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CHAPTER 10

Cold-Chain Systems in China and Value-Chain Analysis

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10.1 INTRODUCTION

People are looking for new supply sources of quality raw materials such as agricultural products and fresh foods. Advanced cold-chain logistics is required to meet consumers’ increasing demand for quality chilled and frozen food. A cold-chain has cold-storage warehouse facilities, cooling operation, and logistics services to maintain the quality of local and imported chilled and frozen food and its products and to ensure them be distributed in time to various points to meet consumers’ needs.

As the international trade of agricultural products becomes fully global, the public is becoming increasingly concerned about food safety, food hygiene, and the reliability of the food supply system. For example, the 2008 melamine contamination of milk in China caused six infant deaths and stirred a public outcry about the country’s food safety system. As melamine contamination spread to different milk brands and milk-containing food manufactured by different producers, imports and sales of Chinese dairy products were banned by over 10 countries (Chan & Lai, 2009). The vaccine scandal in 2016, involving illegal vaccines worth nearly $90 million that had been sold in at least 24 provinces since 2011, caused public panic across China (Wang & Burkitt, 2016). The vaccine produced in Shandong province in eastern China was not stored and transported in the required cold-chain conditions; thus patients taking the ineffective vaccine could suffer severe side effects or even death. Concerns were raised on food and medicine safety regulations and on the transport conditions and traceability along the global supply chain.

China has a huge consumer population for agricultural products, and currently accounts for about 60% of the world’s total vegetable production, 30% of fruit and meat production, and 40% of eggs.
and aquatic products. Every year there are about 400 million tons of agricultural products in circulation (Zhiyan Research, 2016). However, cold-chain supply for perishable products has not kept up with the rapidly expanding market. Temperature-sensitive biopharmaceutical products also require cold-chain supply. However, at present, the biopharmaceutical cold-chain monitoring system scarcely exists in China. Li, Li, and Shuo (2008) discussed the “broken cold-chain” problem in the transportation of products from the pharmaceutical manufacturing factory to patients. Temperature-sensitive products arrive damaged or degraded because of a broken cold chain, which arises from problems concerning management and regulation mechanisms. Rossetti and Handfield (2011) reviewed the radical changes of biopharmaceutical supply chains and identified the major drivers of associated management. Obviously, both the perishable food and biopharmaceutical markets are in urgent need of improved cold-chain systems to ensure the quality and safety of products during the distribution process.

According to the definition by the Global Cold Chain Alliance, “cold chain” refers to the management of the temperature of perishable products in order to maintain quality and safety from the point of slaughter or harvest through the distribution chain to the final consumer. Research on cold-chain issues can be categorized into four topic areas: (1) operations in the cold chain (e.g., production, distribution, storage, and inventory); (2) policy and legislation (e.g., some related standards such as HACCP, ISO22000, and GMP); (3) management (e.g., supply chain coordination, quality management, revenue management, and performance evaluation); and (4) technology (e.g., tracing technology and temperature control).

The cold-chain system is a type of supply chain system whose core requirement is a low-temperature environment that maintains the quality of perishable products. The cold-chain system has a representative supply chain structure with a close relationship to the requirement of temperature. In contrast to a general supply chain system, the cold-chain system has three “T” requirements, namely “time,” “temperature,” and “tolerance.” The quality of refrigerated products decreases over time. In warm temperatures (20–60°C), the growth rate of some microorganisms, for example, doubles for each 3°C rise in temperature (Cengel & Ghajar, 2011). The temperature and time constraints define the complexity of the cold-chain system compared with general supply chain systems.
Time-perishable products require a higher level of coordination in the processes that operate along the stages of a cold-chain system.

This chapter attempts to extend the concept of value chain to build a framework for the cold-chain value system of perishable product markets. We focus on the supply systems of the cold-chain industry and attempt to identify how the performance of the cold-chain can be improved from the supplier relationships. The remainder of the chapter is organized as follows. Cold-chain market demands are explored in detail in Section 10.2. The relevant research of the value-chain system is introduced and applied to the cold-chain industry in Section 10.3, followed by an examination of China’s cold-chain system in Section 10.4. On the basis of an analysis of demand and supply, some implications for the cold-chain industry in China are identified and discussed in Section 10.5. Section 10.6 concludes the chapter.

10.2 OVERVIEW OF COLD-CHAIN MARKETS AND SUPPLY CHAIN CHALLENGES

The cold chain is a supply chain with temperature control. The type of cold chain is categorized by the temperature requirements of the products involved. Maheshwar (2008) classified refrigerated cargoes as food or non-food items and as chilled cargoes and frozen cargoes according to the storage environment. Chilled cargoes, also known as perishable cargoes, are stored above $-10^\circ$C. Correspondingly, frozen cargoes are stored under $-10^\circ$C, usually under $-18^\circ$C (European Council Directive, 1989). In practice, the cold-chain industry is usually differentiated into three categories: fresh agricultural products, frozen processed products, and pharmaceutical products (given in Table 10.1), which each have

| Table 10.1 Categories of cold-chain products |
|---------------------------------------------|
| Category                      | Temperature requirement | Product specification |
| Fresh agricultural products  | 0–20°C                   | Vegetables, fruits; meat, poultry, eggs; aquatic products, horticultural products |
| Frozen processed products    | $\sim -18^\circ$C, ($\leq -15^\circ$C) | Frozen foods, poultry, and other packaging cooked food; ice-cream and dairy products; fast-food raw materials |
| Biopharmaceutical products   | 2–8°C                    | Vaccine, antibiotics, biological products, and food products |
different temperature requirements. Fresh agricultural products vary from 0°C to 20°C, biopharmaceutical products need strict temperature control between 2°C and 8°C, and frozen processed products must be around −18°C and not higher than −15°C.

