billion and ¥14.16 billion by domestic processing companies and consumers, respectively. The results of this study indicate the importance of establishing an effective prevention system for dairy industry and reinforcement of a stringent verifying system for milk product importers.

Keywords: Economic loss, Chinese dairy chain, Food Safety crisis

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1. Introduction

1.1 Background

Chinese dairy industry has been growing rapidly. According to the National Bureau of Statistics of People's Republic of China (NBSC), in the year 1995, domestic milk production was 5.76 million metric tons, while in 2014 this number climbed up to 37.24 million (NBSC 2014a). Thus, domestic milk production grew as much as more than six times in the last 20 years, indicating the dairy industry an important part of Chinese agriculture (Gale 2009). However, comparing with the earlier increase in milk production from 1995, the growth significantly slowed down from 2008 onwards (Liu 2014), which was mainly attributed to the effect of the melamine milk scandal.

Although the dairy industry has grown rapidly in the past couple of decades, Chinese consumers turned to foreign milk products, mainly due to lost confidence in domestic dairy industry after the melamine milk scandal in 2008 (Lu 2011). Under this circumstance, foreign milk companies branched into the Chinese market and expanded their market share. According to some financial research institutions, the Chinese dairy market share has been changed remarkably. Before the melamine milk scandal, domestic brands controlled 70% of the market share, while by the end of 2013, imported milk powder had reached 60% of total sales. Moreover, foreign brands have taken up nearly all the market share of high-end dairy products (Wood 2014). These enormous changes were also shown by NBSC, in the year 2008, 351 thousand metric tons of milk product were imported to China, while four years later this number reached 1145 thousand metric tons (Liu 2014).

On the opposite site, suffering from the melamine milk scandal, Chinese milk exports decreased sharply after 2008. According to NBSC, the export volume was 120 thousand metric tons in 2008, while one year later this number decreased to 36.8 thousand (Liu 2014). Milk exports were greatly hindered by low reputation in international market and higher cost of production due to lagging in technology. In recent years, the export volume slightly increased, but it is still far less than that before 2008 (Chen 2012, Liu 2014).

The Northern provinces produce the largest part of the total milk production in China, while the demand for dairy products is higher in the Southern provinces. Furthermore, there is a huge difference in milk consumption between urban and rural areas, where people have lower income and tend to keep the traditional diet. Although the 2008 melamine scandal shocked the Chinese dairy industry and severely reduced consumers' confidence in local milk brands, the demand of milk kept increasing

(NBSC 2014a). As the nationwide two-child policy has been announced, many institutions predict the demand of infant milk powder will significantly increase (Hutchens 2015, Kondalamahanty 2015).

In China, there are two main structures of the production chain. The main structure comprises producers (farmers and large dairy farms), cow feeding districts, milk processing companies, retailers and consumers. Imports and exports are also critical elements. The other important structure is the so-called integration, which is made up of enterprises and enterprise-owned scaled farms (Qian 2011). To ensure food safety standards, big companies are in favour of integration, but due to the limitation of owned scaled farms, the raw milk is primarily supplied by dairy farmers (Yu 2008). After the 2008 melamine scandal, domestic milk production struggled under structural changes. On one hand, small dairy farmers are collaborating more with small-scaled dairy enterprises, to enforce the combination of farmers and producers. On the other hand, big companies are branching out to the international market, in order to introduce advanced technology and cheaper milk suppliers (Chinabgao.com 2014).

Chinese dairy industry experienced the melamine milk scandal in 2008, from which the whole industry suffered a lot. For a long time, the dairy industry focused on the downstream market, but ignored the upstream milk suppliers, leading to low incomes of milk farmers. In order to increase the protein content at lower costs, milk farmers and milk collecting stations added melamine to raw milk on purpose, to get a higher payment (Qian 2010). After the melamine milk scandal, the consumers' confidence reduced sharply, and it has not been recovered even till now. It is expected that it will take a long time to restore the credibility of the dairy industry (Lu 2011).

1.2 Research Problem

The melamine milk scandal in 2008 revealed accumulated problems in the whole dairy chain structure. As the industry focused on making profit from the downstream market but ignored the interests of upstream milk suppliers, the devastating problem occurred in the upstream milk sources (Qian 2010). After the melamine milk scandal, much attention has been paid to improving the upstream sectors. Encouraged by the new policy, small dairy farmers are moving from backyards to cow feeding districts, where they feed cows and collect milk together, in replace of the former pattern in which farmers fed cows and collected milk separately (Ji 2011). On the other hand, milk processing companies invest in building own farms, in order to ensure adequate and high quality milk supply (Qian 2010, Ji 2011). As the chain structure changed substantially and milk operators are still struggling under structural changes, there will be many uncertainties in studying the dairy industry chain structure, especially the upstream milk supply sector.

As the new dairy chain has been implemented, the question is to what extent this new structure can stand potential future food safety crisis, and how much the economic loss will be in case of such a crisis.

1.3 Objective

The aim of this research is to analyse the economic consequences of a dairy crisis under the new Chinese dairy chain structure. This aim is divided into the following two sub-objectives.

1) Obtain insights into the chain structure of Chinese dairy industry, and build the Chinese dairy chain structure;
2) Estimate economic loss for specific crisis scenarios.

2. Material and Methods

2.1 Chinese Dairy Chain Structure

To obtain insights into the Chinese dairy chain structure, relevant information is mainly based on secondary sources, including government reports, scientific paper and related literature.

To build a quantified dairy chain structure, relevant data which includes volume data of each stage is collected from related literature and digital databases, including database of National Bureau of Statistics of the People's Republic of China and database of General Administration of Customs of the People's Republic of China.

To depict a Chinese dairy chain structure model, Microsoft Visio 2013 is used.

2.2 Crisis Scenarios

The consequences of a potential dairy crisis studied in this research is assumed to be associated with food safety hazard. The most reported food safety hazard in milk will be studied through literature. After explanation of food safety hazards, crisis scenarios will be defined based on reasonable assumptions related to those most reported food safety problems.

