



Faculty of Economics and Business

**Forecasting the Cold Chain Logistics Demand for
Fresh Agricultural Products in China**

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Forecasting the Cold Chain Logistics Demand for
Fresh Agricultural Products in China

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A thesis submitted

In fulfillment of the requirements for the degree of Doctor of Philosophy

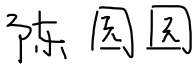
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DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.


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ABSTRACT

Due to improved living standards and a growing emphasis on health, fresh agricultural products have become integral to our daily diets. This trend is primarily attributed to their high protein content and abundant supply of essential vitamins. However, the perishable nature of these goods underscores the critical importance of cold chain logistics, which has the potential to significantly mitigate product deterioration. Presently, the coverage of cold chain logistics in China lags behind that of industrialized nations, resulting in a mismatch between supply and demand. Moreover, outdated technology and a shortage of skilled professionals further exacerbate this disparity. China's diverse geographical landscape and varied lifestyles influence the various demands for cold chain logistics. This study employed a static panel data model to investigate the factors influencing the demand for cold chain logistics for fresh agricultural products, both in coastal and inland regions. The key determinants in China identified include the value added of the primary industry, freight turnover, ownership of civilian goods vehicles, internet broadband access subscribers, and the impact of COVID-19. Value added of the primary industry, ownership of civilian goods vehicles, internet broadband access subscribers, and the COVID-19 pandemic were a few factors that primarily affect coastal regions. On the other hand, the effects of COVID-19, the value added of the primary industry, freight turnover, ownership of civilian goods vehicles, and internet broadband access subscribers were what drive inland areas. Based on these findings, specific development recommendations were proposed for cold chain logistics in different regions of China, aiming to provide theoretical support for advancing the industry. Then, utilizing the GM (1,1) model, future demand for cold chain logistics in fresh agricultural products was forecasted for the next five years, encompassing China as a whole as well as its coastal and inland regions. Projections indicated that by 2027, the demand for

cold chain logistics for fresh agricultural products in China is expected to reach 1,571.14 million tons, with 694.58 million tons in coastal areas and 876.56 million tons in inland regions. These insights were instrumental in facilitating informed investment strategies in cold chain logistics and formulating relevant policies to foster industry development.

Keywords: Cold Chain Logistics, Fresh Agricultural Products, Demand Forecasts, China

Meramalkan Permintaan Logistik Rantai Sejuk bagi Produk Pertanian Segar di China

ABSTRAK

Produk makanan segar menjadi semakin mendapat permintaan di dalam pasaran ekoran daripada peningkatan taraf hidup yang membawa kepada penekanan terhadap kesihatan. Trend ini berlaku ekoran kesedaran terhadap pentingnya kandungan protein yang tinggi dan bekalan vitamin yang tinggi dalam pemakanan. Walau bagaimanapun, sifat mudah rosak produk segar meningkatkan kesedaran keperluan logistik rantai sejukbeku, yang boleh meminimumkan penurunan kualiti produk. Pada masa ini, liputan logistik rantai sejukbeku di China masih ketinggalan berbanding dengan negara-negara membangun yang lain, justeru menyebabkan ketidakseimbangan antara penawaran dan permintaan. Tambahan, teknologi yang ketinggalan dan kekurangan tenaga profesional yang terlatih memburukkan lagi ketidakseimbangan ini. Lanskap geografi yang pelbagai di China dengan gaya hidup yang berbeza banyak mempengaruhi permintaan terhadap logistik rantai sejuk. Kajian ini menggunakan model data panel statik untuk menyiasat faktor-faktor yang mempengaruhi permintaan terhadap logistik rantai sejuk bagi produk pertanian segar, baik di kawasan pesisir mahupun pedalaman. Faktor penentu utama yang dikenal pasti termasuk nilai tambah industri utama, pusingan kargo, milikan kenderaan awam, akses internet jalur lebar, dan impak COVID-19. Nilai tambah industri utama, kepemilikan kenderaan awam, akses internet jalur lebar, dan pandemik COVID-19 adalah beberapa faktor yang utamanya mempengaruhi kawasan pesisir. Sebaliknya, kesan COVID-19, nilai tambah industri utama, pusingan kargo, kepemilikan kenderaan awam, dan akses internet jalur lebar isirumah menunjukkan kesan penentu di kawasan pedalaman. Berdasarkan hasil penemuan ini, cadangan pembangunan khusus dikemukakan untuk logistik rantai sejuk di

kawasan yang berbeza di China, untuk menyokong teori dan kajian sedia ada dan untuk memajukan sektor industri berkaitan. Kajian ini seterusnya menggunakan model GM (1,1) untuk membuat unjuran permintaan masa depan untuk logistik rantai sejuk bagi tempoh lima tahun untuk China umumnya dan untuk kawasan pesisir dan kawasan pedalaman, khususnya. Hasil unjuran menunjukkan bahawa menjelang tahun 2027, permintaan untuk logistik rantai sejuk bagi produk pertanian segar di China dijangka mencapai 1,571.14 juta tan, dengan 694.58 juta tan di kawasan pesisir dan 876.56 juta tan di kawasan pedalaman. Maklumat ini adalah sangat penting dalam memudahkan strategi pelaburan yang berinformasi dalam logistik rantai sejuk dan merumuskan dasar yang relevan untuk memajukan industri.

Kata kunci: Logistik Rantai Sejuk, Produk Pertanian Segar, Ramalan Permintaan, China

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LIST OF ABBREVIATIONS

Breusch-Pagan LM	Breusch-Pagan Lagrange Multiplier
CG	The Central Government
FAP	Production of fresh agricultural products
FDA	The Food and Drug Administration
FE	Fixed Effects
FT	Freight Turnover
FV	Forecasting value
GDP	Gross Domestic Product
GOSC	The General Office of the State Council
IBS	Internet Broadband Access Subscribers
ICAO	International Civil Aviation Organization
IMF	International Monetary Fund
MARD	The Ministry of Agriculture and Rural Development
MC	The Ministry of Commerce
MT	The Ministry of Transport
MTC	The Ministry of Transportation and Communications
NSC	The National Standard Committee
OCGV	Ownership of Civilian Goods Vehicles
OV	Original value
Pooled OLS	Pooled Ordinary Least Squares
RE	Random Effects
Res	Residuals
SFDA	The State Food and Drug Administration

VIF	Variance Inflation Factor
VP	Value added of primary industry
WFAO	World Food and Agriculture Organisation
ZPBQTS	Zhejiang Provincial Bureau of Quality and Technical Supervision

CHAPTER 1

INTRODUCTION

1.1 Introduction

In September 2021, the “Law of the People’s Republic of China on the Quality and Safety of Agricultural Products” underwent revision, officially defining agricultural products as animals, plants, microbes, and their associated products derived from agricultural production operations. Various researchers presented differing viewpoints on the concept of fresh agricultural produce. Botondi et al. (2021) argued that fresh agricultural products, which spoil and decay when kept at room temperature, cannot be preserved for an extended period without proper treatment and must be stored at a specific temperature to maintain their quality and freshness until consumption (Gao et al., 2020). Feng et al. (2022) posited that fresh agricultural products are highly perishable with a limited lifespan, and consumers are particularly sensitive to any decrease in freshness. Haji and Himpel (2024) asserted that meticulous management is required for fresh agricultural products to ensure product quality, especially during times of socioeconomic crisis. Sun et al. (2020) described fresh agricultural products, encompassing both animal and marine sources, as those sold directly to consumers with minimal or no processing involved in their supply chains. Ababouch et al. (2023) defined fresh agricultural products as primarily comprising aquaculture and planting commodities that undergo minimal or no processing prior to entering the market. Nonetheless, the majority of agricultural products have a limited freshness duration. According to Wan et al. (2021), fresh agricultural items, including live fish, fresh meat, fresh vegetables, and fresh fruits, are essential for people and significantly influence the market.

The concept of the cold chain originated in the early 1800s, encompassing the logistics involved in maintaining optimal temperature and humidity conditions to preserve perishable items such as fruits, vegetables, dairy, meats, and seafood (Akram et al., 2023). Subsequent to the rapid advancements in refrigeration technology during the early 1930s in industrialized nations, notably the United States and Europe, formalized food cold chain systems were established (Dong et al., 2023). The 1950s witnessed the emergence of frozen food as a valuable commodity, prompting further refinement and diversification of cold storage chains across Europe and the United States (Ndraha et al., 2020). Cold chain logistics have since attained a high level of maturity in industrialized countries, exemplified by Japan, the United States and Canada (Tang et al., 2023).

The development of China's cold chain logistics sector began in the 1960s with the export of beef products (Xu et al., 2021). By 2001, the foundational operations of cold chain logistics had been established, although the industry was still in its nascent stages (Ye et al., 2022). China's economic advancement spurred urbanization and shifts in the consumer market, hastening the progress of cold chain logistics (Han et al., 2021a). Concurrently, changing lifestyles and growing health consciousness led to an escalating demand for fruits, vegetables, and fresh products with stringent temperature requirements, necessitating their transportation through temperature-controlled logistics to ensure quality and safety. Consequently, the demand for the cold chain industry surged (Awad et al., 2021). The year 2008 marked the onset of a period of rapid development for the cold chain industry, often termed its "golden age." During this period, a plethora of laws, programs, and business standards were successively introduced (Teubner & Stockhinger, 2020). In 2015, the Chinese government introduced and actively supported the "Internet Plus" and "One Belt, One Road" initiatives, significantly facilitating the digital, intelligent, and international

expansion of the temperature-controlled logistics sector (Al-Sayed & Yang, 2018). By 2018, the cold chain industry had transitioned to era 3.0 to achieve transformation and upgrade across various facets (Ilari et al., 2021). The outbreak of COVID-19 in China in 2020 had profound implications for cold chain logistics (Han & Liu, 2022). The domestic cold chain logistics market witnessed substantial growth in 2022. Anticipated significant growth and potential are projected for the cold chain logistics business in 2024 and beyond (Dreyer & Goedhals-Gerber, 2023).

In 2022, over 52 cold chain-related policies and plans were released at the national level, spanning various departments including the State Council, transportation, and agriculture, among others. These policies encompassed several areas such as technical innovation, facility construction, standard establishment, and talent training aimed at enhancing the completeness and efficiency of the cold chain logistics system. Under the guidance of the State Council, the transportation department would optimize the cold chain logistics transportation network and enhance transportation efficiency. Simultaneously, the agriculture department would strengthen collaboration with the temperature-controlled logistics business to facilitate the preservation and distribution of agricultural products (Song et al., 2022).

According to the analysis of the 2022 - 2027 edition of the business plan for the cold chain logistics project by the Collaborative Regional Research Programme Research Institute (CRRPRI, 2021), China's cold storage construction within its cold chain infrastructure has progressed relatively slowly compared to the rapidly growing consumer demand (Gao et al., 2021). Between 2015 and 2019, the overall capacity of refrigerated storage in China consistently increased, as depicted in Figure 1.1: Total Volume and Growth

Trend of Cold Storage in China, 2015-2022. This growth was primarily driven by the rising consumer demand for fresh and perishable products, the expansion of e-commerce in the food sector, and increased government support for cold chain development. By 2019, the total cold storage capacity in the country had reached approximately 60.53 million tons, with an additional capacity of 8.15 million tons. However, despite these efforts, this capacity fell significantly short of meeting the demand, which stood at 235.20 million metric tons.

The slower growth rate in cold storage capacity compared to the demand can be attributed to several factors, including high construction and operational costs, fragmented logistics infrastructure, and a lack of standardized practices across different regions. Additionally, the limited technological advancement and insufficient investment in cold chain logistics further exacerbated the gap between supply and demand.

China lags behind industrialized nations across all facets of cold chain logistics, resulting in disrupted supply chains and a high incidence of spoilage within the cold chain (Aung & Chang, 2023). Therefore, fostering the growth of cold chain logistics in China necessitates investigating the crucial factors influencing its development and forecasting future demand (Shashi et al., 2021a). This study not only serves as a vital reference for shaping relevant policies on cold chain logistics in China but also provides a foundation for the construction and investment in refrigerated transport facilities and equipment.

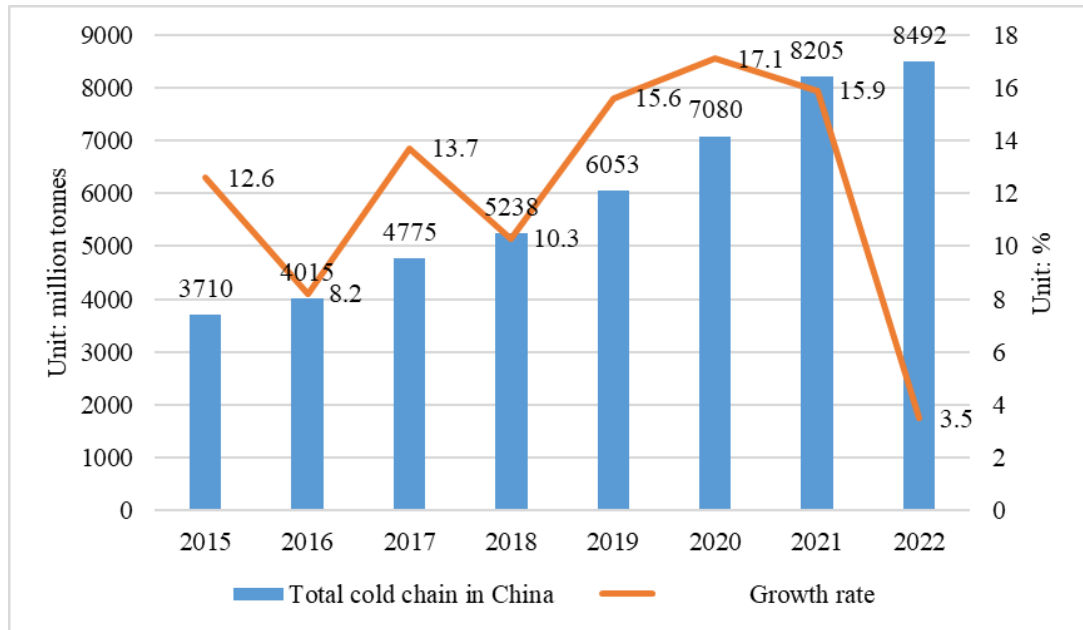


Figure 1.1: Total Volume and Growth Trend of Cold Storage in China, 2015-2022

Source: China Cold Storage Industry Market Data Forecast and Analysis, 2022.