To illustrate the current status of cold-chain markets in China, we specifically analyze three categories in turn below by introducing the current market capacity and distribution, the requirements of the cold-chain system, and a summary of the existing problems and challenges.

10.2.1 Fresh Agricultural Products

Fresh agricultural products comprise fruit, vegetables, meat, milk, and dairy products. From 2008 to 2014, China’s agricultural products in the cold-chain market experienced an annual growth of 35%, reaching 1.6 trillion RMB in 2014. Domestic meat consumption in 2001 of 61 million tons increased to over 87 million tons in 2014. Fig. 10.1 illustrates the

![Figure 10.1](image_url)

**Figure 10.1** Distributions of PCC (kg/year) and PCO (kg/year) of agricultural products. Directions refer to generalized geographical regions of China. *Data are compiled from China Statistical Yearbook 2015.*
per capita demand (unit: per capita consumption, or PCC) and supply (unit: per capita output, or PCO) of each niche agricultural product market in the four regions of China. The vegetable and fruit market is relatively balanced in demand and supply. In contrast, the milk market is quite imbalanced as the output is mainly from China’s western and northeastern regions, but the more developed eastern region has higher consumption. Thus, milk products need cross-regional transportation and distribution from the western and northeastern regions to the eastern region cities. In general, China logistics system is undergoing regionalization (Liu, Wang, & Yip, 2013).

Different cold-chain products have distinct supply systems and may thus have specific requirements for processing, transportation, and storage. However, they all require uninterrupted temperature control and quick delivery. Moreover, fresh agricultural products are necessities for peoples’ daily lives and have a steady demand. Therefore, the circulation of fresh agricultural products is often on a large scale with a low-elasticity demand. For these reasons, fresh agricultural products require a safe, efficient, and robust cold-chain system.

According to statistics from Cold Chain Logistics Committee under China Federation of Logistics & Purchasing, in 2015, the rates of refrigerated transportation and storage for fruit and vegetables, meat, and aquatic foods under the whole cold-chain condition in China were 22%, 34%, and 41%, respectively. In contrast, the rate of circulation of perishables under cold-chain conditions in Europe and North America was over 95%. The rates of loss of fruit and vegetables, meat, and aquatic foods during the logistics process in China were as much as 15%, 8%, and 10%, while that in developed countries was less than 5%, and only 2% the United States (Ding, 2010). The high rate of loss of fresh agricultural products in China is due to the dispersed and small size of farm supply, incomplete refrigeration facilities, a lack of professionalized logistics services, and poor organization of circulation. For example, one critical process in the cold chain is precooling, which restrains the respiration of fresh agricultural products to avoid decomposition. Precooling requires investment into dedicated cold-chain facilities, but owners of small farms cannot afford such investment for fresh agricultural products. Moreover, the wide geographical distribution of supply sources for products such as milk aggravates the difficulties of achieving fast delivery.
10.2.2 Frozen Processed Products

National Bureau of Statistics data show that between 2006 and 2014, the output value of China’s frozen-food industry attained an annual growth rate of 21%, reaching 71.5 billion RMB, thereby becoming the fastest-growing food industry subsector. Statistics from the China Beverage Industry Association indicated that national cold beverage production reached 25.4 million tons in 2012, with an average annual growth of 16% from 2002 to 2012. Seasonal variations in the consumption of ice-cream and dairy products have gradually disappeared.

Quick-frozen products and ice-cream and dairy products are temperature controlled at $-18\,^\circ C$ or below. The temperature must be stable and maintained at all points within products, but may fluctuate briefly upward by no more than $3\,^\circ C$ during transportation.

10.2.3 Biopharmaceutical Products

Biopharmaceuticals include products such as medical drugs, vaccines, blood products, and interferons. China’s biopharmaceutical industry has undergone recent rapid development. The total industry output value was only 15.8 billion RMB in 2002, but had reached over 134.6 billion RMB in 2012 (China Pharmaceutical Yearbook, 2012). Taking vaccines as an example, the outbreak of the SARS (severe acute respiratory syndrome) epidemic in 2003 stimulated the demand for flu vaccine in China: the consumption of flu vaccine was no more than 5 million doses in 2002, whereas more than 15 million doses were administered in 2004 (Yi, Zhang, Wang, Li, & Wang, 2009), which further increased to more than 40 million in 2015.