2.2.1 Food Safety Contamination

In the past decades, a large number of food safety incidents in the dairy chain were reported. The most frequently reported dairy crisis were related to aflatoxins (Decastelli 2007, Bilandžić 2010, Tsakiris 2013), dioxin and dioxin-like compounds (Erickson 1999, Tlustos 2009) and pathogenic micro-organisms (Acker 2001, NEWS 2013). In addition, milk adulteration incidents were also reported (Chan, Griffiths et al. 2008, Pei 2011).

1) Aflatoxins

Aflatoxins can cause a major public health problem. It is a group of mycotoxins (four aflatoxins: aflatoxin B_1, B_2, G_1, G_2) that is produced mainly by two species of filamentous fungi, *Aspergillus flavus* and *Aspergillus parasiticus* (Lorenzini 2005). *Aspergillus spp.* can grow easily in warm and humid environment (Eaton 1994), and infect a wide variety of foods, including peanuts, copra, soya, maize, rice, barley and corn (Yiannikouris 2002, Alborzi 2006). Aflatoxin M_1 (AFM_1), a metabolized form of aflatoxin B_1 (AFB_1), occurs in milk(Galvano 1996). AFM_1 appears within 12 hours after cows eat contaminated feed (Frobish 1986). A number of adverse human health effects have been associated with dietary contamination of aflatoxins, including diarrhoea, hepatotoxicity, apathy, anorexia, mastitis, immunodeficiency, fever, liver cancer, kwashiorkor, and Reye' s syndrome (Eaton 1994).

2) Dioxin and dioxin-like compounds

Dioxins is a general term referring to a group of up to 75 compounds or congeners of polychlorinated divenzo-p-dioxins (Schecter 2006), including the much-studied 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) (Murray 1979, Poland 1982, Mimura 1997, Mimura 2003). Based on toxicity similar to that of TCDD, a wider group of halogenated aromatic compounds have been recognized as dioxin-like compounds, including certain polychlorinated dibenzofurans (PCDFs), biphenyls (PCBs), diphenyl ethers, naphthalenes and others (Lok 2000, Schecter 2013). Dioxin compounds were largely produced for industrial use since World War I. Although the amount has reduced largely, they are still present ubiquitously in the environment due to their thermal and chemical stability. The compounds contaminate soil, water, and vegetation through air deposition, and significantly entry into the terrestrial food chain. Human exposure is nearly entirely from the diet, mainly via milk, meat and meat product (Schecter 1994). Excess exposure to dioxins is proved to be related to high risk for mortality from cancer and ischaemic heart disease (Kogevinas 2001).

3) Adulteration: melamine

Melamine, also known as tripolycyanamide, is a colourless crystalline substance belonging to the family of heterocyclic organic compounds, which are used primarily in the production of plastics, dyes, fertilizers, and fabrics. As melamine is abundant in nitrogen, which is a property of protein, it was misused and added to various food products, suggesting a false increase in protein concentration (Chan, Griffiths et al. 2008, Hau 2009). Studies of melamine oral toxicity reveal that, although low-level exposure to the chemical does not usually cause adverse health effects, high concentrations of melamine crystallizes in the urine, leading to kidney stones and other renal disorder (BRITANNICA 2016a).

4) *Clostridium botulinum* toxins

Clostridium is a genus of rod-shaped and gram-positive bacteria. *Clostridium* produce *Clostridium botulium* neurotoxins, which are made up of seven serogroups (serogroups A to G). Naturally occurring forms of *botulism* include food-borne, intestinal, and wound *botulism*. Food-borne *botulism* is the most common form and occurs when humans or animals ingest food or drinks that contain the preformed neurotoxin. Human wound infection is reported to be caused by the wound *botulism* (Merson 1973). Since 1976, infant *botulism* affecting those aged between 3 weeks to

8 months have often been reported (Midura 1976), and it has been given much attention (Sakaguchi 1982, Cooksley 2010, BRITANNICA 2016b).

2.2.2 Crisis Scenarios

Scenario 1: 50% of domestic raw milk produced in 14 days is contaminated by a food safety contamination at the producer stage. 300 processing companies are supplied by the contaminated raw milk, and one production line at each company is affected for 10 days. 70% of the contaminated milk is still under processing and the remaining 30% has already entered into the market.

Scenario 2: Imported milk from a major imported country of origin is reported to be contaminated by a food safety contamination.

2.3 Economic Losses

The calculation of the economic losses of a possible crisis is based on partial budgeting approach, which compares the situation with a crisis and one without a crisis. The calculation includes additional costs, reduction of costs and reduction of income. Additional income is however not relevant.

To calculate the economic loss caused by a potential dairy crisis, Microsoft Excel 2016 is used.

3. Result

3.1 Chinese Dairy Chain Structure

3.1.1 Structural Changes

The production chain is made up of two ways, one comprises raw milk producers, cow feeding districts and processing companies; the other one consists of enterprises and enterprise-owned scaled farms (Qian, Guo et al. 2011). Before the melamine milk scandal, the dairy processing companies were supplied by three kinds of domestic raw milk: 1) raw milk from individual small farmers which accounted for more than 60% of total raw milk supply; 2) raw milk from milk collecting stations consisting of about 25%; and 3) raw milk supplied by enterprise-owned farms, which accounted for around 15% of total raw milk (Mo 2012).