1.2 Background of the Study

China, with a population exceeding 1.41 billion by 2022, represents the largest single market globally (Mottaleb et al., 2023). Its rapid economic growth, particularly since the 1978 Reform and Opening Up policy, has created significant regional development disparities (Figure 1.2). Despite these advancements, China faces challenges in food security and agricultural imports, partly due to its large population and limited arable land (McMichael, 2020).

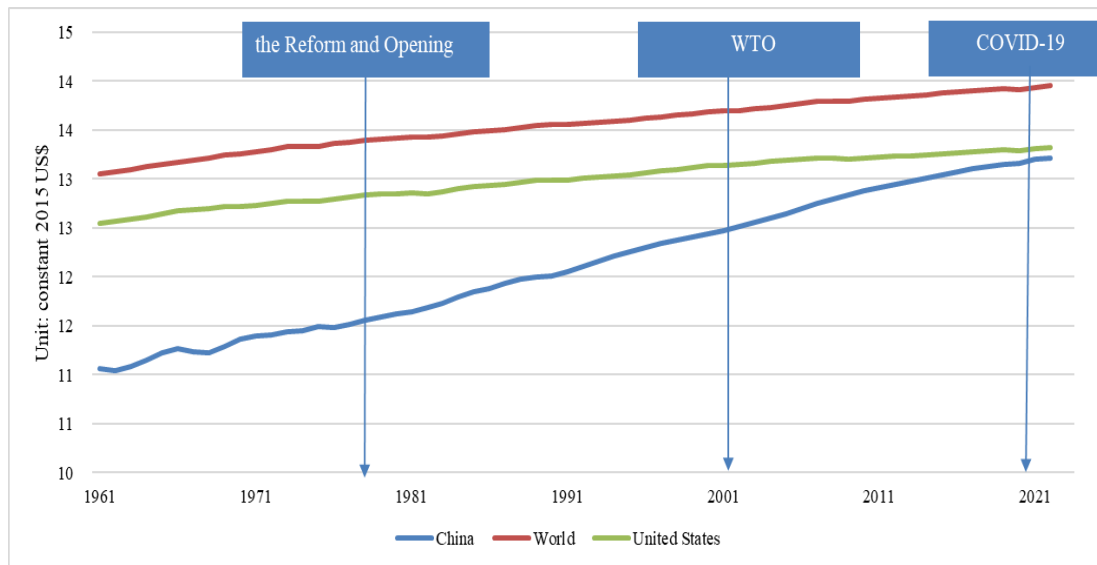
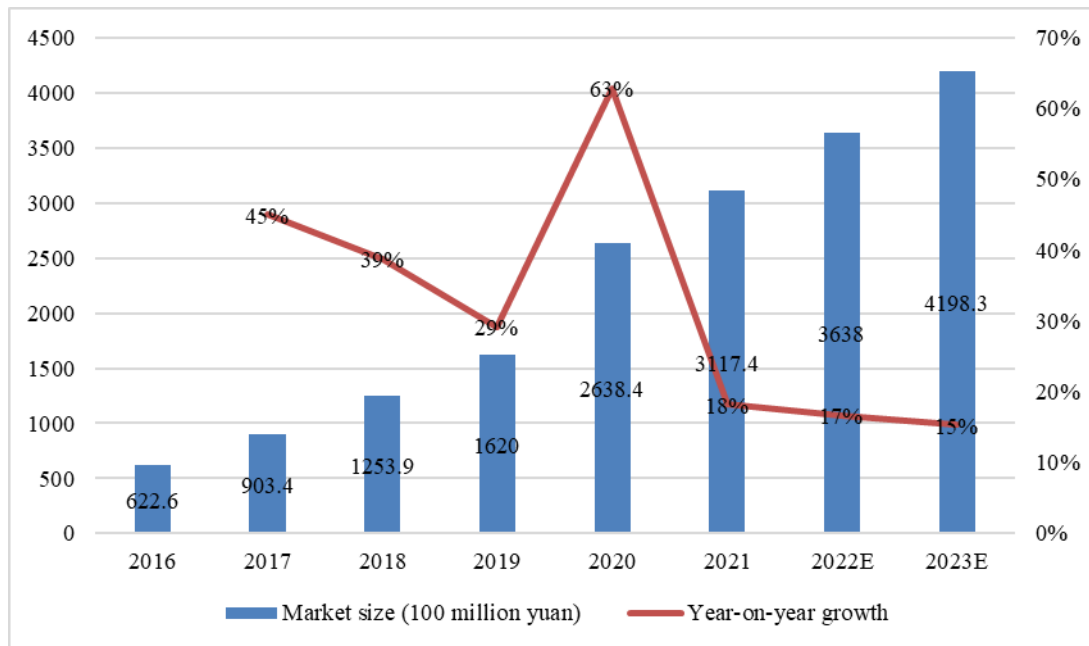


Figure 1.2: Economy Growth Rate for World, China and United States, 1960-2021

Source: Ministry of Commerce, China, 2021.

Agriculture remains a crucial sector, with China maintaining high food production levels and achieving self-sufficiency in staple crops like rice and wheat (He et al., 2021). However, the country's need for imported agricultural products persists due to diverse consumer demands and limitations in domestic production (Zhou, 2022). This need for imports, alongside China's substantial consumer base, has driven the growth of cold chain logistics, crucial for preserving and transporting perishable goods (Yan et al., 2020).

The COVID-19 pandemic further accelerated the demand for cold chain logistics as online transactions for fresh agricultural products surged (Guo et al., 2022). By 2023, the market for fresh agricultural goods in China had reached 419.83 billion yuan (Figure 1.3), highlighting the critical role of efficient cold chain logistics in meeting this increased demand.



Note: Year+E forecasted figure

Figure 1.3: China's Fresh Agricultural Products E-commerce Market, 2016-2023

Source: iiMedia Research, 2021.

The importance of cold chain logistics has progressively garnered attention as a result of advancements in online sales platforms and the increasing need for fresh agricultural commodities (Huang et al., 2020). Fresh agricultural items are highly susceptible to time and temperature (Han et al., 2021b). Inappropriate temperature conditions can trigger biochemical processes, leading to rapid food spoilage and impacting people's ability to consume it normally (Preetha & Narayanan, 2020). The preservation of fresh agricultural products relies on cold chain logistics, which effectively inhibits the growth of germs or molds in raw agricultural items, resulting in reduced loss and long-term preservation (Giannakourou & Tsironi, 2021). Southwest Securities (2023) indicated that the recent post-natal loss rate in the industry exceeds 20%, whereas industrialized countries maintain a rate of less than 5%. Conventional sales channels for agricultural products encompass a sequential process, commencing in the field and extending to wholesalers, distributors, and

fresh stores, culminating in consumer acquisition. Each stage of this process entails physical handling and transportation, with an increased number of links correlating to a heightened risk of loss. In 2021, agricultural experts from the Ministry of Agriculture of China conducted calculations indicating post-harvest loss rates for grains, potatoes, fruits, and vegetables in the country. These rates were found to be approximately 7%–11% for grains, 15% – 20% for potatoes, and 20%–25% for fruits and vegetables, respectively (refer to Figure 1.4).

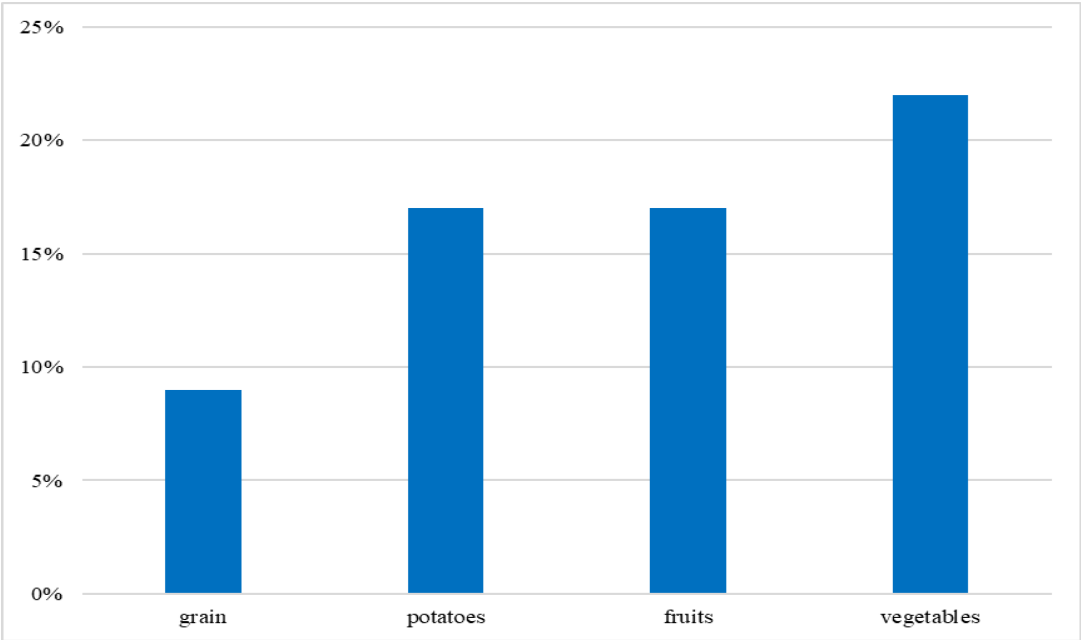


Figure 1.4: The Postpartum Loss Rate in 2020

Source: Ministry of Agriculture of China, 2021.

The General Office of the State Council (GOSC) released the “14th Five-Year Plan” in 2021. The plan highlighted existing imbalances and deficiencies in China’s temperature-controlled logistics sector, particularly in terms of insufficient capacity to adjust the supply and demand of agricultural products across different seasons and regions. Additionally, the plan acknowledged the significant post-harvest losses of agricultural products and waste in food circulation, which still lag behind the standards of developed countries. To address the

need for temperature-controlled facilities and equipment and to meet the public's expectations for the quality and safety of fresh agricultural goods, it was deemed essential to analyse and forecast the demand for cold chain logistics. This would enable the development of a well-designed plan for the growth of cold chain logistics for fresh agricultural goods (He & Yin, 2021). Coastal areas and inland areas in China have different influencing factors and demand for cold chain logistics due to variations in geography and the economy (Fan et al., 2021). This study comprehensively examines the cold chain logistics of fresh agricultural products in China. It analyses the variations in influencing factors and their impact levels across different regions. Additionally, it forecasts the demand for cold chain logistics of fresh agricultural products in various regions.

1.3 Critical Historical Period of Cold Chain Logistics and Policies

According to Zhang (2022a), the history of China's cold chain is documented, tracing its origins back to the late 1950s. The development of the cold chain can be delineated into three distinct phases: the budding phase from 1960 to 1990, the beginning of the development phase from 1991 to 2007, and the rapid development phase from 2008 to the present. In response to the growth of cold chain logistics in China, various government departments have implemented a series of policies to ensure its efficient execution (Shi et al., 2022).

1.3.1 Critical Historical Period of Cold Chain Logistics of China

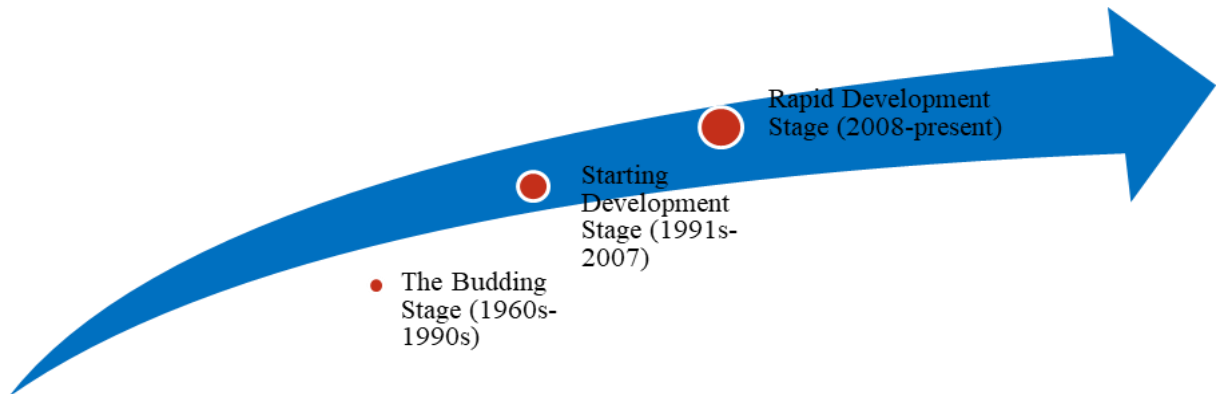


Figure 1.5: China Cold Chain Logistics Development Stage

Source: Zhejiang Securities Research Institute, 2021.