Biopharmaceutical products are very sensitive to temperature and have the strictest temperature requirements of between $2\,^\circ C$ and $8\,^\circ C$. Biopharmaceuticals are sensitive biological substances and are subject to loss of potency with time (Gazmararian et al., 2002). They must be stored properly from the time of their production until the time that they are used to treat patients. Exposure to either excessive heat or cold will result in loss of potency. To maintain product quality, all biopharmaceuticals must be stored continuously at the appropriate temperature during the whole process from production to consumption. The guidelines “Good Distribution Practices (GDP) for Pharmaceutical Products” by the World Health Organization in 2010 show that the distribution process has not been properly emphasized regarding the “establishment, development, maintenance,
and control over the activities involved.” A further complication of the shipment of biopharmaceutical products is that they are often transported in a multibatch, small-lot pattern, but require fast delivery.

### 10.2.4 Problems and Challenges

The time-perishable and vulnerable features of refrigerated products commonly require an uninterrupted control of temperature and quick delivery. The China Supply Chain Council conducted a survey of 378 logistics executives involved in the transportation and storage of temperature-controlled goods (Fig. 10.2). The survey revealed that the two most frequently encountered problems in the cold-chain supply in China were the quality of service and the quality of transport. The results showed that the key areas where cold-chain service providers could improve, as recognized by most companies, were those of service processes and cost-effectiveness. Management, equipment quality, and lead-time were also considered to be important aspects. Price, range of services, and service levels were identified as being the most important criteria when companies select a cold-chain service provider.

Table 10.2 illustrates the distribution costs and gross profit ratios of cold-chain markets in China. Although all the average gross profit ratios of refrigerated product industries are relatively high, especially that of the biopharmaceutical sector, the high distribution costs account for a considerable share of sales revenue.

![Figure 10.2 Main problems of the cold chain in China. Compiled from the survey by China Supply Chain Council in 2006.](image-url)
10.3 Perishable Products, Cold-Chain System, and Value Chain Analysis

Previous studies on perishable products (e.g., Beilock, 1981; Pasternack, 1985) focused on specific segments such as transportation problems and pricing strategies. With the increasing public awareness of food quality and drug safety, the traditionally fragmented perishable product markets have undergone rapid structural changes in the last two decades. The trend in research interests has now shifted to quality control, product traceability and supervision, and coordination in the entire cold chain. Study showed that food safety measures in developed countries have a strong impact on export-oriented supply chains in developed countries (Henson, Brouder, & Mitullah, 2000). Cold chain is changing from a system dominated by producers/exporters (often run by government bodies and producer groups) feeding products into traders and wholesalers toward a system dominated by end-customers (Drewry Shipping Consultants, 2003). Research also focused on the increasing importance of biopharmaceutical cold-chain management as a result of the growing market, the requirements for storage and distribution, the monitoring of temperature, and regulatory trends (Bishara, 2006). It was also found that the need for appropriate equipment to store and transport vaccines in developing countries led to innovations in refrigeration equipment as well

### Table 10.2 Distribution costs and gross profit ratios of cold-chain markets in China (2009)

| Items                                           | Fresh agricultural products (milk and dairy only) | Frozen processed products | Biopharmaceutical products |
|-------------------------------------------------|--------------------------------------------------|---------------------------|---------------------------|
| Number of enterprises                           | 812                                              | 301                       | 768                       |
| Total profit from sales revenue (RMB billion)   | 33.026                                           | 4.522                     | 22.719                    |
| Total selling and distribution cost (RMB billion) | 19.416                                           | 1.679                     | 5.619                     |
| Average gross profit ratio (%)                  | 23.5                                             | 16.9                      | 30.6                      |
| Ratio of distribution cost to sales profit (%)  | 58.8                                             | 37.1                      | 24.7                      |

Compiled from Global Economic Data, Indicators, Charts & Forecasts (CEIC) China Database; (3) = (2)/(1).
as adoption of high-performance vaccine cold boxes and carriers (Lloyd & Cheyne, 2017).

Generally, there are two categories of study that address this new issue regarding perishable products, the research on cold chains and supply relationship, and the research of value-chain analysis. In terms of the cold supply chains, an analytical model of product quality and supply configurations was developed with an optimal batch size of storage, and addressed the energy and environmental concerns of cold chains (Zanoni & Zavanella, 2012). The survey of the industry experts’ insights about European food service supply chains showed that the industry is aiming at creating customer value (Darkow, Foerster, & von der Gracht, 2015). The cold chains of aquatic products were also discussed and it was shown that within certain temperature range, lower temperature brings higher profit level, and their findings encouraged better temperature control of cold chains (Wu, Deng, Zhang, & Zhang, 2015). One type of cold chains, i.e., the pharmaceutical supply chain was studied with a systematic review of research on managerial issues, and the research direction about structure of pharmaceutical supply chains was highlighted (Narayana, Pati, & Vrat, 2014). Regarding the vaccine cold-chain system, three key issues were identified limiting this cold-chain system through experiment studies in 10 countries, i.e., insufficient cold-chain capacity, lack of optimal equipment or technology, and inadequate temperature monitoring and maintenance (Ashok, Brison, & Letallec, 2017).