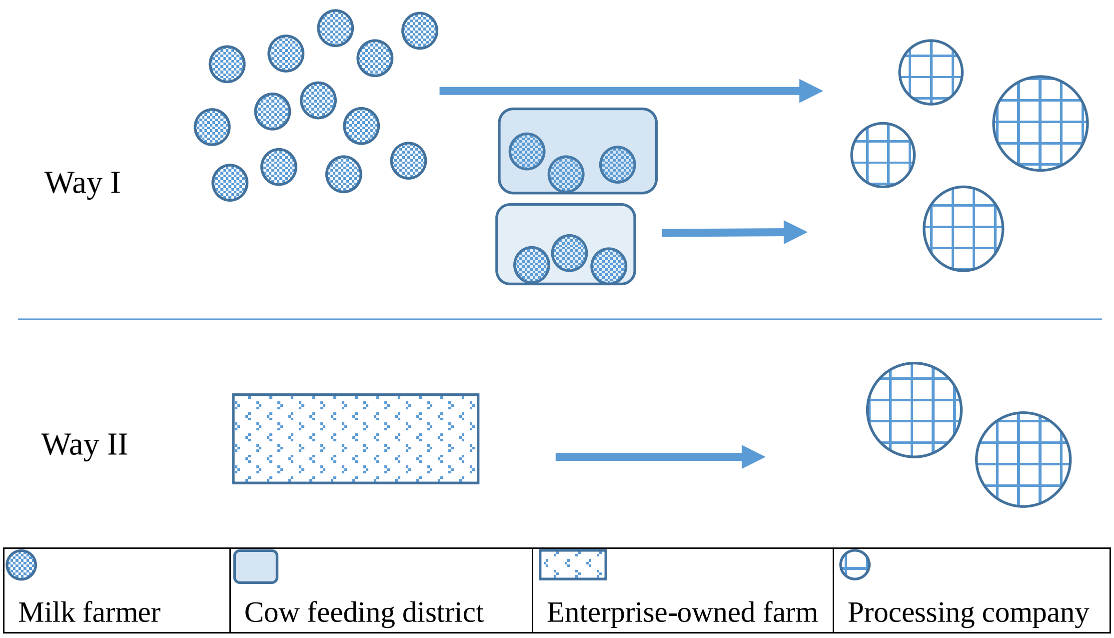


Figure 1. Raw milk supplied chain of Chinese dairy chain structure.

The structure showed a highly scattered scheme. Normally, raw milk was collected from individual small scale farmers at the farm or at milk collecting stations, then delivered to the processing companies. According to statistics from the Ministry of Agriculture, there were 20,393 milk collecting stations across the country, serving 1.18 million dairy farmers in China, but only 5151 stations (25.3%) had industrial and commercial business licenses, 2850 stations (14.0%) had a hygiene license and about half of all stations (10,396) used modern milking machinery for milk collection (Qian 2011). The data indicated a probable unsanitary raw milk collection profile.

The primary cause of the melamine milk scandal is generally considered to be the highly scattered structure of the nationwide milk supply. In order to solve the devastating problems, the government and dairy sector introduced a series of policies, by centralizing cow feeding and milk collection, to improve the chain structure (Zhou 2008). On one hand, small dairy farmers were persuaded to join cow feeding districts, where they were able to feed cows and collected milk together, instead of doing it separately (Mo 2012). On the other hand, large dairy enterprises were encouraged to build enterprise-owned large scale farms, in order to concentrate feeding cows, and to guarantee sufficient and high quality raw milk supply.

Many small scale farmers moved to cow feeding districts and enterprise-owned scale farms grew rapidly. According to a study around Greater Beijing area, the percentage of individual small scale farmers decreased from 98% in August 2008 to 60% in September 2009. 26% of small scale farmers moved to cow feeding districts and 12% stopped their business (Mo 2012). The changes in feeding system were crucial according to the Dairy Association of China (China 2014a). The group of dairy farmers who raised less than 5 cows consisted of 42.8% in 2006, but this number decreased to 22.5% in 2012. In response, large scale dairy farms grew rapidly. The largest feeding scale (more than 1000 cows) group made up only 3% in 2006, however, after growing for many years, this group accounted for 15.4% of the national total cows in 2012.

Table 1. Statistic of Chinese cow feeding scale between 2006 and 2012

Cows/herd \ Year	2006	2007	2008	2009	2010	2011	2012
Total (Million)	10.69	12.19	12.34	12.60	14.20	14.40	14.94
1-4 (%)	42.8%	39.7%	32.4%	28.1%	26.4%	23.9%	22.5%
5-19 (%)	28.4%	34.2%	31.5%	29.3%	27.1%	24.9%	21.8%
20-99 (%)	15.7%	9.7%	16.5%	15.8%	15.9%	18.3%	18.4%
100-199 (%)	3.8%	4.2%	4.0%	4.0%	4.1%	4.5%	5.0%
200-499 (%)	3.7%	4.7%	5.5%	6.8%	7.1%	7.6%	7.3%
500-999 (%)	2.6%	3.6%	4.5%	7.7%	9.0%	8.7%	9.6%
Above 1,000 (%)	3.0%	3.9%	5.6%	8.3%	10.4%	12.1%	15.4%

Dairy Association of China (China 2014a).

Besides producing stage, reconstruction took place in the processing stage as well. Small companies exit from the market due to deficiency in financial ability and market competitiveness. Correspondingly, big processing companies with strong financial ability were encouraged to collaborate with foreign dairy companies, in order to introduce advanced technology. According to the Dairy Association of China

(China 2014a), after a series of reconstructions, the number of processing companies decreased to 649 in 2012, from the number of 815 in 2008. There were 669 small size enterprises in 2008, but the number decreased to 459 in 2012. In contrast, the number of large scale enterprises grew from 9 in 2008 to 37 in 2012.

Table 2. Statistics of Chinese dairy processing companies

Scale / Year	2006	2007	2008	2009	2010	2011	2012	2013
Total enterprises	717	736	815	803	784	644	649	658
Small enterprises	601	598	669	646	617	484	459	------
Medium enterprises	107	126	137	144	154	145	153	------
Large enterprises	9	12	9	13	13	15	37	------

Dairy Association of China (China 2014a).

Table 3. Statistic of processed dairy product of China between 2006 and 2013

Year / Product Type	2006	2007	2008	2009	2010	2011	2012	2013
Dairy Product (Million Tons)	14.60	17.87	18.10	19.35	21.60	23.88	25.46	26.98
Liquid Milk (Million Tons)	12.44	14.41	15.25	16.42	18.46	20.61	21.47	------
Dry Dairy Product (Million Tons)	2.16	3.46	2.85	2.93	3.14	3.27	3.99	------

Dairy Association of China (China 2014a), KPMG (KPMG 2015).

Due to lost consumers' confidence in Chinese domestic milk, a dramatic increasing volume in imported milk and milk product can be seen after 2008. The volume of imported dairy product was 1146 thousand in 2012, and the number was more than three times of that in 2008 (351 thousand).

Table 4. Chinese imported dairy product volume between 2006 and 2013

Type / Year	2006	2007	2008	2009	2010	2011	2012	2013
Dairy Product (Thousand tons)	347.83	298.58	351.07	597.01	745.29	906.07	1145.58	1826.8
Liquid milk (Thousand tons)	4.55	4.86	8.32	14.31	17.12	43.09	101.68	194.8
Dry dairy product (Thousand tons)	343.28	293.72	342.75	582.70	728.17	862.98	1043.90	1632

General Administration of Customs of People's Republic of China (China 2014b); Dairy Association of China (China 2014a); KPMG (KPMG 2015).