The development of China's cold chain logistics began in the late 1950s and extended into the early 1990s, as depicted in Figure 1.5. During this period, China constructed large-scale cold storage facilities in major production areas and cities to ensure the availability of fresh products such as meat, poultry, and seafood on the market. These facilities were pivotal for meeting both domestic demand and international export requirements while regulating supply during off-peak seasons (Chen et al., 2023). Despite some progress, there was a notable scarcity of cold chain resources due to limited technology and equipment, hindering the system's coverage and efficiency (Han et al., 2021c). Transportation primarily relied on railway refrigerated trucks and water-cooled vessels, complicating large-scale distribution and cross-border trade while maintaining product quality and safety (Kawa et al., 2023). Despite challenges, China recognized the importance of temperature-controlled logistics for the food industry's growth during this period (Dai et al., 2020), laying the groundwork for future development (Batwa & Norrman, 2020).

From the early 1990s to 2007, China's cold chain logistics experienced significant growth (Mak & Max, 2021). The expansion of supermarket chains in major cities like

Shanghai and Beijing drove increased demand for frozen and chilled food, making cold chain logistics essential to meet this growing market demand (Peng, 2023). With retail terminals advancing, the significance of temperature-controlled logistics in the market has become increasingly prominent (Tsang et al., 2021). Major urban supermarket chains invested significantly in cold chain equipment and technology, accelerating progress across the refrigeration chain (Li et al., 2023). This period saw enhancements in refrigerated vehicles, warehousing equipment, and temperature monitoring technology, ensuring more reliable food preservation methods (Doderio et al., 2021). Progress during this phase laid the foundation for long-term viability in the food supply chain and future expansion of the temperature-controlled logistics network (Huang et al., 2020b). Technological advancements led to improved regulations and standards, bolstering the government's focus on food safety and quality (Yang et al., 2022), and facilitating domestic market dissemination and international trade competitiveness (Pu et al., 2022).

Since 2008, China's cold chain logistics have experienced rapid growth (Li & Liu, 2022). Factors such as rising national income levels, increasing per capita consumption, and growing demand for high-quality food products have fuelled this growth (Van & Tran, 2024). Events like the 2008 Beijing Olympics heightened standards for cold chain logistics, expanding the operational capacities of China's cold chain companies (Pan & Sun, 2023). During this period, China's cold chain industry was established, laying the groundwork for the entire cold chain ecosystem (Blessley & Mudambi, 2022). Active national organizations' efforts attracted significant foreign investment, with international companies like Meilan and Swire entering the market (Xie et al., 2022a). The expansion of Pilot Free Trade Zones facilitated the entry of international cold chain companies, while domestic food companies increased investment in cold chain logistics (Ayoubi & Radmehr, 2023). Companies like

Shuanghui and Bright established separate logistics entities to enhance supply chain control and product quality (McMichael, 2020b). The rise of e-commerce platforms like Jingdong and Tmall expanded opportunities for cold chain logistics, driving ongoing innovation and industry improvement (Zhu et al., 2021). Technological, equipment, and management advancements accelerated the digital and intelligent transformation of the cold chain logistics system (Attaran, 2020), granting China a competitive edge globally and forming the basis for an extensive food logistics network (Peng et al., 2020).

1.3.2 Critical Historical Policies of Cold Chain Logistics of China

In response to the growth of cold chain logistics in China, various government departments implemented a series of policies to ensure its efficient execution (Liu et al., 2022). In 2005, the GOSC issued the Regulations on the Administration of the Circulation of Vaccines and Preventive Vaccination. These regulations required vaccine operations and vaccination points to have refrigerated facilities, equipment, and a refrigerated storage system that met the standards for storage and transportation management to ensure the quality of vaccines being used (GOSC of China, 2005). In 2007, the State Food and Drug Administration (SFDA) released the Measures for the Supervision and Administration of Drug Distribution. These measures mandated that drug manufacturers and operators must utilize cold storage facilities and equipment for transporting and storing drugs, as specified in the relevant regulations (SFDA of China, 2007). The Zhejiang Provincial Bureau of Quality and Technical Supervision (ZPBQTS) approved and released the “Pharmaceutical Cold Chain Logistics Technology and Management Specification” in November 2008. This marked the introduction of regulations for the management of cold chain logistics for pharmaceutical products in China (ZPBQTS of China, 2008). In March 2009, the GOSC released the “Logistics Industry Adjustment and Revitalization Plan.” This plan elevated the

logistics industry to one of the ten industrial adjustment and revitalization plans and emphasized the growth of cold chain logistics as a crucial sector within the logistics industry (GOSC of China, 2009). The Food and Drug Administration (FDA) of Jiangsu Province convened a meeting in Suzhou in September 2009 to formulate the provincial guidelines for the temperature-controlled logistics of medicines (FDA of Jiangsu Province of China, 2009). In February 2010, the Ministry of Commerce (MC) organized a national conference on the management of the pharmaceutical distribution industry in collaboration with several pharmaceutical associations (MC of China, 2010).

The “Development Plan for Cold Chain Logistics of Agricultural Products (2010–2015)” was devised by the National Development and Reform Commission (NDRC) in June 2010, serving as an inaugural, comprehensive roadmap for the advancement of temperature-controlled logistics within China’s agricultural sector (NDRC of China, 2010). Subsequently, in 2011, the General Office of the State Council (GOSC) introduced a set of directives, known as the “Nine Articles,” aimed at fostering the expansion of the logistics industry. Furthermore, the GOSC proposed a range of policies and measures to foster the sustainable development of the temperature-controlled logistics industry, supplemented by financial and tax incentives (GOSC of China, 2011). In 2012, two national standards were introduced consecutively: the Classification and Basic Requirements of Cold Chain Logistics and the Code of Practice for Temperature-controlled Logistics of Pharmaceuticals (GOSC of China, 2012). In October 2014, GOSC implemented medium-term and long-term plans for the development of the logistics industry. This plan included the establishment of temperature-controlled logistics parks, the enhancement of the temperature-controlled logistics network for agricultural produce, and the development of logistics standards for agricultural goods,

processed food, pharmaceuticals, and the cold chain. Additionally, GOSC aimed to construct 12 significant logistics projects (GOSC of China, 2014).

In November 2015, the GOSC released the Guiding Opinions on Accelerating the Development of the Living Service Industry and Promoting the Upgrading of the Consumption Structure. The document suggested improving the urban circulation network, streamlining rural commerce and trade channels, and strengthening the construction of a modern wholesale and retail service system. The urban and rural circulation infrastructure was carefully designed, with a focus on developing comprehensive business and trade service centres, agricultural wholesale markets, marketplaces, and storage facilities for important commodities. Additionally, there was an emphasis on promoting the establishment of large-scale logistics and distribution centres, rural postal logistics facilities, express distribution centres, and cold chain logistics facilities for agricultural products (GOSC of China, 2015). In February 2015, the GOSC released a series of directives aimed at fortifying reform and innovation efforts while expediting the modernization of agriculture. These directives outlined various strategies to accelerate the transformation and advancement of the national agricultural goods market system. Specifically, the directives emphasized enhancing the infrastructure and ancillary services, bolstering the trading framework, reinforcing the core network facilitating nationwide agricultural product circulation, expanding the establishment of warehousing and logistical facilities for key agricultural commodities, improving the development of agricultural product markets at their production locales, expediting the establishment of a cross-regional temperature-controlled infrastructure, and sustaining efforts in piloting the establishment of public welfare agricultural wholesale markets (GOSC of China, 2015).

In 2016, the MC and the National Standard Committee (NSC) released a notice regarding the demonstration of standardization of the cold chain circulation of agricultural products. The aim was to strengthen and enhance the standard system of cold chain circulation, with a particular focus on improving the standards in different areas (MC & NSC of China, 2016). In 2017, as stated in Central Document No. 1, there was a renewed focus on enhancing the growth of temperature-controlled logistics for agricultural products to promote the advancement of China's agriculture (GOSC of China, 2017).

The Opinions of the GOSC on Accelerating the Development of Cold Chain Logistics were issued in April 2017. These opinions centered around promoting the growth of cold chain logistics, with a focus on ensuring food safety and enhancing consumption. The main objective was to foster the coordinated development of industries both upstream and downstream while also aiming to discover and nurture new sources of economic growth. This reflected a unique approach to supply-side structural reform and development (GOSC of China, 2017). In August 2017, the Ministry of Transportation and Communications (MTC) released a document called "Opinions on the Implementation of Accelerating the Development of Cold Chain Logistics to Safeguard Food Safety and Promote Consumption Upgrading." This document emphasized important aspects such as infrastructure, transportation management, digitalization, industry oversight, and supportive policies. It also outlined the key objectives for transportation to advance the growth of temperature-controlled logistics (MTC of China, 2017).

In February 2018, the Central Government (CG) released Document No. 1, titled "Opinions of the State Council of the CPC Central Committee on the Implementation of the Strategy for the Revitalization of the Rural Areas." This document proposed various

suggestions, such as the need to enhance the temperature-controlled logistics and warehousing system for agricultural produce, the creation of a public service platform for agricultural product sales, and the provision of support for supply and marketing, postal services, and a postal service platform (CG of China, 2018). In April 2019, the NDRC and the MC jointly issued a set of directives titled “Opinions on Advancing High-Quality Development of Logistics and Fostering the Establishment of a Robust Domestic Market.” This document advocated for enterprises to innovate within the operational framework of temperature-controlled infrastructure and to establish third-party platforms for comprehensive monitoring of temperature-controlled logistics processes (NDRC & MC of China, 2019).

In the wake of the COVID-19 pandemic that emerged in early 2020, there was a regular implementation of limitations on temperature-controlled logistics. In April 2020, the Ministry of Agriculture and Rural Development (MARD) issued guidelines to speed up the construction of storage and refrigeration facilities for agricultural products. The focus was on areas where fresh and live agricultural products are produced, regions known for special agricultural products, and areas affected by poverty. By the end of 2020, MARD had provided support to several new agricultural management projects in villages and towns to enhance the development of storage and refrigeration facilities. The aim was to significantly improve the capacity for storing and preserving fresh and live agricultural products at their source and to greatly reduce post-production losses (MARD of China, 2020).

In May 2020, the NDRC released Opinions on the Implementation of Further Reducing Logistics Costs. This document outlined plans to establish national backbone cold chain logistics bases to address the lack of temperature-controlled facilities in both urban

and rural areas. The goal was to integrate cold chain logistics with the production and distribution of agricultural goods and improve scalability. In June 2020, the MARD issued a notice to enhance the development of cold chain facilities for storing and preserving agricultural products. The objective was to regulate process management, provide policy support, strengthen supervision and management, improve guidance services, and maximize the benefits of policies (MARD of China, 2020). In August 2020, the Ministry of Transport (MT) issued a notification aimed at bolstering measures for the prevention and management of the COVID-19 pandemic within temperature-controlled logistics networks. The aim was to improve coordination between departments and prevent the potential contamination of cold chain food with the new coronavirus. The notice focused on strengthening the management of international cold chain container transport and ensuring thorough disinfection of transport equipment used for cold chain goods. Additionally, an information registration system was implemented to provide robust support for the prevention and control of the COVID-19 pandemic in temperature-controlled logistics (MT of China, 2020).

In August 2021, MC released the Special Action Plan for High-Quality Development of Commerce and Trade Logistics (2021–2025). This plan aimed to enhance the utilization of innovative temperature-controlled facilities and equipment, such as mobile cold storages, constant-temperature refrigerated trucks, and refrigerated trailers. Additionally, it involved the establishment and construction of several national core cold chain logistics bases. Furthermore, the plan supported the development and refurbishment of large wholesale markets for agricultural products and import/export ports, with a focus on constructing and upgrading refrigerated warehousing facilities. The overall objective was to expand the coverage of urban and rural cold chain networks and enhance the equipment used in terminal cold chain facilities. Businesses that have the capability are urged to establish a

comprehensive cold chain distribution system and an advanced monitoring and tracing platform for temperature-controlled logistics (MC of China, 2021).

In April 2022, MT released a document titled “Implementation Opinions on Accelerating the High-Quality Development of Cold chain Logistics and Transport.” Their primary focus was on enhancing supply-side structural reform, with the key objective of promoting high-quality growth in cold chain logistics. They considered reform and innovation as the main driving forces and aimed to meet the increasing demands of the people for a better life. The focus would be on the development of innovative transportation methods, the improvement of technology and equipment, the enhancement of the temperature-controlled transport supervisory system, and the promotion of efficient, practical, secure, and standardized growth in temperature-controlled transport. In addition, it would provide strong support for guaranteeing food safety, minimizing food distribution waste, encouraging increased consumption, and advancing environmental sustainability (MT of China, 2022).

China has consistently adopted a temperature-controlled logistics strategy for fresh agricultural produce in recent years, clearly highlighting the sector’s significance to the country. Concurrently, the temperature-controlled logistics sector in China has undergone substantial expansion. This phenomenon can be primarily ascribed to the enforcement of several national legislations, fostering a supportive policy landscape conducive to the rapid proliferation of cold chain logistics infrastructure (Li, 2020).