The goal of supply chain management (SCM) is the creation of both value and satisfaction for customers and the improvement in the competitive advantage of supply chain partners (Cooper, Lambert, & Pagh, 1997; Langley & Holcomb, 1992; Mentzer et al., 2001). The implementation of SCM requires the integration of processes from sourcing, to manufacturing, and to distribution across the supply chain. Four critical elements of supply chain strategy that impact the achievement of supply chain integration and performance consist of strategy vision, insourcing—outsourcing strategy, supply chain segmentation and architecture design, and product and service design.

The insourcing—outsourcing strategy manages outsourced operations to establish core competencies and maintain competitive advantages. It links closely to the firm’s strategic vision and the ways in which value can be created for customers. Supply chain architecture addresses the design of both the physical structure and conceptual structure of the supply chain. It is necessary to meet specific customer needs at the required service levels. It has been found that Chinese third-party logistics
providers’ customer orientation significantly influences improvements in customer—firm logistics (Tian, Ellinger, & Chen, 2010). In addition, it was also been addressed that opportunistic behavior by buyers could reduce incentives for private investment in cold-chain infrastructure, but that long-term commitment by chain partners would strengthen the potential for private markets to provide cold-chain services (Salin & Nayga Jr., 2003).

The strategic perspective on SCM emerges from Porter’s theory of value chain and value system. Porter (2001) used the terms “value chain” and “value system” to discuss company strategies in terms of the management of relationships with other firms. The value chain describes the full range of activities involved in forming a product or service from conception, through the different phases of production, and delivery to end users. The value system basically extends the idea of the value chain to interlink organizational value chains (Kaplinsky & Morris, 2001). Value-chain analysis is a powerful tool for strategic planning as it allows the value generated along the chain to be scrutinized to increase profit margin. By exploiting the upstream and downstream information flowing along the value chain, firms may try to bypass intermediaries, create better business models, or make improvements in their value-creation system. Nevertheless, it is worth noting that the profitability of segments changes over time and with changes in business environment. Also, customer value theory indicates that what customers value changes over time (Flint & Mentzer, 2000; Woodruff, 1997). Therefore, it is critical to understand the dynamics of the value-chain system.

The recent research of value-chain analysis has been extended to material flows and supply chains. For instance, the methodology of value-chain analysis was used to study the combination of material flow analysis of the UK aluminum sector with a consideration of the economic dimension of those material flows (Dahlström & Ekins, 2007). Besides, a conceptual model for the scrap tire reverse supply chain was proposed and the value-chain analysis method was applied to the scrap tire reverse supply chain (de Souza & D’Agosto, 2013). It was also shown that establishing nutrient cycles may solve the problem of efficient management of nutrients and lead to innovative added-value chains with a higher added-value (Maß, Grundmann, & Und Polach, 2014). The material flow and value-chain analysis method was used to quantitatively analyze the value flow of iron resources in China (Yan & Wang, 2014).
10.4 SUPPLY CHAIN INTEGRATION STRATEGY OF THE COLD-CHAIN SYSTEM

10.4.1 Value Chain View of the Cold-Chain System

From the perspective of the value chain, cold chains (or cold supply chains) are a series of value-adding activities that occur under temperature control. The cold-chain system is a combination of primary activities, from material supply to the sale of products with the management of temperature, and supporting activities include technology, infrastructure, information and finance, and human resources. Fig. 10.3 illustrates the value-chain system of the cold-chain industry. Similar to general supply chains, a typical cold chain consists of raw material suppliers, manufacturers, distributor retailers, and third-party logistics providers. In contrast to general supply chains, technologies are especially critical to the cold-chain industry as the cold-chain system integrates advanced refrigerated and frozen equipment and technology, dynamic temperature-tracking and monitoring technologies, and developed logistics technology.

The center of the system is the product flow, beginning from raw material supplies to the finished products entering the consumption stage. The value-added activities along the cold chain can be decomposed into seven primary activities, namely materials supply, manufacture, process, storage, transportation, distribution, and sales. The bottom layer in Fig. 10.3 specifies the primary activities. The success of the flow of products along the cold chain requires close cooperation among suppliers, manufacturers, logistics service providers, and dealers. A single enterprise can perform one, several, or even all of the primary activities.

![Figure 10.3 Value-chain system of the cold-chain industry.](image-url)
Process adds value to products by maintaining product quality along supply chains. In the door-to-door delivery process, refrigerated products should be packaged under controlled temperature conditions, not exposed to heat, and prevented from variations in temperature. Storage generates time value by solving the temporal mismatch between demand and production. Transportation creates value by solving the spatial mismatch of demand and production. In the cold-chain system, temperature fluctuation is the major reason for deterioration in product quality, whereas transportation is the most difficult aspect regarding the maintenance of steady, low temperatures during the passage of the product from the manufacturing factory to end-customers. The transportation of refrigerated cargoes differs from that of general cargoes because it needs efficient refrigerated transportation, maintenance of refrigerated storage, and an integrated cold chain to preserve the quality of foods/products. Good, timely distribution increases product value through meeting consumers’ diverse demands. Sales create value through facilitating consumers.