In contrary to imports, the exports of Chinese dairy products sharply decreased. The volume was about 37 thousand one year after the melamine milk scandal, which was less than one third of the export volume before 2008. The export volume slightly increased after 2010, however, the number was still far less than the volume before the melamine milk scandal.

Table 5. Chinese exported dairy product volume between 2006 and 2013

	2006	2007	2008	2009	2010	2011	2012	2013
Dairy Product (Thousand Tons)	74.86	134.56	120.63	36.78	33.76	43.33	44.90	38.83
Liquid Milk (Thousand Tons)	39.70	47.22	39.53	20.87	23.67	26.02	27.80	26.48
Dry Milk Product (Thousand Tons)	35.16	87.34	81.10	15.91	10.09	17.31	17.10	12.35

General Administration of Customs of People's Republic of China (China 2014b), Dairy Association of China (China 2014a).

3.1.2 Current Chain Structure

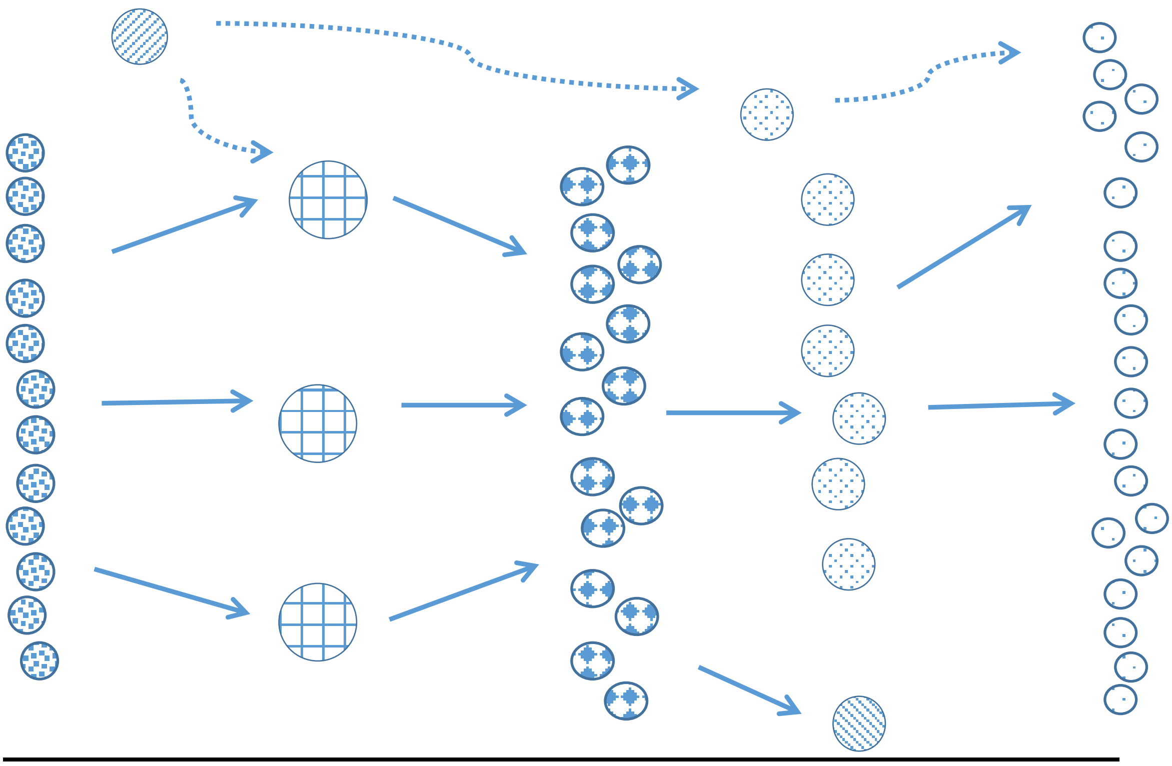
Table 6. General statistics of Chinese dairy industry between 2006 and 2013

Year	2006	2007	2008	2009	2010	2011	2012	2013
Milk Cow (Million)	10.69	12.19	12.34	12.60	14.20	14.40	14.94	------
Produced Cow Milk (Million tons)	31.93	35.25	35.56	35.21	35.76	36.58	37.44	35.31
Processing company	717	736	815	803	784	644	649	658
Processed dairy product (Million tons)	14.60	17.87	18.10	19.35	21.60	23.88	25.46	26.98
Imports (Thousand tons)	347.83	298.58	351.07	597.01	745.29	906.07	1145.58	1826.8
Exports (Thousand tons)	74.86	134.56	120.63	3.78	33.76	43.33	44.90	38.83
Consumer (Billion)	1.31	1.32	1.33	1.33	1.34	1.35	1.35	1.36

Dairy Association of China (China 2014a); General Administration of Customs of People's Republic of China (China 2014b); National Bureau of Statistics of China (NBSC 2014); KPMG, (KPMG 2015).

Based on statistical data of dairy industry in 2013, a chain structure model is depicted below. The milk producers produce raw milk (35.31 million tons) at home, at cow feeding districts and at enterprise-owned scale farms. Then the raw milk is delivered to processing companies (658 companies), where raw milk is processed into milk products. The end-products (26.98 million tons) are distributed to retail places, where consumers can buy milk products.

In addition, the imports and exports are also two important elements in the chain. Some of the imported milk is supplied to the processing companies, then used for further processing. And some milk products are directly distributed to retail places, where consumers can directly buy the imported milk products. In terms of exports, some of the end-products are used for exports.



Raw milk - 35.31 million tons of milk yield	Processor - 658 processors - 26.98 million tons of milk product	Retailer - ------	Consumer - 1.36 billion
Import - 1826.8 thousand tons	Export - 38.83 thousand tons	End-product - 26.98 million tons	Supply and distribute

Figure 2. Chinese dairy chain structure, data based on statistics of year 2013.

3.3 Estimation of Economic Loss

3.3.1 Calculating items

All cost items can be categorised into direct costs and indirect costs (Moran 2009). The cost items discussed below are those affected by a dairy crisis. When a food safety crisis happens, the costs might increase regardless of the income.