1.4 Problem Statement

The availability of fresh agricultural produce is crucial to the stability of China's agricultural market. During the COVID-19 pandemic, the imbalance of supply and demand for fresh agricultural products exposed significant weaknesses in the supply chain. Consumer demand surged, but the capacity to regulate supply and demand across regions was insufficient, leading to challenges in maintaining product freshness and meeting consumer needs. These challenges are particularly pronounced in China's coastal and inland regions, where demand varies greatly.

China's fresh agricultural produce temperature-controlled logistics has grown significantly in the last decade, the market size of China's cold chain logistics industry grew from 110 billion yuan in 2012 to over 380 billion yuan in 2020, with a compound annual growth rate of 16.8%, but it has yet to establish a national logistics infrastructure (Zhao, 2020). The sector faces multiple challenges, including insufficient infrastructure, a lack of professional training, and inadequate technological innovation. The uneven economic development between coastal and inland regions has resulted in fragmented logistics systems, further complicating the cold chain's effectiveness.

Moreover, the "first kilometre" of logistics - encompassing initial transportation, quality inspection, and packaging remains a significant bottleneck, particularly in rural areas. Despite improvements in rural infrastructure, the cold chain system often fails to maintain the required standards, leading to frequent disruptions.

Technological limitations further exacerbate these issues. The adoption of advanced cold chain logistics technology is uneven, with significant gaps in areas such as freshness

preservation and long-distance transportation. This is compounded by the low proportion of professional cold chain logistics vehicles, which limits the overall efficiency of the system.

In summary, China's cold chain logistics for fresh agricultural products faces several pressing issues: inadequate infrastructure, inefficiencies in supply chain management, and a lack of innovation. Addressing these challenges is crucial for ensuring a reliable supply of fresh agricultural products across both coastal and inland regions. To this end, this study aims to analyse the factors influencing cold chain logistics demand in these regions, the influencing factors for cold chain logistics demand for fresh agricultural products differ between coastal and inland areas, but studies comparing these factors are limited. Coastal and inland regions exhibit significant differences in economic development, infrastructure, and market demand. Understanding these determinants helps in formulating logistics strategies tailored to the specific characteristics of each region, considering the impact of COVID-19 and utilizing a static panel data model to predict future demand. The findings will provide valuable insights for improving the cold chain logistics system and ensuring the safety and quality of fresh agricultural products in China.

1.5 Research Questions

- i. What are the determinants influencing the demand for fresh agricultural products cold chain logistics in China's coastal and inland regions?
- ii. How do the impacts of these determinants differ between the coastal and inland regions of China?
- iii. What are the projected demands for fresh agricultural products cold chain logistics in China as a whole, as well as in its coastal and inland regions, for the years 2023 to 2027?

1.6 Objectives of the Study

1.6.1 General Objective

The general objective of this study is to analyse the factors influencing the cold chain logistics for agricultural products across China, with a focus on regional differences between coastal and inland areas. Additionally, the study seeks to forecast the demand for cold chain logistics for fresh agricultural products both nationally and within specific coastal and inland regions of China.

1.6.2 Specific Objectives

Specifically, this study intends to achieve the following objectives:

- i. To examine the determinants of fresh agricultural products cold chain logistic demand in China, specifically coastal and inland regions;
- ii. To compare the impact of the determinants of fresh agricultural products cold chain logistic demand determinant between coastal and inland regions of China;
- iii. To forecast the 2023–2027 demand for fresh agricultural products cold chain logistics in China as a whole and in its coastal and inland regions.

1.7 Significance of the Study

1.7.1 To the Body of Knowledge

The cold chain logistics of fresh agricultural produce in China have long suffered from issues of illogical resource allocation. The utilization rate of logistics facilities, such as warehouses and distribution vehicles, has been low. Additionally, the division of labour among stakeholders in the agricultural temperature-controlled logistics market has been

deemed unscientific and unreasonable. This has led to a more serious problem of blind and disorderly competition, resulting in relatively low efficiency in market resource allocation. The lack of efficiency in resource allocation in the field of cold chain logistics has led to dilemmas such as resource waste and excessive resource use. This study introduces a panel data model to investigate the determining factors of cold chain logistics in China as well as in coastal and inland areas. Furthermore, it conducts a comparative analysis to examine the varying impacts of these factors across different regions. The overall cold chain logistics demand for fresh agricultural products in China is projected, with a separate analysis conducted for both coastal and inland provinces. It not only enhances the understanding of forecasting cold chain logistics and the factors that affect cold chain logistics in different regions but also enhances the understanding of the synergy between fresh agricultural products and cold chain logistics, ultimately establishing logistics as a significant source of profit for enterprises.

1.7.2 To the Industry and Business Sectors

China, as a significant agricultural nation, places great importance on addressing the “three rural” problem, which is a key concern for both the Party and the State (Xue et al., 2021). Logistics demand is a crucial component of the logistics system and is essential for its proper functioning (Eisenmann et al., 2021). To address the random distribution of logistics resources, it is important to use the right demand forecasting methods to accurately predict the overall demand for those resources in a certain area at a certain time (Biswas et al., 2024). This approach maximizes the efficiency of resource utilization, leading to a reduction in logistics costs and ultimately achieving the efficient operation of the logistics system. This study conducts a comprehensive forecast of the demand for cold chain logistics for fresh agricultural produce in the entire country, as well as in the coastal and inland regions

separately. It also examines the impacts of various factors on demand in different regions. The findings of this study have significant practical implications, which can be summarized as follows:

1.6.2.1 Enhancement of the Cold Chain Logistics System

Although China's logistics industry had a delayed beginning, there has been some improvement in addressing the challenges of cold chain logistics, such as the industrial system, infrastructure site selection, and warehousing and distribution efficiency (Zhang et al., 2021). However, these improvements have not yet met the standards of modern logistics development. Historically, the development of temperature-controlled infrastructure, machinery, and systems for fresh agricultural produce has not kept pace with the demands of the era. In order to address the historical inadequacy of agricultural temperature-controlled logistics facilities and equipment and enhance the development of fresh agricultural produce temperature-controlled logistics systems, it is imperative to precisely forecast the need for such logistics.

16.2.2 Provide a Data Basis for Enterprises to Invest in Facilities and Equipment

Each year, a significant number of agricultural products experience damage during the process of logistical shipping (Wang et al., 2021). In addition to the substantial loss of fresh agricultural produce caused by equipment and facility breakdowns during transportation and logistics, there is also a large loss of agricultural products during the separation, packing, distribution, and processing stages (Gordeeva et al., 2021). Forecasting the demand for cold chain logistics in the agricultural industry can assist firms in improving the system by providing them with a basis for investing in infrastructure and equipment.

1.6.2.3 Improve Food Safety and Realise Rapid and High-Quality Circulation of Fresh Agricultural Products

To satisfy consumers' demands for food safety, it is imperative to proactively enhance cold chain logistics and the quality of fresh agricultural produce circulation (Roy & Srivastava, 2022). Over the past few years, agricultural products have frequently fallen short of the standards necessary for refrigerated transportation, leading to a cascade of food-related issues (Stamber et al., 2021). With the increasing emphasis on food safety, there is now a favourable opportunity for the advancement of cold chain logistics (Jagtap et al., 2020). The implementation of temperature-controlled logistics for fresh agricultural produce has the potential to enhance dietary quality and cater to the demands of contemporary lifestyles while also fostering economic growth (Shashi et al., 2021b). Due to the perishable nature of meat, fish, and other agricultural products, the use of advanced transport and distribution equipment is essential to ensure their safe and efficient transportation (Abbas et al., 2023). Currently, conducting thorough research on cold chain logistics for fresh agricultural produce could expedite food safety initiatives and provide assistance in achieving a healthy and high-quality circulation of these products (Bharti, 2020).

1.6.2.4 Promote Local Logistics Development

On one hand, this study scrutinizes the influential factors affecting the cold chain logistics of fresh agricultural produce in both coastal and inland regions of China comprehensively. On the other hand, it establishes a rigorous and efficient logistics demand prediction model, offering a quantitative foundation for urban planning and data-backed insights for crafting evidence-based logistics development policies. The study findings furnish a tangible framework and data substantiation for government agencies to devise strategies tailored to the specific contextual nuances of each region.

1.8 Scope of the Study

This study focuses on the Chinese context, with specific attention given to both its coastal and inland regions, examining fresh agricultural goods as its primary subject of investigation. The main objective is to conduct a thorough analysis of the factors influencing China's cold chain logistics, particularly in coastal and inland areas, while also exploring geographic disparities. Additionally, the study aims to anticipate the demand for cold chain logistics in transporting fresh agricultural produce and provide recommendations based on the findings. To achieve this, the analysis integrates data from reputable sources such as the China Statistical Yearbook and the Cold Chain Logistics Yearbook. In 2015, China encountered food safety challenges in e-commerce, leading to heightened awareness of cold chain logistics for food transportation. Concurrently, the government rolled out the "Internet Plus" strategy, which included "Internet Plus Agriculture," aiming to modernize agriculture and improve supply chain efficiency. Consequently, cold chain logistics assumed a crucial role, spurring rapid industry growth. This era marked a significant milestone for China's cold chain logistics, especially concerning fresh agricultural produce, thus justifying the chosen data collection period from 2015 to 2022.

1.9 Structure of the Study

Chapter 1 includes the study background, critical historical period of cold chain logistics and policies, problem statement, research objectives, research significance, and scope of the research. Chapter 2 mostly focuses on preparing a literature review. This entails analysing theoretical research, the empirical findings of similar studies, and pinpointing any deficiencies in the current literature. Chapter 3 mostly focuses on the study methodology. Chapter 4 discusses the study findings and encourages discussion, while Chapter 5 analyses the results to draw conclusions and offer recommendations.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is structured into four distinct sections. The initial segment is the introduction, which provides an overview of the topics covered in the subsequent subsections of this chapter. A theoretical analysis of the relevant theoretical underpinnings in the existing literature on demand forecasting for cold chain logistics of fresh agricultural produce forms part of the second part. The third portion presents the pertinent empirical literature and evaluates the study findings of other researchers. The fourth section focuses on the research gaps, encompassing an examination of the current research's limits, unresolved concerns, and potential directions for future research.

2.2 Theoretical Studies

This section presents two fundamental theoretical concepts: logistics management theory and demand forecasting theory. These concepts collectively establish the theoretical foundation for studying the demand forecasting of fresh agricultural produce in cold chain logistics. Logistics management theory is essential for comprehensively understanding the processes of cold chain logistics. Logistics management encompasses the complete journey of products, starting with the production site and ending with delivery to consumers. It focuses on optimizing this process to achieve maximum benefits (Xin et al., 2022). Temperature control, transportation route planning, and warehousing management are essential elements of logistics management theory in cold chain logistics (Turan & Ozturkoglu, 2022). By utilizing logistics management theory, this study may gain a deeper comprehension of how fresh food moves along the supply chain and efficiently address a

range of obstacles, including temperature variations and delays in delivery. Furthermore, the idea of demand forecasting plays a pivotal role in this study. Accurately estimating demand for fresh agricultural products is a crucial aspect of cold chain logistics, known as demand forecasting. This theory emphasizes the utilization of past data, market trends, and other pertinent elements to precisely forecast future demand using diverse models and methodologies. The accuracy of demand forecasting has a direct impact on the effectiveness of logistics operations and the preservation of product quality in a cold chain environment. This is because fresh agricultural products are extremely sensitive to temperature and time. Hence, the theory of demand forecasting equips us with efficient tools and methodologies to optimize market demand fulfilment, minimize inventory expenses, and mitigate risks in cold chain logistics. Together, these concepts provide a solid theoretical foundation for studying the demand forecasting of fresh agricultural produce within cold chain logistics. By establishing these theoretical underpinnings, this study aims to offer new insights into how logistics efficiency and demand predictability can optimize the supply chain for perishable goods.

2.2.1 Logistics Management Theory

Logistics management theory has evolved significantly over the decades, beginning with its origins in military logistics and supply chain management. Initially, logistics was primarily concerned with the movement and supply of military goods during wars. However, as industrialization and globalization accelerated, logistics management began to develop as a distinct academic and practical discipline within business operations. The foundational principles of logistics management were formalized in the mid-20th century, with scholars emphasizing the optimization of material flow, inventory management, and distribution networks (Bowersox & Closs, 1996). Early theories focused on cost reduction through more

efficient transportation and inventory management, a concept famously encapsulated by Peter Drucker, who referred to logistics as the “last frontier of cost reduction” (Pope, 1974). Over time, logistics management expanded to include the coordination and integration of various functions across the supply chain, giving rise to modern supply chain management, which emphasizes the interconnection of suppliers, manufacturers, distributors, and retailers (Hugos, 2024).

Logistics management theory is built on several core principles, the first principle is systematic planning and coordination. Logistics management involves the strategic planning of all logistical activities, including procurement, transportation, warehousing, and distribution. The objective is to optimize the flow of goods, services, and information from origin to destination while minimizing costs and maximizing service levels (Bowersox et al., 2002). The second principle is Cost-Benefit analysis. A key component of logistics management is balancing cost efficiency with service quality. This involves analysing trade-offs between different logistical elements, such as transportation modes, inventory levels, and warehousing strategies, to achieve optimal performance (Ballou, 2004).