The biopharmaceuticals industry has a relatively long value chain, comprising research and development (R&D), clinical trials, production, distribution, and sales. The pattern of value creation in the biopharmaceuticals value chains is “u-shaped,” whereby high levels of profit are concentrated in the upstream R&D and in the downstream sales.

A comprehensive value-chain analysis can determine the profitability of activities and identify the allocation of profit along the value chain. Such an analysis can also help to focus on the core business and, more importantly, to take effective measures impacting the upstream and downstream operations in order to maximize the profit. As the profitability of segments can change both over time and with changes in the business environment, firms should also select a supply chain strategy in accordance with the market structure.

10.4.2 Analysis of the Supply Chain Structure

Fig. 10.4 illustrates some typical supply chain structures of the cold-chain industry in China.

Manufacturers in the fresh agricultural food supply chain (second column of Fig. 10.4) are farmers, who, although numerous, generally operate at a small scale and have no market power in China. The upward suppliers are the seed and feed producers, and the traditional downward retailers are the supermarkets and grocery stores. Raw agricultural
products are packaged for transportation or processed for easier storage by big food producers, and sales and product logistics are usually organized by numerous distributors. The big food producer or distributor in China is usually the leading/key firm in the supply chain. Thus, the agricultural food market is almost perfectly competitive in each segment. Most farmers and distributors in China are too small and have no capabilities to invest in dedicated cold-chain facilities and assets.

The frozen-product industry (third column of Fig. 10.4) in China is a monopolistic competition market with several well-known brands. The food manufacturer is the core enterprise in the supply chain and is oriented to customer demands. The frozen-food manufacturers adopt different sales channels, either through distributors or through subsidiaries for direct sales. Frozen products have certain special infrastructural requirements for distributors, such as refrigeration warehouses and cold-chain transportation equipment. If these and other cold-chain resources are relatively scarce in the industry, the distributor will have high bargaining power owing to a lack of substitutability. For that reason, the distributor pattern is vulnerable under a market environment characterized by uncertainty.

The biopharmaceuticals supply chain (fourth column in Fig. 10.4) includes R&D institutions, manufacturers, pharmaceutical distributors, and hospitals as the retailers. The distribution segment of the cold chain involves multiple parties and thus the subcontracting problem increases

| Value-creating segments | Fresh agricultural products | Frozen processed products | Biopharmaceutical products | Integrated supply chain |
|-------------------------|-----------------------------|--------------------------|---------------------------|------------------------|
| Supply                  | Seeds, feed producers       | Farmers                  | Biochemical reagents      | Suppliers              |
| Manufacture             | Farmers                     | Manufacturers            | Manufacturers             | Manufacturers          |
| Process                 | Food producers              |                          |                          | Integrated third-party logistics providers |
| Circulation             | Distributors                | 3PL                      | Self-distribution         | Retailers              |
| Retail                  | Retailers                   | Hospitals                |                           | Retailers              |
| Consumers               |                             |                          |                           |                        |

**Figure 10.4** Supply chain structures of cold chains in China.
risk. Furthermore, the multibatch, small-lot shipment pattern does not enable an economic scale of transportation to be achieved.

10.5 CASES IN CHINA

In this section we review four cases in China and illustrate their supply chain structures (Fig. 10.4).

10.5.1 China Oil and Foodstuffs Corporation: Integrated Cold-Chain Services

China Oil and Foodstuffs Corporation (COFCO) is China’s largest group in food processing, manufacturing, and trade. Founded in 1952, COFCO is a state-owned enterprise specializing in the import and export of cereals, oils, and foodstuffs. Accompanied by improvements in the market mechanism in China, COFCO began its product-based diversification process in 1992, transforming from a traditional trade agent to a grain and oil food-processing company. Today, COFCO is a diversified group involved in a range of activities including the foodstuffs business, finance, transportation, warehouses, and port facilities.

With the elimination in 2008 of the control on dealing commodities after entry to the WTO, COFCO had a second shift in strategic positioning in the context of international competition. COFCO oriented its position to become the main channel within China’s grain market and trade, the leader of food supply integration, and an internationally competitive grain merchant. It proposed an integrated supply chain strategy early in 2009, with the aim of building a comprehensive plant—process—logistics—trade industry pattern.

COFCO’s integrated supply chain strategy can be divided into two aspects. One is the vertical integration of the single-product supply chain, specifically, integration of the processing of raw materials and supply services upward, and entry into the sales areas. Through the vertical integration of products, services, and information between the upstream and downstream processes, COFCO tightly controls the food supply and distribution process and internalizes the supply process. The other aspect is the horizontal integration of different industry chains, whereby COFCO integrates the logistics, finance activities, and sales channels of various industry chains.

The integration strategy drives the structural changes in ownership investment, sales channels, and the supply system. In the main, COFCO
completes the strategic layout through large-scale investment, mergers, and acquisitions. On the one hand, COFCO invests in grain and meat processing bases in different regions of China and collaborates with grain-planting bases and farms to improve the supplies of raw materials and to smooth the cold-chain logistics process. On the other hand, it takes over well-known food brands to enter the downstream sales field. Furthermore, COFCO attempts to make its own sales in online brand stores rather than through common agencies, such as grocery stores. COFCO has established a B2C e-business platform Womai to reach customers directly and to create brand recognition.