For raw milk producers, the direct cost items include labour costs, feed, forage and energy costs. Indirect cost items include construction and machinery depreciations. The reduced income affected by a crisis is also discussed.

For milk product processors, less raw milk leads to reduction of costs, however, some costs increase, including labour costs, tracking and tracing, sampling and testing, business allowance, analysis costs, blocking costs, transportation costs, storage costs, recalling costs, press release costs, destruction costs. Indirect costs include depreciation of construction and machinery. Besides cost items, the revenues are also affected by a crisis.

The consumers may have to pay extra costs, because the price of milk products may increase due to domestic milk deficiency caused by a food crisis in large amount of imported milk.

3.3.2 Calculation of Direct Costs and Revenues

This study is focused on the direct cost items and revenues despite plenty of indirect costs and revenues are involved. Direct cost and revenue items which are mostly related to the economic losses are discussed below. They can be either positive or negative.

Table 7. Volume and price of domestic milk production and foreign trade in 2013

Domestic chain	Raw milk		Processed milk product	
	Volume/ Million tons	Average unit price/¥/Ton	Volume/ Million tons	
	35.31	3610	26.98	
Foreign trade	Import		Export	
	Volume/ Thousand tons	Average unit price/$/Ton	Volume/ Thousand tons	Average unit price/$/Ton
	1826.8	3911	38.83	------

Dairy Association of China (China 2014a); General Administration of Customs of the People’s Republic of China (China 2014b).

Scenario 1: 50% of domestic raw milk produced in 14 days is contaminated by a food safety contamination at the producer stage. 300 processing companies are supplied by the contaminated raw milk, and one production line at each company is affected for 10 days. 70% of the contaminated milk is still under processing and the remaining 30% has already entered in the market.

In this case, the producer and processor stages are both affected. The calculation is divided into two parts. The influence on producers is analysed followed by processors.

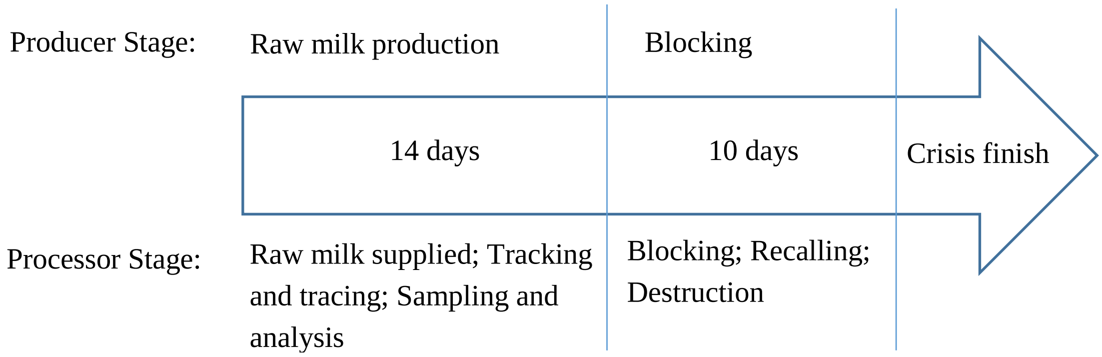


Figure 3. Time table of the food safety crisis.

Producer Stage:

Raw milk. Raw milk is normally paid monthly, that is, milk producers supply raw milk to the milk processing companies every day and are paid at the end of each month or early the next month. When the raw milk is confirmed to be contaminated during processing, the milk producers are not paid. However, the producers still need to feed cows every day, even though they are not able to get payment. The forage and labour costs remain the same, but the loss is caused by income reduction. The reduction in income of producers is determined by the volume and price of the milk.

$$CV = RM * 50\% * \frac{14}{365} \quad (1)$$

$$= 35.31 \text{ million tons} * 50\% * \frac{14}{365}$$

$$\text{Income Reduction}_{50\% \text{ raw milk}} = CV * UP_{domestic} \quad (2)$$

$$= CV * ¥3610$$

Given the yearly domestic raw milk (RM) production of 35.31 million tons and the average unit price ($UP_{domestic}$) of 3610 Chinese Yuan (¥) per ton in the year 2013, the contaminated volume (CV) is 677,178 tons and the decrease in revenue of farmers is estimated to be ¥2.44 billion.

Blocking. Once the food safety contamination is confirmed, the involved dairy farms are assumed to be blocked for 10 days. Although the contaminated farms are blocked, the production capacity remains the same. Cows still consume feed and produce the same amount of raw milk, but the farmers are not able to get the payment. Under this condition, the costs remain the same but farmers have to suffer no income for extra 10 days. The income reduction caused by blocking is calculated as:

$$\text{Reduced Income}_{\text{Blocking}} = \text{RM} * 50\% * \text{UP}_{\text{domestic}} * \frac{10}{365} \quad (3)$$

$$= 35.31 \text{ million tons} * 50\% * ¥3610 * \frac{10}{365}$$

For farmers, the income reduction caused by blocking is about ¥1.75 billion.

The calculation indicates a total revenue loss of ¥4.19 billion of raw milk producers.

Processor Stage:

Tracking and tracing. The cost of tracking and tracing (TT) is determined by the internal labour cost (LC_{In}), the number of extra working hours (H) and the number of involved batches.

One batch means in one processing company, the particular type of end-products from the same raw materials and production line within one day (General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, 2010). In Scenario 1 the number of affected batches is:

$$\text{No.}_{\text{Batch}} = \text{No.}_{\text{Company}} * \text{Day} \quad (4)$$

$$= 300 \text{ companies} * 14 \text{ days}$$

From the calculation it is clear to see in Scenario 1 there are 4200 batches involved in the crisis.

The cost of tracking and tracing (TT) is calculated as:

$$\text{Cost}_{\text{TT}} = \sum (\text{LC}_{\text{In}} * \text{H} * \text{No.}_{\text{Batch}}) \quad (5)$$

$$= \sum (40 \text{ ¥/h} * 16 \text{ h} * 4200)$$

Referring to Lascano-Alcoser (2011), the working hours for tracking and tracing per batch is 16 hours. The extra internal labour costs vary widely in China and it is assumed as ¥40 per hour. The number of involved batch is 4200, as calculated in Formula (4). The estimated extra costs of tracking and tracing is therefore ¥2.69 million.