The third principle is systematic planning and coordination value creation. Logistics creates value through the efficient management of time and space. Time value is generated by ensuring timely delivery, while spatial value is created by bridging the gap between production and consumption locations. These concepts are critical in cold chain logistics, where maintaining product freshness over time and distance is paramount (Qi et al., 2020). The fourth principle is technology integration. With advancements in technology, logistics management has increasingly relied on information systems to enhance visibility, coordination, and decision-making. The integration of Enterprise Resource Planning

systems, Warehouse Management Systems, and Transportation Management Systems has become essential for achieving real-time data access and optimizing logistics operations (Christopher, 2016).

To ensure effective organization and collaboration of various tasks, logistics management theory has been developed to strategically plan, allocate resources, give instructions, synchronize, monitor, and supervise logistical activities (Zhu et al., 2023). Logistics management plays a pivotal role in the supply chain by strategically planning, coordinating, and overseeing the efficient flow and storage of goods, services, and associated information from origin to destination, ultimately aimed at meeting customer demands while minimizing redundancy (Charles et al., 2023). The primary goal of logistics management is to provide customers with top-notch logistics services at an affordable cost (Calixto, 2016; Yang, 2022). The expenses related to logistics exert a substantial influence on the competitiveness of both the macroeconomic (country) and microeconomic (firm) levels (Bouattour et al., 2024). Logistics expenses serve as indicators of the performance, efficacy, and competitiveness of the logistics sector. Hence, monitoring logistics costs is a crucial component of logistics management (Kabak et al., 2020). Due to the exorbitant costs associated with logistics, Nishizawa (1970) argued that logistics constituted the “third profit source,” prompting firms to achieve greater benefits by reducing logistics costs.

Effective management of logistics activities not only reduces costs but also adds higher value to the profit of logistics firms (Krishnan et al., 2024). Logistics activities have the potential to provide value in terms of time. For instance, specific products are limited to certain seasons, being produced and eaten only during those times, resulting in temporal variations. These issues can be resolved by implementing efficient logistics practices,

including the management of collection, storage, transportation, and other related factors. Logistics plays a crucial role in creating time value (Alfons Weersink et al., 2021).q

Furthermore, logistics activities also contribute to the creation of spatial value. The spatial distribution of production and consumption does not always align, as there is a time delay between transporting products from the supply location to the consumption location (Qi et al., 2020). This delay, along with the strategic placement of transportation routes, adds value and contributes to the spatial significance of logistics. Logistics activities facilitate the consolidation of product transportation from several places to a specific consumer market, hence augmenting the value of the items (Wilson & Goffnett, 2022).

To maintain the quality and freshness of the product for an extended period, a specific temperature needs to be maintained during the production stage. This requirement can be realized by implementing temperature-controlled logistics (Huang et al., 2020c). In the distribution phase of fresh agricultural products, it is essential to have temperature-controlled infrastructure and equipment to ensure the proper handling of the products (Shashi et al., 2021c). This involves using refrigerated or frozen trucks for transportation and cold storage facilities for storing the fresh agricultural goods. During the stage of selling fresh agricultural goods, access to temperature-controlled facilities is necessary (Bhatia & Bhat, 2020). Temperature-controlled logistics is an integral part of the entire process of circulating fresh agricultural produce. However, it is essential to strategically plan the utilization of cold chain equipment to minimize unnecessary costs and maximize revenues for enterprises (Lin et al., 2020).

In cold chain logistics, logistics management theory is applied to manage the unique challenges of temperature-sensitive products. The development of temperature-controlled

logistics, which includes refrigerated transportation, cold storage, and specialized packaging, reflects the adaptation of logistics management principles to maintain product integrity across the supply chain. This study leverages the theoretical foundations of logistics management to address the complexities of cold chain operations, focusing on optimizing temperature control, route planning, and storage management to enhance the efficiency of fresh agricultural product distribution.

2.2.2 Demand Forecasting Theory

Philosopher and economist Adam Smith, a prominent Scottish thinker of the 18th century, is credited with developing the foundational theory of supply and demand, which laid the groundwork for the modern study of economics (Steeds, 2024). Demand refers to the quantity of a good or service that consumers are both willing and able to purchase at a specific price within a given period (Morlotti et al., 2024). In an economy, individuals seek to satisfy a range of needs and desires, including food, healthcare, clothing, entertainment, and shelter (Gu, 2024). The demand for a product at a particular price reflects the anticipated utility or satisfaction that an individual expects from consuming that product. Utility, which varies across individuals, represents the degree of satisfaction derived from the product (Herniyati, 2024).

If the demand curve is linear, it can be expressed as $Q_d = a - bp$, where p denotes the price of the good and Q_d is the quantity demanded. In this equation, a represents the intercept on the vertical axis, which signifies the theoretical quantity demanded when the price of the good is zero. This intercept can be interpreted as the maximum possible demand for the product in the absence of any price constraints. The coefficient b indicates the slope of the demand curve, reflecting the rate at which demand decreases as the price increases. A

steeper slope suggests that demand is highly sensitive to price changes, while a flatter slope indicates that demand is less responsive to fluctuations in price. This linear relationship provides a simplified model of consumer behaviour, useful for analysing market dynamics and predicting how changes in price will impact the quantity demanded.

Two primary factors influence the demand for a good or service: its utility in fulfilling a need or desire, and the consumer's ability to pay for it (Anggraini & Thongjeen, 2024). Real demand emerges when a consumer's willingness to fulfil a need is matched by their actual ability and readiness to pay (Paley et al., 2024). Several factors affect the demand for a product, including its price, perceived quality, the prices of competing goods, and consumers' income levels (Aripin & Matriadi, 2024). Consumer preferences also play a crucial role, and effective branding or advertising strategies can significantly boost demand for certain products. Typically, prices rise during periods of high demand and fall when demand is low. This dynamic occurs as consumers compete to obtain scarce goods, thereby driving prices upward. Even when governments impose price ceilings, this tendency persists, often leading to the emergence of informal black markets with elevated prices (Ho & Chow, 2024).

The theory of demand constitutes one half of the broader theory of supply and demand, which serves as a fundamental organizing principle in market economies (Skousen, 2024). Demand theory posits that prices rise for goods that are in demand and fall for goods that are not. These price changes act as signals to producers, indicating when to increase or decrease the production of a given good (Mulligan, 2024). Demand theory is a foundational concept in economics that examines the relationship between consumer demand and the price of goods and services within a market. This relationship is typically depicted through

the demand curve, which generally slopes downward from left to right, illustrating that as the price of a good decreases, the quantity demanded by consumers usually increases. Conversely, as the price rises, the quantity demanded typically decreases. This inverse relationship between price and quantity demanded is essential for understanding consumer behaviour and market dynamics (Mulligan, 2024).

The theoretical foundation of demand forecasting lies in the idea that future events can be anticipated by analysing both current and historical data (Maris et al., 2018). Many time-series analysts believe that patterns in past data can be identified and effectively used to forecast future values (Alqatawna et al., 2023). Business forecasting employs two types of models: qualitative and quantitative (Rathore et al., 2022). Quantitative forecasting involves the use of statistical analysis tools to generate predictions. This approach integrates methods, historical data, and relevant information into a precise mathematical model to identify the fundamental principles governing future trends, thereby generating forecasts. Quantitative forecasting is a data-driven and objective method focused on explaining past events (Zellner et al., 2021). In contrast, qualitative forecasting relies on human judgment and is more subjective. Its primary aim is to anticipate future events rather than explain past occurrences (Goodwin & Fildes, 2022).

Demand forecasting is a systematic approach that involves analysing historical data to assess and predict future consumer demand for a specific product or service (Seyedan & Mafakheri, 2020). This strategic practice supports decision-making in supply chain management by forecasting future sales volumes and revenue streams (Hofmann & Rutschmann, 2018; Kumar et al., 2020; Yu, 2022). Accurate demand forecasting enables businesses to optimize inventory levels by anticipating future sales, which in turn helps

managers make informed decisions about various operational aspects, such as inventory management, warehouse allocation, strategic flash sales, and customer service improvements (Bharadiya, 2023; El Jaouhari et al., 2022).

As noted by Abolghasemi et al. (2020), demand forecasting is crucial as it significantly impacts decision-making at multiple levels within firms. Companies often prioritize accurate and efficient forecasting of future demand, and recent literature has seen considerable advancements in improving forecasting accuracy (Feizabadi, 2022). Demand forecasting plays a pivotal role in supply chain management in the retail sector, where replenishment systems for certain products are built based on projected future demand (Yue et al., 2007). In tourism, demand forecasting is critical for economic growth, as it informs decisions related to resource allocation and risk assessment (Law et al., 2019). Accurate demand forecasts provide practitioners and academics with essential data to make informed decisions, underscoring the importance of this practice in both commerce and trade. Companies must accurately predict market trends to position themselves strategically in both the short and long term, especially given the inherent uncertainty of the future (Banerjee et al., 2020).

In this research, demand theory provides a fundamental understanding of market behaviour within cold chain logistics, where the perishability of agricultural products makes precise demand prediction crucial. Demand forecasting theory, by utilizing historical data, offers tools to anticipate the demand for perishable goods, thus optimizing logistics operations and minimizing waste. The application of these theories allows for a deeper understanding of the challenges within cold chain logistics and informs the research hypotheses or objectives. For instance, the study could explore how accurate demand

forecasting enhances operational efficiency and reduces losses within the cold chain, thereby contributing to both sustainability and profitability.

2.3 Empirical Findings of Similar Studies

This section comprises four components. The first part focuses on the empirical literature pertaining to fresh agricultural products. The second part consists of an empirical analysis focused on cold chain logistics. The third part focuses on the variables' selection. The fourth part consists of an empirical investigation focusing on static panel data models. The fifth part provides a comprehensive analysis of the empirical literature on models utilized for predicting future demand.

2.3.1 Review on the Fresh Agricultural Products

The subject of fresh agricultural goods has received considerable scholarly focus in recent years across multiple fields of study. China conducted an extensive study on fresh agricultural products from 2020 to 2023, resulting in the publication of 1,300 publications over the course of three years. China, the United States, and Italy have all conducted extensive studies on fresh agricultural goods. During this period, each country published over 400 publications, as indicated in Figure 2.1.

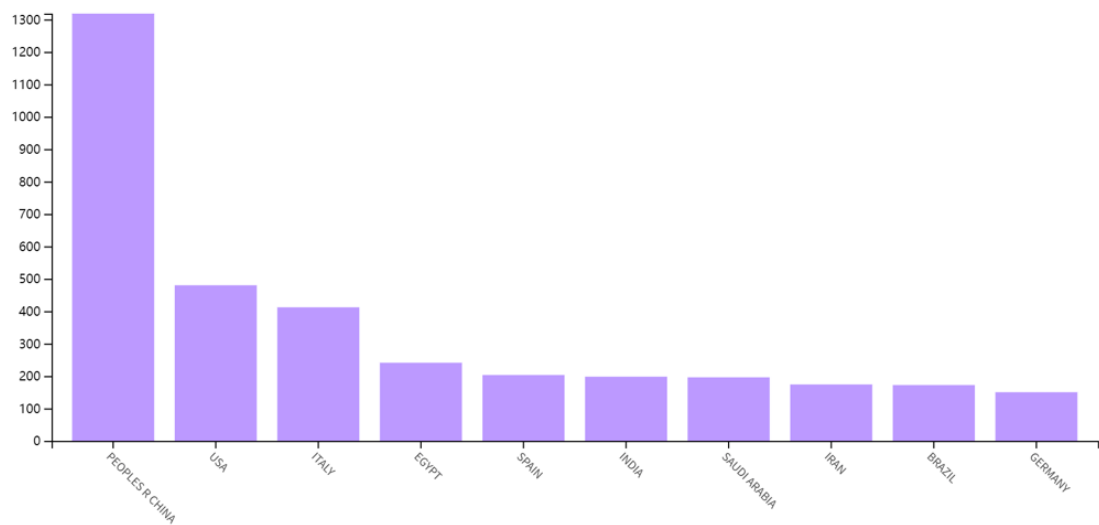


Figure 2.1: Number of Articles on Fresh Agricultural Products Published by Country from 2020 to 2023

Source: Obtained from Web of Science journal database, 2023.

The study then utilized CiteSpace to analyse and identify various research objectives in different nations. A comprehensive dataset of 698 papers published in 2023 on the topic of fresh agricultural products was extracted from the Web of Science database. Subsequently, the CiteSpace software was employed for analysis, revealing the diverse research objectives of different countries in this field. Figure 2.2 illustrates the current research focus on fresh agricultural products and its corresponding national distribution, encompassing topics such as leafy vegetables, agricultural product quality, variable selection, and more. This section concentrates on defining the characteristics and types of fresh agricultural products.