A supply system with integrated cold-chain services is the key success factor of food supply chains. COFCO conducts strategic planning for its logistics system and the layout of logistics nodes. COFCO’s logistics system is composed of warehousing and processing centers in producing areas, distribution centers in sales areas, and transshipment centers in seaport and riverport terminals. As an example, COFCO’s food logistics park in Shenzhen is the core part of its cold-chain supply network in Shenzhen and Hong Kong, providing professional cold-chain services for its own food supply chain and for other food companies. The park has 50,000-ton-capacity refrigeration warehouses, a 150,000 m² normal-temperature warehousing and distribution center, and a 50,000 m² food-processing and service center. These facilities allow COFCO to provide comprehensive integrated cold-chain services, including storage, processing, distribution, and regional transshipment services.

COFCO integrates raw material suppliers, distributors, and logistics providers to reduce both production costs and transaction-related costs. The value of brand is another incentive for forward integration.

10.5.2 Yili Group: Backward Integration

Yili Group is a leading brand of dairy products in China. It is engaged in the processing and manufacturing of milk products, including fresh milk, milk powder, and ice-cream. Compared with other dairy companies, Yili Group has the competitive advantage of being the largest high-quality source of milk in northern China. In its internal organization, Yili Group takes a divisional organizational form consisting of the liquid milk division, the milk powder division, the yogurt division, the raw milk division, and the ice-cream and beverage division. Each division has its subsidiary
companies and is in charge of the delivery of products to retailers. In the early stages, Yili Group’s distribution network was production site based and supported with different transportation modes.

As the geographical distribution of milk production and consumption is imbalanced, long-distance transportation is time consuming and costly. More importantly, it cannot meet the increasing requirement of freshness and quality in the final market. With market expansion, the original distribution network is no longer suitable for future development. For that reason, the major challenge for Yili Group was how to effectively shorten the distribution time to its end-customers. Customer orientation and quality is the core value of Yili Group. To ensure the quality of its products, Yili focuses on the control of upstream milk supply and adopts a backward integration strategy.

The integration of upstream pastures is seen as a means of achieving quality control and cost reduction. Yili Group places much effort in developing its own pastures through self-building, acquisition, and collaboration. Also, production factories are built in the major cities, which have the largest milk consumption. Through collaboration with both local dairy farmers and the government, Yili Group has built a network of regional milk-producing bases in more than 10 cities. This has greatly shortened the transportation distance and reduced the distribution time for delivering cold-chain products to the market.

Yili Group has implemented a flat structure to achieve quick responses. For example, for liquid milk, the milk-source—factory—distribution—centralized-retailer structure is the general pattern used. A distribution center has been built to meet the needs of small- and medium-sized customers in the appropriate time frame. In the milk production area, another supply pattern is directly from the factory to the consumer. The elimination of a distributor level simplifies the cold-chain process and thus reduces distribution time and ensures the quality of the product.

To ensure the quality control of each process, Yili Group utilizes an enterprise resource planning system to integrate the information from fresh milk stations to retailers. In the upstream, Yili Group establishes a data record for each cattle unit for the convenience of trace-back. In the downstream, the inventory information of retailers is transmitted in real time to Yili Group. Transportation information is obtained through tracking milk lorries using a Global Positioning System.
10.5.3 China Railway Express Co. Ltd. Supply: Integrated Transportation

Fast, service-demanding transportation has increased the opportunity for the integration of modes via joint ownership or special arrangements, i.e., joint distribution and integration through third-party logistics. China Railway Express Co. Ltd. (CRE) is the largest domestic rail express company and a subsidiary of China’s Ministry of Railways. CRE has developed an extensive rail transportation network and auxiliary highway networks. Its core businesses include parcel delivery, express shipments, and contract logistics. CRE has operated a cold-chain supply service since 2007 based on its original package-delivery business. This service was widely welcomed by manufacturers of high-value perishable products, including the world's largest chocolate manufacturer (Mars China), several state-owned biopharmaceutical products research institutes, and other biopharmaceutical enterprises.

CRE investigated the cold-chain market and finally focused on two niche markets, one being the biopharmaceutical product market and the other being the high-end food market. Both of these markets are high profit and have strict requirements for temperature control and short delivery time.

Shipment of candy products requires controlled temperatures between 0˚C and 20˚C. Mars China also wanted to shorten their distribution time to the southern and northwestern China markets. For biopharmaceutical products, such as vaccines and insulin, the transportation temperature must be confined to 2–8˚C. Both candy products and biopharmaceuticals need protection from moisture, dust, and odors as well as from theft and damage.

To meet these requirements, CRE chose railway baggage cars and package express trains as the main means of transportation, along with road feeder services. Based on advanced cool-storage refrigeration technology, CRE designed small containerized cargo units (SCCUs), which are a palletized, small cool-storage refrigeration container needing no internal power source. The container is equipped with cool-storage refrigeration slabs chilled to the necessary temperature and can maintain a constant temperature for 48–96 hours. The outside plastic material of these containers is lightweight but high strength, which minimizes shipping weight but provides sufficient durability to withstand the rigors of transportation.