Sampling and testing. The costs of sampling and testing (ST) include extra internal labour costs, sample collection and analysis costs.

$$\text{Cost}_{\text{ST}} = \sum(\text{Extra Labour} + \text{Business Allowance} + \text{Analysis}) \quad (6)$$

$$= \sum (\text{LC}_{\text{In}} * \text{H} * \text{No.}_{\text{company}} + \text{Allowance per day} * \text{Day} * \text{No.}_{\text{company}} + \text{Analysis Fee} * \text{No.}_{\text{Batch}})$$

$= \sum$ (40 ¥/h*56 h*300 companies+250 ¥/h*10 d*300 companies+300 ¥/batch*4200 batches)

Supposing the sampling and testing takes 10 days. The staff who take responsibility of sampling and testing work 12 hours per day and all of them are paid extra business allowance. For one company, the extra working time is 44 hours (4 hours extra per day from Monday to Friday and 12 hours per day at weekends) and it costs ¥40 per hour. Totally, 300 involving companies have to spend ¥528 thousand for extra labour. Business allowance is paid to staff if the sample collection takes place in another city and it is assumed to be ¥250 per day on average. Assuming each company assigns one employer to collect samples in another city for 10 days. For the purpose of business allowance, all involved companies have an increment budget of ¥750 thousand. The analysis costs vary between areas and it is supposed to be ¥300 per batch. 300 involved companies are required to pay ¥1.26 million for analysis fee. Taking the three cost items into account, all those involved companies are supposed to have an additional cost of ¥2.54 million.

Blocking. During the blocking period (10 days) the production lines still work, but supplied with less raw milk from uncontaminated farms. Affected by less raw milk, the operation time is 2 hours less than usual for 10 days. Despite of less working time, the companies have to pay same salary to their staff, but less working time leads to less operating costs, therefore in general the costs decrease. Supplied with less raw milk, there will be less outputs, subsequently an income reduction may be seen.

$$\text{Revenue Reduction}_{\text{Blocking}} = 70\% * 50\% * \text{Total Revenue} * \frac{10}{365} \tag{7}$$

$$= 70\% * 50\% * ¥283.2 \text{ billion} * \frac{10}{365}$$

$$\text{Cost Reduction}_{\text{Operation}} = \text{Energy} * \text{Less Operation Hour/Day} * \text{No}_{\text{Day}} * \text{No}_{\text{company}} \tag{8}$$

$$= 1.5 \text{ ¥/h} * 2 \text{ h} * 10 \text{ d} * 300 \text{ companies}$$

$$\text{Loss}_{\text{Blocking}} = \text{Cost Reduction}_{\text{Operation}} - \text{Revenue Reduction}_{\text{Blocking}} \tag{9}$$

As the margin varies widely from different kinds of milk products and companies, it is not proper to propose an average profit margin, however, the total revenue (main business) of milk processing companies in 2013 (¥283.2 billion) is considered in this case. The involved companies are supplied by 50% less raw milk in 10 days, amongst the contaminated milk, 70% is under processing, so the impacted revenue reduction is ¥2.72 billion. Supposing the energy costs (electricity, water, gas et al.) ¥1.5 per hour. As the affected companies work 2 hours less per day in the blocking period (10 days), the companies pay ¥180 thousand less than usual for operation. The calculation result shows a negative of ¥2.72 billion, indicating the revenue reduction exceeds the operation cost reduction, therefore the action of blocking leads to a loss of ¥2.72 billion.

Recalling. When the contaminated end-products are confirmed, a recall of all the contaminated end-products (30% of the contaminated milk) in the market has to take place. The processors are responsible for the recalling costs, including extra internal labour costs (In_{LC}), transport costs, storage costs and press release costs.

$$\begin{aligned} Cost_{Recalling} &= \sum \text{Extra Labour} + \sum \text{Transport} + \sum \text{Storage} + \sum \text{Announcement Release} \qquad (10) \\ &= LC_{In} * H * No._{company} + UP_{Transport} * 30\% * CV * Distance \\ &\quad + UP_{Storage} * 30\% * CV * No._{Day} + UP_{Announcement} * No_{Retail} \\ &= ¥40 * 50h * 300 + ¥0.23/ton/km * 30\% * 677178 tons * 100km \\ &\quad + ¥2.5/ton * 30\% * 677178\ tons * 5d + ¥1 * 10000 \end{aligned}$$

Supposing each company spends extra 50 working hours to cope with recalling and it costs ¥40 per hour. 300 involved companies have to pay ¥600 thousand for extra labour costs. Presuming the transport cost is ¥0.23 per ton per kilometre (km) and the distance from each retail place to the processing company is 100 km. The storage cost is supposed to be ¥2.5 per ton per day (12306.cn n.d.) and it takes 5 days to store the recalled products before they are destroyed. The volume of contaminated milk is aforesaid 677,178 tons (calculated in (1)), therefore, the calculation shows an increase in costs of ¥10.9 million for transport and ¥5.93 million for storage, respectively. The recall announcement in the public media (such as TV, broadcast, newspaper) is not legally obligatory, however, prompt announcement in retail places are required. It is assumed that the cost of announcement in one retail place is ¥1. Given the case all contaminated milk products are recalled from 10,000 retail places, the press release cost is ¥10 thousand. Taking the four cost items into account, the cost of recall is expected to be ¥17.44 million.

Destruction. Once the contamination is confirmed, the milk under processing and all the defective end-products have to be destroyed. The impact of destruction includes extra labour costs, costs of disposal and revenue loss. Currently there are two discarding methods, which are pollution-free approach and incineration. The former way costs much more (¥1000/ton) than incineration (¥50/ton). To save costs, the way of incineration is commonly used.

$$Loss_{Destruction} = \sum \text{Extra Labour} + \sum \text{Incineration} + \sum \text{Revenue Loss} \qquad (11)$$

$$= LC_{In} * H * No._{company} + UP_{Incineration} * CV + 50\% * \text{Total Revenue} * \frac{14}{365}$$

$$= ¥40 * 16\text{ h} * 300 + ¥50/\text{ton} * 677{,}178\text{ tons} + 50\% * ¥283.2\text{ billion} * \frac{14}{365}$$

The extra labour is supposed to be 16 hours and costs ¥40 per hour for each company. The costs paid for extra labour is ¥192 thousand. All the contaminated milk products are discarded by incineration, which costs ¥50 per ton, thus the incineration of all contaminated milk costs ¥33.86 million. The dairy processing companies reached a total revenue of ¥283.2 billion in 2013 (KPMG 2015) as aforementioned in (7), therefore the loss revenue caused by destruction of all contaminated milk and end-products is expected to be ¥5.43 billion. Based on the above factors, the cost of destruction is estimated to be ¥5.47 billion.