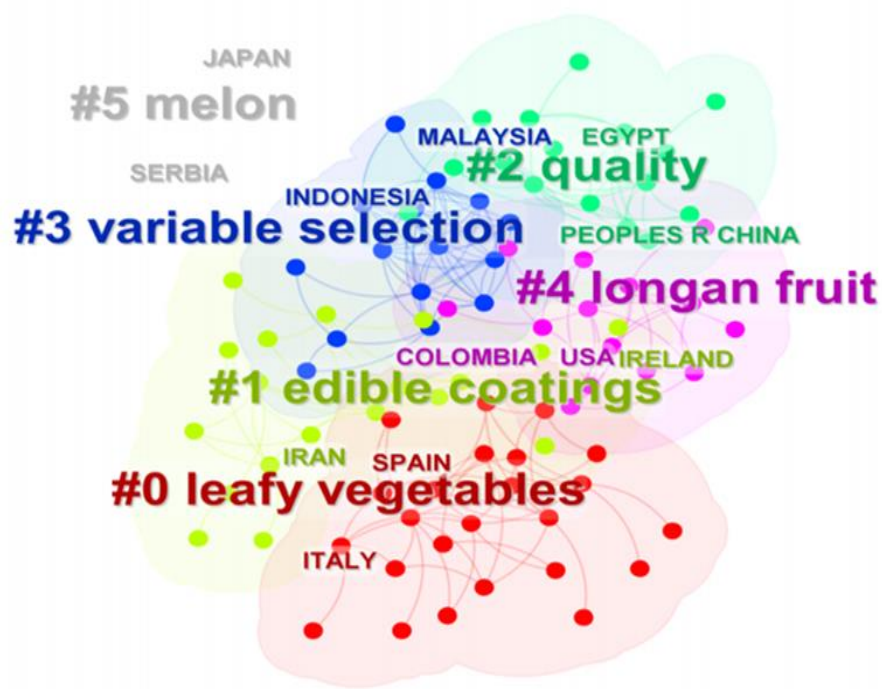


Figure 2.2: Fresh Agricultural Products Cluster Diagram

Source: Constructed using CiteSpace from Web of Science journal database, 2023.

2.3.1.1 Characteristics of Fresh Agricultural Products

The primary characteristic of fresh agricultural goods is their acute responsiveness to time. The limited shelf life and ongoing degradation over time restrict the duration for transporting and trading fresh agricultural produce at ambient temperature (Aday, 2020). Perishability is the second characteristic of fresh agricultural products. Due to the high moisture content in fresh agricultural produce, bacteria and molds can easily proliferate in unfavourable temperature circumstances, resulting in food spoilage and deterioration (Esteso et al., 2021). Hence, the implementation of a real-time temperature control system inside the cold chain is imperative to ensure the preservation of the high quality of fresh agricultural goods (Torres-Sánchez et al., 2020).

Fragility is the third characteristic of fresh agricultural produce. During the circulation process, fresh agricultural produce is susceptible to damage from mechanical treatment, such as vibration, friction, and collision (Dai et al., 2024). This is due to factors such as texture, composition, and structure, which ultimately impact the appearance, quality, and nutritional value of the fresh products (Zhang et al., 2023; Onwude et al., 2020). The final characteristic of fresh agricultural products is their seasonal nature. Each distinct category of fresh agricultural products has a designated harvest period, during which there is no artificial treatment involved (Mesías et al., 2021). As a result, the production of fresh agricultural products exhibits subtle seasonal variations, particularly in the case of fruit and vegetable products (Liu et al., 2022; Richards & Rickard, 2020).

2.3.1.2 Types of Fresh Agricultural Products

Sun (2021) suggested specific types of fresh agricultural items suitable for research, including fruits, vegetables, meat and poultry, eggs, milk, and aquatic products. Li (2022) identified tea, fruits, vegetables, meat, and aquatic items as specific categories of fresh agricultural products in their study on forecasting cold chain logistics demand for fresh agricultural products in Guangdong Province. Wang (2017) chose five distinct categories, including fresh fruits, vegetables, aquatic products, meat products, poultry and egg products, and dairy products, to represent the sector. Li (2022) categorized fresh agricultural items into six key groups while examining temperature-controlled logistics requirements during the COVID-19 pandemic: fresh vegetables, aquatic products, fruits, poultry and egg products, meat products, and dairy products. Kasza et al. (2024) conducted a study on fresh agricultural items, with a specific focus on vegetables, fruits, meat, poultry and egg products, dairy products, and aquatic products. In their study, Zhou & Zeng (2023) specifically examined the prediction of cold chain logistics demand for fresh agricultural items in Jiujiang City,

located in Jiangxi Province. They specifically chose fruits, seafood, vegetables, and meat as fresh agricultural products. In Meishan City, Zhou et al. (2023) identified four categories of agricultural items, namely vegetables, aquatic products, meat, and fruits, to be used as indicators for predicting cold chain logistics. This selection was determined by the specific requirements of cold chain logistics in this city and the presence of pertinent data.

In accordance with the scholarly classification framework for fresh agricultural products, and to ensure the comprehensiveness and precision of the study outcomes, this study categorized fresh agricultural products into six distinct groups: fruits, vegetables, meat, aquatic products, poultry and egg products, and dairy products.

2.3.2 Review on the Cold Chain Logistics

Given the significance of the quality and flavour of fresh agricultural produce in today's world, numerous scholars in different nations have initiated research on cold chain logistics. Figure 2.3 demonstrates that China has conducted significantly more research in cold chain logistics in the past three years compared to other nations, with Ireland and the United States following closely behind. Chinese scholars have authored four times as many articles on cold chain logistics research in the previous three years compared to Ireland and ten times as many compared to the United States. This highlights the significant relevance of cold chain logistics in China.

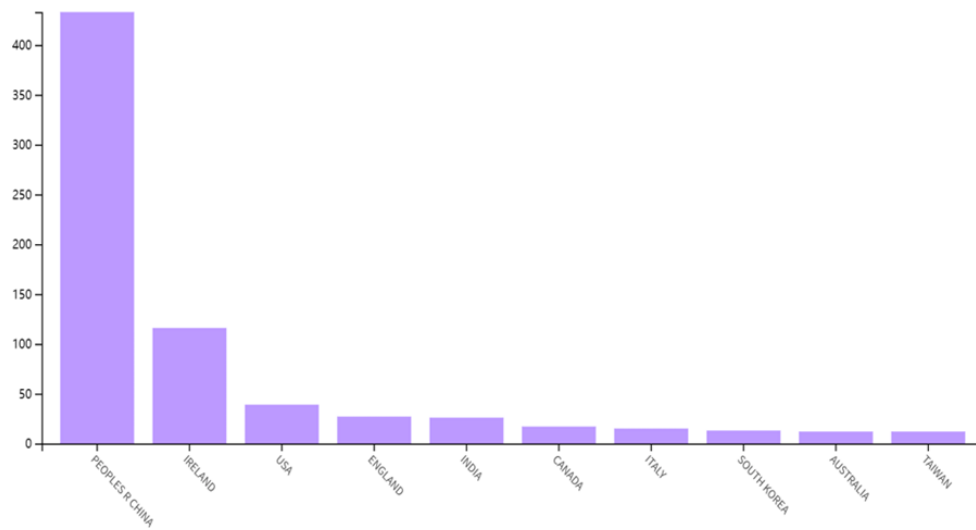


Figure 2.3: The Number of Papers on Cold Chain Logistics Published by Country from 2020 to 2023

Source: Web of Science journal database, 2023.

This study extracted a comprehensive dataset of 604 academic publications published between 2020 and 2023 on the topic of cold chain logistics from the Web of Science database. The dataset was then analysed using CiteSpace to identify and compare the study priorities in different nations. Figure 2.4 illustrates that worldwide, the primary research areas for cold chain logistics are regression analysis, green leafy vegetables, and shelf life, among others.



Figure 2.4: Cold Chain Logistics Cluster Diagram

Source: Constructed using Cite Space from Web of Science journal database, 2023.

Shashi et al. (2021d) furnished a conceptual delineation of cold chain logistics as the organized conveyance and preservation of perishable commodities within regulated low-temperature environments. This operational framework encompasses a diverse spectrum of goods, including agricultural produce, meat derivatives, and dairy products. In contemporary logistics, this process serves as a pivotal mechanism for ensuring the efficient, secure, and regulated movement of perishable commodities (Chen, 2020). Its scope extends beyond foodstuffs to include various other items, such as pharmaceuticals and cosmetics, with the overarching goal of guaranteeing their quality and safety throughout the supply chain (Chukwu & Adibe, 2022). As consumer spending burgeons in tandem with economic growth and rising income levels, there arises a heightened concern regarding the safety and quality of food products, coupled with a growing impetus for dietary modernization and diversification. Notably, Nguyen and Li (2022) underscored the daily consumption

prevalence of perishable fresh agricultural products. The implementation of cold chain logistics emerges as an indispensable strategy for preserving the freshness and quality of such items. This multifaceted approach entails a series of stages, including precooling treatment, refrigerated storage, transportation, processing, and distribution, all aimed at maintaining optimal temperature conditions from origin to final destination (Goedhals-Gerber et al., 2024). Moreover, the proliferation of internet-based commerce has intensified the demand for premium perishable goods, thereby accentuating the imperative for robust cold chain logistics systems (Tang et al., 2023). In addition to its role in preserving product integrity, cold chain logistics serve as a critical link between production sites, distribution hubs, and urban wholesale markets, a function of particular significance amidst the increasing digitization and modernization of agricultural practices (Vos & Cattaneo, 2021).

2.3.3 Variables Selection

The Production of Fresh Agricultural Products

Wang (2017b) observed that certain segments of the fresh product distribution chain lacked cold chain facilities. Nevertheless, the developmental trajectory of industrialized nations suggests an imminent market shift towards the widespread adoption of cold chain logistics. The China Cold Chain Logistics Development Report (2010) underscored the imperative of conducting a comprehensive assessment of the total demand for cold chain logistics. The report advocated incorporating the overall output of refrigerated commodities, such as meat, seafood, frozen pasta, fruits, vegetables, milk, and other perishable items, as determinants of cold chain logistics transportation. Li et al. (2021) employed a forecasting model to project the total demand for cold chain logistics in a specific economic region. Their model was predicated on the aggregate production of meat, eggs, aquatic goods, fruits, vegetables, milk, and other agricultural items requiring refrigerated transportation. The

objective was to furnish a comprehensive and meticulous depiction of the necessity for cold chain logistics in the region. Zhang (2020) conducted a study on demand forecasting for cold chain logistics in Hebei Province. The total demand for cold chain logistics for fresh agricultural products was estimated based on the collective production of vegetables, fruits, meat, poultry, eggs, milk, aquatic goods, and other perishable products necessitating cold chain transportation.

Zeng et al. (2022) investigated the forecasting of cold chain logistics requirements for citrus crops in Liuzhou City, specifically focusing on pomelo, mandarin, tangerine, and orange citrus fruits. They collected production data from 2014 to 2020 and applied the Grey GM (1,1) model to forecast citrus fruit production for the upcoming decade. Additionally, they conducted residual tests to examine the projected findings. Zeng and Zhu (2022) developed a Grey GM (1,1) model to predict the future demand for cold chain logistics of agricultural products in Hunan Province. Utilizing historical data on the output of fresh agricultural goods in Hunan Province from 2010 to 2021 as input, their model projected the demand from 2022 to 2026. In their research, Zou and Cui (2023) scrutinized the market need for cold chain logistics in Hubei Province, focusing on fresh agricultural products like fruits, vegetables, various meats (e.g., swine, beef, mutton, and poultry), poultry eggs, milk, and aquatic items. The production of these goods served as benchmarks for evaluating the necessity for cold chain logistics in the region, with the study employing the production of newly harvested agricultural items as the dependent variable.

By consolidating the findings of prior researchers, this study utilized the production of fresh agricultural goods as a proxy for assessing the demand for cold chain logistics in the fresh agricultural sector, serving as the dependent variable.

The five independent variables—value added of the primary industry, freight turnover, ownership of civilian goods vehicles, internet broadband access subscribers, and the impact of COVID-19—were strategically chosen based on their demonstrated significance in prior studies and their relevance to the current study’s focus on forecasting.

Value Added of the Primary Industry

The value added of the primary industry serves as a crucial economic measure tied to agricultural productivity, making it a more direct indicator of cold chain logistics needs than broader economic indicators. So, the value added of the primary industry was selected due to its pivotal role in agricultural output, which is intrinsically linked to the demand for cold chain logistics. Historically, China has predominantly emphasized agriculture, particularly the production of fresh agricultural goods. As the production of these goods has risen, the price of each unit has decreased, leading buyers to increase their purchasing power. The rise in public health consciousness has significantly increased residents’ online demand for fresh agricultural products, thereby driving up the need for cold chain logistics (Li, 2022b). According to Wang (2022), agriculture is the main industry, and the added value of this sector primarily influences the circulation of agricultural products.

Zhang (2023) posited that agriculture constitutes a pivotal component of the primary industry, emphasizing a direct correlation between the primary industry’s output value and the level of agricultural advancement. The entire output of the primary industry significantly influences the cold chain logistics of agricultural products. Wu and Han (2015) uncovered the economic impact of the primary industry’s augmented value on the imperative for cold chain logistics in Jiangsu Province. Wang and Yan (2018) investigated the utilization of the primary industry’s added value as an economic indicator for forecasting the demand for cold chain logistics of agricultural products in the Beijing, Tianjin, and Hebei regions of China.

LV and Chen (2020) scrutinized the supplementary benefits provided by the primary sector while investigating the factors influencing the demand for cold chain logistics of aquatic products.