The cold-chain supply costs can be divided into three parts: variable transportation costs, refrigeration costs, and management fees. From the perspective of cold-chain business activities, there are six main aspects,
namely, freezing and refrigeration, packaging, transportation, R&D, information technology, and management. The refrigeration component refers to the energy consumption of freezing slabs and the operating costs of refrigeration equipment. Packaging includes equipment costs such as refrigeration slabs, depreciation costs, and packaging material costs. It is worth noting that transportation costs consist of two parts, namely, the cargo cost and backhaul cost. Table 10.3 provides information on the cost of each process. For the transportation cost, we assume that the transportation distance is 3000 km at a container turnover rate of 10 days.

Prior to using the SCCUs, Mars China had relied on trucks to deliver its chocolates from Beijing to Xinjiang Province, on the far western border of the country. Shipments that measured greater than 9 m$^3$ were shipped directly to the city of Urumqi—a journey of about 9 days. Those measuring less than 9 m$^3$ required two transfers, in Xi’an and Lanzhou, which lengthened the delivery time to about 14 days to Urumqi and to 14–18 days to surrounding areas.

With the introduction of CRE’s SCCU model, transit times have been substantially shortened. It now takes just 4 days for Mars China’s shipments to reach Urumqi and only 4–6 days for delivery to surrounding cities. Both the transit times and the time taken to receive signed “bills of lading” from the consignees have been reduced by more than 50%.

### 10.5.4 Cross-Border Fruit Transport

The Association of Southeast Asian Nations (ASEAN) is the key cooperation region under the Belt and Road Initiative (BRI) proposed by China.$^1$ China–ASEAN trade increased from US$192.6 billion in 2008

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Table 10.3 Cost structure of third-party cold-chain supply providers in China

| Unit                  | Unit cost (RMB/km) | Percent of total cost |
|-----------------------|--------------------|-----------------------|
| Refrigeration         | Per year           | 25                    | 4                     |
| Package               | Per round trip     | 21.31                 | 15                    |
| Transport             | Per container      | 1015                  | 44                    |
| R&D                   | Per year           | 15.05                 | 2                     |
| Information technology| Per year           | 15.4                  | 2                     |
| Management            | Per year           | 519.2                 | 23                    |

Based on an unpublished survey of a fresh food transport project (2009).

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$^1$ The BRI refers to the Silk Road Economic Belt and the 21st century Maritime Silk Road.
to US$452.2 billion in 2016. In this context of booming trade, China is increasingly sourcing from the region, especially from the Greater Mekong Subregion (GMS) countries. Besides two provinces of China (specifically Yunnan Province and Guangxi Zhuang Autonomous Region), GMS includes five countries located in the center of Indo-China Peninsula, namely Cambodia, Laos, Vietnam, Myanmar, and Thailand. Cross-border trade has improved significantly in the last years. There is a huge demand in China for tropical fruits, flowers, and other agricultural products from Thailand and Vietnam.

Fruits and other agricultural products from Thailand are traditionally exported to China by sea transport. Fresh fruits stored in refrigerated container are shipped from Laem Chabang Port to Guangzhou Port and then transshipped to Guangzhou Jiangnan Market. Through this largest fruit market in China, fruits are finally distributed to cities of South China. The white dashed line in Fig. 10.5 shows the fruit cold chains of ocean transport.

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2 Guangxi is located in the South China and has a unique location connecting China to Southeast Asia. With the secure and efficient cold chains that connect major seaports and road junctions, Guangxi is key to linking up the food sectors in the Mainland, the ASEAN countries, and other countries. Under the Beibu Bay Development, Guangxi will continue to play a pivotal point as a trading center in the China-ASEAN.
shipping route, i.e., Laem Chabang–Hong Kong–Guangzhou. It takes about 6–7 days from the export port to the import port. Due to the economies of scale of transport costs, currently sea transport is still adopted in large scale among transnational fruit trade. China bulk port system is advancing to handle higher import trade (Yang, Wang, Xu, & Zhang, 2017).

Fig. 10.5 illustrates the fruit cold chains from Thailand to China (by sea) and from Thailand to Laos to Vietnam to China (by road). Cold chains along the One-Belt-One-Road are multimodal.

Some fresh fruits, such as durian, mangosteen, and longan, are perishable, time sensitive, and relatively high priced. As these fruits require more rapid and more efficient delivery to the consumers in China, they are increasingly transported through land transport by refrigerated container trucks. Fruits from orchards in South and Southeast Thailand are converged by fruit wholesalers or exporters to Bangkok, and then loaded on refrigerated trucks by cross-border logistics service providers. There are two main corridors for fruit cold chains to Nanning in China by way of Laos and Vietnam, known as R9 and R12. They are identified by blue (gray in print version) line in Fig. 10.5. R9 starts from Bangkok, passes through Mukdahan–Savannakhet border crossing between Thailand and Laos, Dansavan–Laobao border crossing between Laos and Vietnam, Langsan–Youyiguan border crossing between Vietnam and China, and finally reaches Nanning in Guangxi Province of China. The total length of corridor R9 is 1931 km, and the average transport time is 33.5–37.5 hours. The total length of corridor R12 is 1748 km, for trips of 28.5–30.5 hours. The borders on R12 are NakonPhanom (Thailand)–Thakhek (Laos), Naphao (Laos)–Chalo (Vietnam), and Langsan (Vietnam)–Youyiguan (China). R12 is the fastest corridor between Bangkok and Nanning, which is now favored by most fruit logistics service providers. These two transnational land transport corridors have different highway grade, pavement quality, and speed limit in different segments. Most segments of the highways are single lane. In particular, segments of pavement near Naphao border in Laos are currently severely damaged. Thus, traffic congestions happen occasionally, which delays the delivery of perishable fruits.