Table 8. Effect of cost and revenue items in terms of partial budgeting approach.

Item	Added cost	Reduced cost	Added income	Reduced income	Result
Producer Stage:					
Raw milk				– ¥2.44 billion	– ¥2.44 billion
Blocking				– ¥1.75 billion	– ¥1.75 billion
Loss of producer:					– ¥4.19 billion
Processor Stage:					
Tracking and tracing	– ¥2.69 million				– ¥2.69 million
Sampling and testing	– ¥2.54 million				– ¥2.54 million
Blocking		+ ¥180 thousand		– ¥2.72 billion	– ¥2.72 billion
Recalling	– ¥17.44 million				– ¥17.44 million
Destruction	– ¥34.05 million			– ¥5.43 billion	– ¥5.47 billion
Loss of processor:					– ¥8.2 billion
Total loss:					– ¥12.39 billion

+: positive effect; –: negative effect.

The calculation shows the potential economic loss caused by a crisis is up to ¥4.19 billion for milk producers and ¥8.2 billion for processing companies, respectively. In total, the dairy industry might suffer a loss of ¥12.39 billion as a result of a domestic food safety crisis.

Scenario 2: Imported milk from a major imported country of origin is reported to be contaminated by a food safety contamination.

If a large part of imported milk is contaminated, there will be raw milk deficiency in the dairy market. When the demand remains the same, the supply decreases and the price increases.

Producer Stage:

As the price of raw milk keeps going up, farmers are able to earn more money. Assuming the price of nationwide raw milk increases with *a* (10%) and remains at high level for half year.

$$\text{Added Income}_{\text{producer}} = a * \text{RM} * \text{UP}_{\text{RM}} * \frac{6}{12} \quad (12)$$

$$= 10\% * 35.31 \text{ million tons} * ¥3631 \text{ per ton} * \frac{6}{12}$$

RM and UP_{RM} represent the yearly domestic raw milk production (35.32 million tons) and unit price of raw milk (¥3631 per ton) in 2013 respectively. The milk producers are supposed to earn an extra ¥6.16 billion for raw milk.

Processor Stage:

To keep sufficient supply, the processing companies have to pay a higher price for raw milk. In the current circumstances, the dairy companies may have two strategies to face raw milk deficiency, one is to pay the extra cost themselves, the other is to transfer the extra cost to consumers.

The processing companies are likely to pay for the increasing costs themselves. If the price of milk products goes up, consumers probably choose soymilk as substitutes. To keep the market share, the dairy processing companies might not raise the price of end-products, although they have to pay a higher price for raw milk. In such a situation, the economic loss for the processing companies is the extra cost of raw milk, which is ¥6.16 billion as calculated in (12).

Consumer:

If the processing companies decide to transfer the extra cost to consumers, subsequently, the consumers have to pay more for end-products. Assuming the price of raw milk increases nationally and all the dairy processing companies raise up the price for all products. The economic loss for the consumers is the price premium part of all the dairy end-products.

$$\text{Cost}_{\text{consumer}} = b * \text{Sales Revenue} * \frac{6}{12} \quad (13)$$

$$= 10\% * ¥283.2 \text{ billion} * \frac{6}{12}$$

Assuming the price adjustment lasts for half year and it increases with 10%. '*b*' denotes the extra part of the price and 'Sales Revenue' represents the total sales revenue of dairy processing companies in the year of 2013 (¥283.2 billion). The calculation result shows the consumers have to pay an extra ¥14.16 billion for milk and milk products if a food safety crisis happens in the majority of imported milk.

Table 9. Economic effect on each party

Party	Result
Domestic milk producer	+ ¥6.16 billion
Domestic milk processing company	– ¥6.16 billion
Consumer	– ¥14.16 billion

+: positive effect; –: negative effect.

4. Discussion

4.1 Dairy Chain Structure

In this study, the analysis of the Chinese dairy chain structure focuses on the producer and processor stages, because these two stages are most likely to suffer economic loss caused by a potential food safety crisis.

The main reason of the notorious melamine milk scandal was attributed to the highly scattered milk producing structure. Some milk farmers and milk collecting stations were criticized of milk fraud, mainly caused by inadequate supervision. To solve the problem, the Chinese dairy industry announced reforms of producer and processor stages. From the statistics, it is obvious to see the number of farmers who fed the least cows has been reducing. These small farmers now feed cows and collect milk together at cow feeding districts, where more mutual supervision of milk fraud takes place. On the other hand, the large farms are growing fast and introduce advanced feeding and milking technologies, to ensure the safety and quality of milk. As a result, the concentrated producing structure is expected to be able to avoid milk fraud. Subsequently, it is expected that the probability of possible food safety crisis decreases and the milk producer stage can withstand a potential food safety crisis to a higher degree.

In terms of processing companies, many small companies quit from the market, on the contrary, large companies strengthen themselves with strong financial ability and advanced technology. After the restructuring, the deficit small companies are taken over by medium or large companies, as a result, the surviving companies can make effective use of funds. Therefore, the processing companies are able to invest in and improve their safety and quality assurance system. The restructured chain is expected to enable the processor stage to reinforce their resistance to a potential food safety crisis.

4.2 Estimation of Economic Loss

For the purpose of estimating economic loss associated with food safety contamination, the quantified dairy chain structure is used. In this study, the crisis scenarios are defined with the most reported food safety contaminations. The duration of possible food safety crisis is defined regardless of different effects of each food safety hazard. In reality, the impact may differ from different food safety contaminations. Once the contamination is confirmed, the involved companies can adjust their production plans, including raw milk cost, producing time and product volume. When calculating economic loss, the variables of production plans may have direct impacts on the result.