Freight Turnover

Freight turnover reflects the volume of goods transported, providing a nuanced view of logistics demand that combines transportation efficiency with infrastructure development, and it serves as a key indicator of logistics demand by quantifying the movement of goods over distances. Freight turnover quantifies the overall volume of goods moved across a defined distance. It signifies the need for transporting goods in various economic sectors and the total number of transportation services offered by those sectors. Moreover, it shows the need for freight volume in different sectors of the economy (Wang, 2022). Zhang (2023) suggested that freight turnover was a crucial parameter for statistical analysis in the logistics sector, precisely reflecting the demand for cargo transportation across all sectors of the national economy within a certain period. When predicting the demand for cold chain logistics for fresh agricultural products in Shanxi Province, he selected freight turnover as an indicator of transportation capacity. Li (2022b) stated that the epidemic had a notable impact on road transport, leading to a corresponding reduction in the turnover of road transport commodities. The rotation capacity of goods increased the mileage limit for transportation, separate from the transportation capacity of commodities. This capacity indicated China's capabilities in cold chain logistics and the residents' need for cargo volume in transportation. Commodity turnover significantly affected transportation capacity, which in turn impacted the growth of cold chain logistics. Wang (2017b) stated that the freight turnover capacity of fresh agricultural goods cold chain logistics imposed a limitation on transportation distance in addition to the freight capacity. The difference between them lay

in the specifics of the transportation network. Improving and putting into effect the modernization of the transportation network for fresh agricultural goods' cold chain logistics could boost operational efficiency and meet the cold chain's demands.

Ownership of Civilian Goods Vehicles

The ownership of civilian goods vehicle reflects the capacity of the logistics network, and it is a practical indicator of logistical capacity and infrastructure development. China's economy and technology have seen swift advancement since 2008, resulting in a notable surge in the demand for commodities and a big increase in the quantity of road-operated vehicles due to enhanced infrastructure (Wang & Yan, 2018). The expansion of temperature-controlled logistics for agricultural products is closely linked to the general progress of logistics. The logistical demand's magnitude might indicate the level of logistics development and consumer demand capacity (Wang et al., 2018).

Wang et al. (2018) chose the scale of logistics demand as a key element influencing the need for temperature-controlled logistics for agricultural products. They selected ownership of civilian goods vehicles as a metric to gauge the impact of logistics demand scale. Qi and Tai (2015) conducted a study predicting the demand for cold chain logistics in China for fresh agricultural products. They utilized civilian cargo vehicle ownership as an index to assess the level of logistics improvement. Liang et al. (2018) predicted the demand for cold chain logistics in Tianjin for fresh agricultural products. They determined that owning civilian goods vehicles was a reliable indicator of the level of logistical expansion. Wang and Yan (2018) stated that cold chain agricultural products primarily rely on road transport. They utilized the quantity of things transported and the possession of civilian goods vehicles in Beijing, Tianjin, and Hebei as key indicators to gauge the extent of

logistics advancement. This study considered ownership of civilian goods vehicles as a crucial indication for assessing the progress of cold chain logistics.

Internet Broadband Access Subscribers

Internet broadband access subscribers capture the intersection of technological advancement and logistics, highlighting the growing influence of e-commerce on the cold chain sector, which other technology-related variables may not fully address. And Internet broadband access subscribers serve as a proxy for technological advancement and e-commerce growth, which significantly impacts logistics, especially in the context of temperature-controlled supply chains. The quantity of computer internet users serves as a gauge of the extent of internet advancement and coverage capability in a particular area. The internet's advancement in this field contributes to information processing, sharing, temperature monitoring, and food traceability in the temperature-controlled logistics of agricultural products (Wang, 2022).

Zhao and Gao (2022) found that internet broadband access subscribers played a crucial role in evaluating the progress of cold chain logistics for fresh agricultural products in Henan Province. Research indicated that the internet broadband access subscribers significantly impacted the need for cold chain logistics in the fresh agricultural goods industry. Huang and Wang (2020) conducted research on the elements that affected the need for cold chain logistics for fresh agricultural products. They concentrated on the quantity of internet broadband access subscribers. Zhang and Zang (2018) suggested that the quantity of internet broadband access subscribers served as a gauge for the growth prospects of temperature-controlled logistics amid the swift development of e-commerce. Rural e-commerce had seen substantial expansion in recent years, posing a huge challenge to cold chain logistics and affecting the demand for these services. In conclusion, internet broadband

access subscribers have a notable impact on the need for cold chain logistics, particularly for fresh products.

COVID-19

The inclusion of COVID-19 reflects the need to account for major disruptions that have a direct and lasting impact on logistics. This variable is critical in understanding how external shocks can drastically shift logistics demands, which other variables might overlook. The COVID-19 pandemic introduced unprecedented disruptions to supply chains, particularly affecting the logistics of perishable goods. Yao et al. (2021) discovered that COVID-19 altered the trajectory of short-term economic growth, with notable effects across all sectors. The agricultural product logistics business experienced shortages in manpower and manufacturing capacity throughout all stages of agricultural product procurement, shipping, packaging, and sale. Urban areas had an excess of agricultural items, causing shortages in supermarkets and price increases. Meanwhile, rural areas had more agricultural products than needed, creating an imbalance in the agricultural market. Thus, COVID-19 greatly affected the demand for logistics in the agricultural sector. Forecasting demand, properly allocating resources, balancing supply and demand, and mitigating the epidemic's adverse effects on agricultural logistics were essential tasks. This was highly important for coordinating agricultural logistics and ensuring the efficiency of the logistics system. Li (2022b) described COVID-19 as an unpredictable factor. The occurrence of these events could lead to a scarcity of fresh agricultural goods and a rise in their demand, thereby affecting the need for temperature-controlled logistics due to force majeure factors. This analysis considered COVID-19 as an unpredictable occurrence that impacts the need for cold chain logistics in the fresh agricultural products market.

Summary of DV and IV

The selection of variables in this study is based on a thorough review of research conducted by various scholars. These variables are chosen with consideration given to factors such as data availability, completeness, and the rationale behind their inclusion. Please refer to Table 2.1 for a comprehensive list of selected variables.

Table 2.1: Variable's Descriptions

Variables	Authors
Q_{FAP} : Production of fresh agricultural products	Wang (2017), Li et al. (2021), Zhang (2020), Zeng et al. (2022), Zeng and Zhu (2022), Zou and Cui (2023).
X_{VP} : Value added of primary industry	Li (2022), Wang (2022), Zhang (2023), Wu (2015), Wang and Yan (2018), Lu and Chen (2020).
X_{FT} : Freight Turnover	Wang (2022), Zhang (2023), Li (2022), Wang (2017).
X_{OCGV} : Ownership of Civilian Goods Vehicles	Wang and Yan (2018), Wang et al. (2018), Qi and Tai (2021), Liang et al. (2018).
X_{IBS} : Internet Broadband Access Subscribers	Wang (2022), Zhao and Gao (2022), Huang and Wang (2020), Zhang and Zhang (2018).
$X_{COVID-19}$: COVID-19	Yao et al. (2021), Li (2022).

Source: China Statistical Yearbook, 2015-2022.

2.3.4 Review on Static Panel Data Modelling

Ever since the publication of the seminal article by Nerlove and Balestra (1996) on panel data, the use of this econometric tool has rapidly grown. Panel data, which integrates time series and cross-sectional data, has become a fundamental aspect of modern econometrics (Rodríguez-Caballero, 2022). Western economists have extensively employed micro panel data to explore important areas such as microeconomics, development economics, and labour economics (Batrancea et al., 2022). More recently, researchers have

increasingly used panel data to address macroeconomic issues. Its ability to control for biases from unobservable economic factors makes panel data models more reliable than traditional cross-sectional data models. Additionally, panel data approaches improve the reliability of estimates by increasing the amount of sample data and reducing correlations among economic variables (Zhang, 2022). Panel data models are particularly effective at identifying impacts that may remain hidden in either time series or cross-sectional data alone, enabling the development and validation of more complex behavioural models (Kripfganz & Schwarz, 2015).

For example, Lee and Suh (2022) utilized static panel data methods to assess how environmental, social, and governance (ESG) factors influence financial performance in organizations, both collectively and individually. Their study, which analysed 351 companies listed in the FTSE 350 index from 2002 to 2018, revealed that companies with stronger ESG performance tend to achieve better financial outcomes. This finding implies that integrating ESG factors into business strategies can lead to sustainable financial performance, influencing policymakers to promote ESG reporting standards and corporate transparency.

Similarly, Nathaniel et al. (2021) examined the relationship between carbon dioxide emissions and economic growth in selected African economies from 1990 to 2014, using a fixed panel data model. Their research highlighted a significant positive relationship between increased energy consumption and economic growth. The study underscored the trade-off between energy consumption and environmental sustainability, indicating the need for policies that balance economic development with environmental protection, such as the

adoption of cleaner energy technologies and energy efficiency improvements across the continent.

Li and Liu (2020) analysed panel data on global and Chinese air cargo and mail turnover alongside GDP data from 2007 to 2017, retrieved from the International Civil Aviation Organization Council and the International Monetary Fund. Their research showed a strong correlation between air cargo turnover and GDP growth, suggesting that improvements in the air transportation sector can significantly boost economic performance. The findings emphasize the importance of investments in aviation infrastructure and policies aimed at fostering international trade and transportation efficiency.

Qin (2010) developed an electricity forecasting model using panel data on total electricity consumption, GDP, the proportion of the secondary industry in GDP, and scientific research funding across various Chinese provinces between 1990 and 2008. The results indicated that economic development and industrial structure shifts are key drivers of electricity demand. The study's findings suggest that policymakers should focus on promoting energy efficiency in industrial sectors and increasing investments in renewable energy sources to accommodate rising electricity demand while minimizing environmental impacts.

Finally, Qi (2010) gathered macro panel data on civilian car ownership, GDP per capita, road transport network density, and road passenger (freight) transit volume from the China Statistical Yearbook (1985–2007). Their analysis revealed significant regional disparities in automobile usage across Chinese regions, with economic growth and infrastructure development being the primary determinants of car ownership. These findings have important policy implications, as they suggest the need for targeted transportation

policies and infrastructure investments that address regional inequalities and support sustainable urban development.

2.3.5 Review on the Demand Forecasting Method

Various scholars have utilized different demand forecasting methods to predict the demand for fresh produce cold chain logistics across different provinces and cities in China, providing valuable insights into regional logistics needs and policy implications.

Wang and Yan (2018) employed a range of quantitative techniques, such as neural network models, GM (1,1) models, and other methodologies, to calculate China's logistics demand. The study revealed that the Grey Model offers benefits such as independence from assumptions regarding data statistical features, a lack of sample size limitations, and high prediction accuracy. Gray prediction is a method for predicting systems containing uncertain factors. Gray forecasting through the identification of the degree of difference between the development trend of the system factors, that is, correlation analysis, and the generation of raw data processing to find the law of the system changes, to generate a strong regularity of the data series, and then establish the corresponding differential equation model, to predict the future development trend of the state of things. It constructs a gray prediction model with a series of quantitative values that reflect the characteristics of the predicted object observed at equal time intervals and predicts the number of characteristics at a certain moment in the future or the time to reach a certain number of characteristics. The Grey Model is a univariate model that solely relies on the information from the dependent variable during the modelling process. Describing the influence of additional factors on the need for cold chain logistics in the agricultural goods system is challenging. Although the neural network approach yields very accurate predictions, its performance becomes erratic when the dataset is limited.

Liang et al. (2018) conducted a case study in Tianjin Municipality, using historical economic development data to select indicators influencing the demand for agricultural product cold chain logistics. By employing a multivariate regression method, they developed a scientifically sound model for predicting fresh agricultural produce cold chain logistics demand in Tianjin. Their study provided specific recommendations for improving agricultural product cold chain logistics in the region. The policy implications of this research are clear: local governments should use economic indicators to forecast logistics demand accurately and allocate resources effectively. This approach could help regions like Tianjin optimize their cold chain infrastructure, ensuring that it meets future demand.

Wu and Han (2015) analysed economic data from Jiangsu Province between 1990 and 2012 to identify factors influencing freight volume. Using a multiple linear regression model, they developed a regression equation to predict freight volume for the next decade. Their study highlighted the importance of understanding the relationship between economic growth and logistics demand, offering insights into the rational allocation of logistics resources and the development of logistics infrastructure. This research has significant policy implications, particularly in guiding the formulation of government policies aimed at modernizing the logistics sector. By aligning logistics infrastructure investments with projected economic growth, regional authorities can support sustainable logistics development.

Su and Huang (2023) found that the BP neural network model demonstrated minimal forecasting error and strong predictive performance when applied to logistical demand. Similarly, Zhai (2021) used a BP neural network to develop a forecasting model for inventory demand, emphasizing the model's accuracy and reliability. Wang (2023) applied

the BP neural network model to predict cold chain logistics demand in Chongqing Municipality from 2021 to 2025. The results showed that the model accurately captured the growth trajectory of cold chain logistics demand, providing a solid foundation for logistics planning by both government agencies and logistics enterprises. This underscores the importance of adopting advanced predictive models, like the BP neural network, to enhance the accuracy of demand forecasts, which can help policymakers and businesses in Chongqing better plan for future logistics needs.

Huang et al. (2023) also devised a demand forecasting model based on the BP neural network, with their findings indicating minimal forecasting error and a favourable fit. These studies collectively highlight the potential of neural network models in improving the precision of logistics demand forecasts. From a policy perspective, incorporating advanced predictive technologies can significantly enhance logistics planning and resource allocation, leading to more efficient and responsive cold chain logistics systems.

Yang et al. (2021) used the GM (1,1) Model and exponential smoothing to forecast logistics demand, while Zhou et al. (2021) applied a genetic algorithm and support vector regression machine to predict logistics demand in specific regions. Both studies demonstrated the effectiveness of these models in forecasting logistics needs, suggesting that combining different forecasting techniques can improve accuracy and adaptability. This has policy implications, as decision-makers should consider hybrid models that leverage multiple forecasting approaches to account for the varying factors influencing logistics demand.