The road infrastructure network within the ASEAN countries determines the accessibility of the international land transport corridors, while the cross-border transport mechanism within the ASEAN countries influences the efficiency of transport procedures. GMS countries signed and implemented GMS Cross-Border Transport Facilitation
Agreement (CBTA). The agreement focuses on transport and trade facilitation measures that enhance connectivity across international borders and improves linkages among the six GMS countries for increased cross-border trade and investment. It covers various measures such as elimination of intermediary stops or transshipment, one-stop single-window customs inspection, facilitation of movement of persons and goods, and standardization of requirements for infrastructure and vehicles. When fully in place, the CBTA is expected to greatly reduce the amount of time spent in crossing borders and promote cross-border and third country trade.

Nevertheless, border issues are still a main barrier for regional cross-border trade. The refrigerated container needs to be replaced on another truck before enter the third country. For example, Thailand and Vietnam freight vehicles are not allowed to enter each other through Laos, because vehicle standards diverge and the road sizes differ. Cargoes or containers need to be reloaded on local vehicles in a car park near the border. Also, documents for customs clearance need to be reprocessed when crossing the border. These operations bring increases of both transit time and vehicle switching and container handling cost. Furthermore, there is a significant lack of temperature-controlled equipment and facilities for cross-border cold-chain logistics. As a result, large amounts of perishable goods are wasted.

In the foreseeable future, there will be tremendous market growth of fresh tropical fruits from ASEAN countries in China. With the closer collaboration between China and ASEAN under the Belt and Road Initiative, improvements of cross-border fruit transport in the regional situation are expected. It is also expected to boost the infrastructure connectivity and facilitation of cross-border trade among member states of ASEAN.

10.5.5 Key Findings of Case Studies

It is crucial to match the supply chain strategy with specific products for the manufacturing company in the cold chains. In Fig. 10.6, we summarize a simplified framework of supply chain strategy selection. The two dimensions based for selection are value created in the manufacturing process and the interdependency with the upstream and downstream firms. The former dimension is derived from the perspective of profit margin in the value chain. It reflects the profitability of the producing
segment. The latter dimension is the relationship of the manufacturing company with upstream and downstream partners in the supply chain. It reflects the product’s competitive edge.

Low-value-creation manufacturers with low-value-creation-producing processes intend to outsource cold-chain supply activities beyond production to reduce costs. For example, the biopharmaceuticals manufacturer, which has a relatively low profit margin in the value chain, is prone to outsourcing the transportation and distribution of drugs. As it is closely related to the upstream firms, the company might choose to buy advanced product technology to improve the quality of the product and productivity, or, in the case of the big firms, to invest in R&D.

Manufacturers enjoying the high value created in the producing process have the incentive to adopt supply chain integration to maximize the monopoly profit. Backward integration is suitable for firms that desire dedicated assets and a reduction in supply uncertainty. The backward integration strategy is more appropriate for firms who want to create the value of brand.

This can be used to explain why manufacturers in different sectors within the food industry exhibit different preferences for cold-chain organization. The frozen-product and other processed-food producers choose a forward integration strategy to pursue greater profit margins and to quickly respond to customer demands. They cut out the distributor level and sell directly to the retailer or customer to achieve forward integration. The fresh-milk producer needs quality control from the raw sources, and manufacturers are prone to integrate upstream supply and run their own refrigerated logistics, even suffering large investments and high logistical costs to do so.

Figure 10.6 Matching supply chain integration strategy to cold-chain products.
10.6 CONCLUSIONS

In this study, we have applied value-chain analysis and examined the supply chain structure. The “value-chain analysis” is product oriented and is suitable for a single product. The “supply chain structures” can provide information about different organizations and their behaviors in different market structures. Diagrams of supply chain structures can illustrate the interactions between organizations along the value chains.

We have analyzed integration in cold chains in China. In particular, for three different cold-chain products, different integration strategies will be adopted. We analyzed the integration cases of China’s three leading cold-chain service providers. Based on the value-chain analysis, we proposed the policy and direction for the cold-chain industry in China.

There is huge potential for growth in the emerging cold-chain market in China, especially with regard to increasing the rate of cold-chain supply. With the growing requirements for high-quality food by end-consumers and for increases in quality assurance from food businesses, we believe that the rising and urgent demand will drive a rapid increase in the development and adoption of cold-chain supply. As railways possess an advantage in long-distance transportation, we further predict market space for long-distance cold-chain transportation.

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