The cost items discussed in this study are restricted to those most directly to a food safety crisis. However, the actual costs comprise of overheads and variable costs, which are not directly associated with a food safety crisis. As a result, the actual economic loss might be higher if all miscellaneous cost items are taken into account.

4.2.1 Analysis of Domestic Food Safety Crisis

According to the estimation, the economic loss caused by a domestic food safety crisis is approximately ¥4.19 billion for producers and ¥8.2 billion for processing companies. The total amount (¥12.39 billion) is much higher than the annual budget of China Food and Drug Administration (¥1.72 billion (CFDA 2015)) and that of European Food Safety Authority (€79.49 million, approximate ¥572 million (EFSA 2015)).

Moreover, if the crisis has severe impact on consumers' health, the involved companies have to compensate their consumers. It is known that in melamine crisis, the involved companies paid up to ¥1.1 billion to injured consumers. There is no doubt the compensation caused by a food safety crisis must be extremely huge.

More severely, in case a serious dairy crisis breaks out again, the unquantified social damage would be even worse. Currently Chinese consumers have rare confidence in Chinese dairy industry. In addition, the credibility of Chinese dairy industry is still low in international market. If a serious dairy crisis happens again, it is certainly that both domestic dairy market and export trade must have difficulty in growing.

It is no doubt the dairy industry has to take efficient actions to prevent potential dairy crisis in the near future, amongst which a preventive and rapid alert system is considered to be practical and effective. Assuming the budget of ¥12.39 billion is assigned to development of a preventive system, and the amount is evenly distributed to 10 years. Thus, the annual budget of a preventive system could be approximately ¥1.2 billion on average. Comparing to the annual budget of EFSA and CFDA, the budget of ¥1.2 billion each year seems sufficient for a prevention and rapid alert system. In terms of the efficiency of a preventive system, the European Rapid Alert System for Food and Feed (RASFF**)** system can be taken as an example. RASFF takes care of sending, receiving and responding to urgent food and feed safety notifications. With the supervision of RASFF, many food safety risks had been averted before they could have been harmful to consumers. Thanks to RASFF, the EU has a low risk of facing huge economic loss caused by food safety crisis. The outcome of RASFF indicates the importance of a specialized food safety preventive and rapid alert system.

Another solution for prevention of a serious food safety crisis is sampling and detection hazards for food safety. Regular samplings and analysis for contamination at both producer and processor stages enable the milk farmers and dairy processing companies to control the quality and safety of the raw milk and milk products, and to find an effective solution at early stage in case of a severe crisis.

Thirdly, an enforcement of supervision system can assist in the early prevention. Mutual supervision among farmers at the cow feeding districts takes place. To some degree, the mutual supervision helps to avoid food fraud crisis in terms of morality. Supervision by a third party may also help to improve the working environment of the industry, and to enhance the sense of responsibility of business operators as well.

4.2.2 Analysis of Foreign Food Safety Crisis

The calculation result of food safety crisis of imported milk shows a significant impact on dairy economy. Due to raw milk deficiency, domestic processing companies may have to pay an extra ¥6.16 billion for raw milk regardless of the increasing income of farmers. In addition, consumers suffer the risks of paying ¥14.16 billion extra for milk products. Although the food safety contamination in imported milk does not have direct negative influence on farmers, it leads to more severe long-term consequences.

If the price of raw milk stays at the high level for a long time, the dairy farmers have incentives to enlarge their feeding scales in order to earn more money. When the demand remains the same, the supply increases, the price decreases. The farmers will get lower price for the same volume. If there is excessive raw milk in the market and the price would be at low level for a long time, the farmers may sell cows to reduce milk production.

The long-term consequences described above were proven by the Fonterra C*lostridium* incident (Times 2013, Ccstock.cn 2015, People.cn 2015). Thus the hypothesis is highly probable to happen if the imports are contaminated under current dairy chain structure.

Besides, to keep market share, dairy processing companies may not increase the retail prices when facing with increasing raw milk costs, despite their dilemma in the dairy market. If the processing companies keep the price of end-products at low level for a long time, they are likely to face serious financial difficulties. More severely, such problems may result in market disorder.

To solve the potential problems from imports, an importer verifying system is needed. In 2014, the General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China (AQSIQ) issued an announcement of verifying system for foreign infant formula manufacturers. According to the new regulation, all foreign infant formula manufacturers who intend to export infant formula products to China have to register through the system. After verifying the qualifications, only those who are verified by AQSIQ are eligible to export infant formula products to China. Since the implementation of the regulation, some foreign milk companies are not approved to enter into Chinese market any longer caused by insufficient safety and quality control measures. To some degree, the new verifying system prevents possible food safety crisis originating from infant formula. For further prevention, it is expected to spread the verifying system to all imported milk products.

5. Conclusion and Recommendation

The analysis of the Chinese dairy chain shows a dynamic structure, which means there are some variables under changes. Nevertheless, the current structure indicates a more concentrated cow feeding and milk processing distribution. The concentrated structure is expected to withstand a possible food safety crisis to a higher degree.

The estimation of possible economic loss caused by food safety crisis predicts a huge economic loss for producers, processing companies and consumers as well. As a result of a domestic food safety crisis, the raw milk producers are estimated to have an income reduction of ¥4.19 billion, and the dairy processing companies may have to pay an extra of up to ¥8.2 billion costs. Additionally, food safety crisis originating from imported milk and milk products results in an economic loss of ¥6.16 billion for domestic processing companies, and consumers suffer the risks of paying an extra ¥14.16 billion for the same amount of milk. More severely, the crisis may have a series of long-term consequences for dairy industry, or even lead to market disorder.

To prevent possible food safety crisis originating from domestic raw milk and dairy products, the establishment of a preventive system for the dairy industry is needed. Besides, cow feeding districts and processing companies are encouraged to implement regular sampling, in order to detect possible crisis and cope with it at early stage. It is also suggested to enforce a supervision system, in which mutual supervision and third party regulation can take place.

From the point of preventing a food safety crisis from imported milk, it is recommended to improve the importer verifying system. The current verifying system only applies to infant formula manufacturing companies, and it is expected to exert more effect when the verifying system is extrapolated to all imported milk products.

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