Li (2017) employed the GM (1,1) forecasting model to predict cold chain logistics demand for fresh agricultural products in Chongqing, offering a scientific basis for

determining the need for cold chain facilities and equipment. Similarly, Li (2022) used grey correlation analysis to develop a demand forecasting index system for Guangdong Province and constructed a GM (1, N) model to predict cold chain logistics demand for fresh agricultural products. The study's validity was confirmed, providing policymakers with a reliable tool for planning cold chain infrastructure in Guangdong. The policy implication here is that local governments can use these predictive models to guide investments in cold chain facilities, ensuring that they meet future demand efficiently and sustainably.

Various academics utilize distinct forecasting methodologies to predict demand. This study categorizes and condenses different forecasting techniques and their corresponding benefits and constraints (refer to Table 2.). To achieve somewhat accurate outcomes, neural network models used for prediction necessitate a dataset containing a minimum of 10,000 entries (Su & Huang, 2023). Multiple linear regression models are commonly employed to forecast a dependent variable using known independent factors. However, it is important to note that in this study, the value of the independent variable, which predicts the demand for cold chain logistics for fresh agricultural produce in the next five years, is still unknown. However, the data in this study did not exceed 10,000 items. Hence, this study opts for the GM (1, 1) model to forecast the demand for cold chain logistics in relation to fresh agricultural items.

Table 2.2: Advantages and Disadvantages of Different Forecasting Models

Forecasting Model	Advantages	Disadvantages	Reference
Neural network model	The neural network model, with its remarkable flexibility and capacity for self-learning, is capable of approximating any continuous function at any level. This makes it well-suited for the task of forecasting and analysing nonlinear systems.	In cases where the pattern was not very pronounced and the original record was not consistent, there would be significant variations in forecasting and analysis. When the data is represented in a high-dimensional space and there are multiple degrees of connectivity between the data, the variety of the neural network grows, leading to an increase in the variance of prediction and analysis.	Su and Huang (2023); Zhai (2021); Wang (2023); Huang et al. (2023).
Multiple regression model	The analysis of the effects of different elements was simple and convenient. It is possible to accurately measure and validate the amounts of each ingredient and adjust them as needed, hence improving the accuracy of equation forecasting and analysis.	Neglected the impact of interaction effects and non-linear causality. It required a substantial quantity of data for evidential purposes.	Liang et al. (2018); Wu and Han (2015).
GM (1,1) model	It was suitable for addressing the problem of scarcity and instability of relative information content. The technique has the ability to demonstrate the constraints and interdependent connections between the pieces.	As the forecast period lengthens, the system becomes more susceptible to future uncertainty or random events, making it more suitable for short- to medium-term forecasting.	Wang and Yan (2018); Yang et al. (2021); Zhou et al. (2021); Li (2017); Li (2022).

2.4 Literature Gap

Perishable agricultural products, due to their short shelf life and sensitivity to environmental conditions, present unique challenges for logistics management, particularly within cold chain logistics systems. This is why accurate demand forecasting for cold chain logistics is critical to ensure timely delivery, minimize waste, and maintain product quality from farm to table.

A detailed examination of the existing literature reveals a significant gap: most research efforts have focused on specific provinces or cities, often overlooking broader geographical contexts, such as China's coastal and inland regions. While these studies have contributed to our understanding of cold chain logistics in localized areas, their narrow focus limits the generalizability of the findings across the entire country. Coastal regions, typically more economically developed, and interior regions, which have distinct logistical needs due to their unique geographical and economic characteristics, have not been sufficiently compared or integrated into a unified analytical framework. This oversight presents a critical research gap, especially given the growing importance of efficient cold chain logistics across the nation as China's fresh agricultural produce market continues to expand.

To address this gap, this study adopts a random effect panel data model to investigate the determinants of cold chain logistics demand for fresh agricultural produce across both coastal and inland regions of China. By incorporating a broader dataset that spans multiple regions, this study offers a more comprehensive understanding of the factors influencing demand, accounting for both regional differences and commonalities. The random effect panel data model is particularly well-suited for this analysis, as it allows for the examination

of both time-invariant and time-varying factors across different regions, capturing the unique characteristics of each area while also identifying general trends.

One of the novel contributions of this study is its consideration of the impact of the COVID-19 pandemic on cold chain logistics demand. The pandemic has disrupted supply chains globally, with significant implications for the fresh agricultural product market in China. By integrating COVID-19 as a variable in the demand forecasting model, this study not only provides an up-to-date analysis of how the pandemic has affected logistics demand but also offers insights into the resilience and adaptability of China's cold chain systems during periods of crisis. This is a pioneering effort, as previous studies have largely overlooked the pandemic's specific effects on cold chain logistics, despite its clear relevance to the sector.

Furthermore, this study also delves into the issue of geographical heterogeneity. It explores how regional disparities, such as differences in infrastructure, economic development, climate, and agricultural practices, influence the demand for cold chain logistics in various parts of the country. This analysis allows for a nuanced understanding of how different regions may require tailored logistics strategies to effectively meet their unique demands. For instance, coastal areas, which often have better-developed infrastructure and closer proximity to major ports, may have different logistical needs compared to inland regions, which may face challenges such as longer transportation distances and less-developed cold storage facilities.

In addition to analysing current demand, this study also provides a forward-looking forecast for cold chain logistics demand across China, encompassing both coastal and interior regions. By generating nationwide demand forecasts, this research offers valuable

insights for policymakers, logistics providers, and agricultural producers, helping them plan and allocate resources more effectively. This holistic approach addresses the limitations of previous studies that focused on specific regions and provides a more comprehensive picture of the cold chain logistics landscape in China.

Ultimately, this study represents an innovative contribution to the field by expanding the scope of research on cold chain logistics demand forecasting to include both coastal and inland regions, as well as by integrating the impact of COVID-19 into the analysis. By addressing previously neglected aspects and providing new insights into geographical heterogeneity, this work fills an important gap in the literature and offers practical implications for enhancing cold chain logistics systems across China.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the methodology for forecasting the demand for fresh agricultural produce cold chain logistics in China. It focuses on two aspects: the static panel data model, which analyses the factors that influence the demand for fresh agricultural produce cold chain logistics in China, China's coastal areas, and China's inland areas; and the GM (1,1) Grey forecasting model, which forecasts the demand for fresh agricultural produce cold chain logistics in China's coastal areas, inland areas, and the entire country for the next five years (2023 - 2027).

3.2 Research Design

This study begins by introducing two significant theories, including logistics management theory and demand forecasting. Through a review of the literature, insights into the elements that influence the demand for cold chain logistics of fresh agricultural products, the methodologies used to determine the key components, and the ways to quantify the demand for cold chain logistics of fresh agricultural produce are obtained. The study conducted panel data analysis models to examine the correlation between independent variables and the demand for cold chain logistics of fresh agricultural products in China, including its coastal and inland areas. Additionally, spatial heterogeneity analysis was performed to assess the variation in significant influencing factors across different regions of China and the varying impact of these factors in different regions. Following that, the estimated demand for cold chain logistics for fresh agricultural products in China from 2023 to 2027 was analysed separately for the entire country as well as for the coastal and inland

regions of China. The accuracy of the projections was then analysed, and ultimately, specific recommendations were proposed. The research design is illustrated in Figure 3.1. Figure 3.2 presents a conceptual framework divided into two main parts. Firstly, it identifies the determinants of cold chain logistics for fresh agricultural products in China, specifically distinguishing between the coastal and inland regions. A comparative analysis of the influencing factors in these two regions is conducted to understand their spatial heterogeneity. In the diagram, Q_{FAP} represents production for fresh agricultural products, VP denotes the value added of the primary industry, FT signifies freight turnover, $OCGV$ indicates ownership of civilian goods vehicles, IBS represents internet broadband subscribers, and $COVID-19$ denotes the COVID-19 pandemic. The second part involves forecasting the demand for cold chain logistics for fresh agricultural products in China, the coastal region, and the inland region.

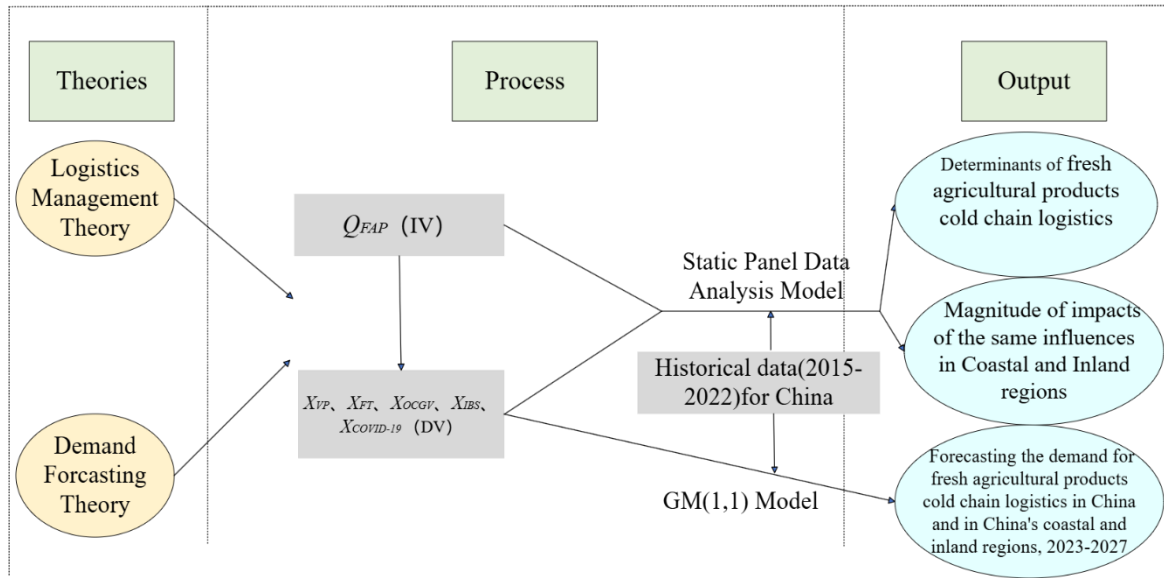


Figure 3.1: Research Design

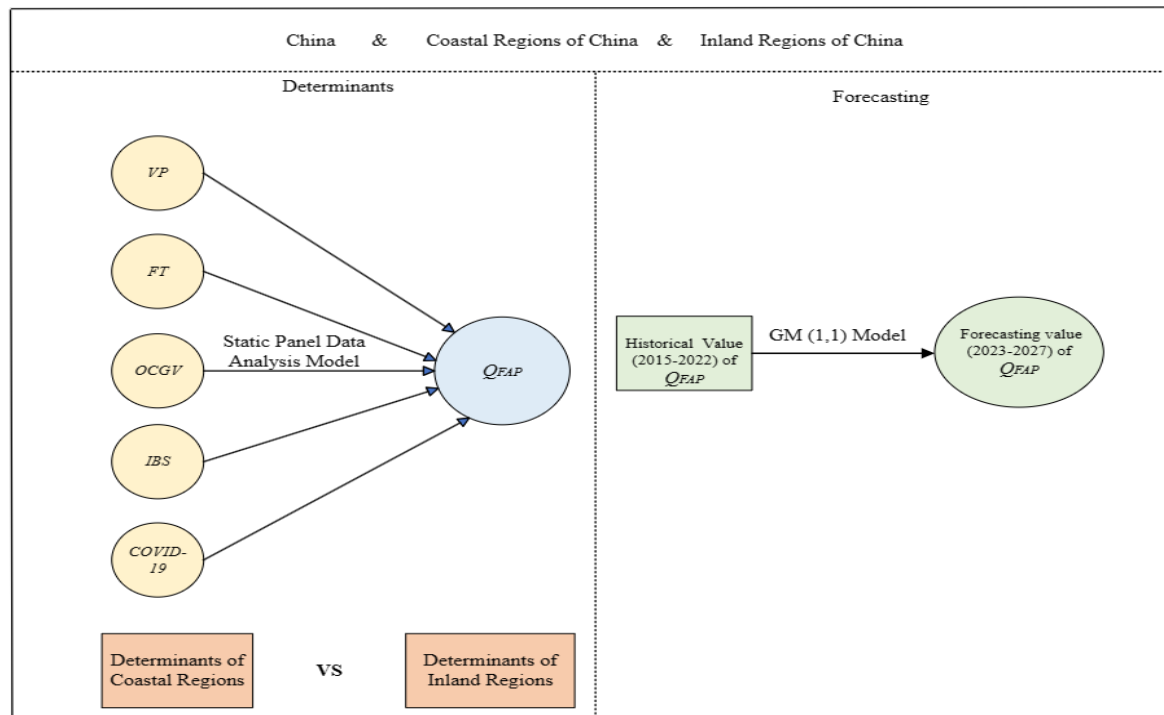


Figure 3.2: Conceptual Framework

3.3 Data Description

3.3.1 Sampling

China is located in the eastern part of the Asian-European continent along the western coastline of the Pacific Ocean (Feng et al., 2024). Covering 9.6 million square kilometres, it is divided into coastal and inland regions based on geography and economic development (Wang et al., 2021) (refer to Figure 3.3). Coastal regions, including Hainan, Taiwan, Liaoning, Tianjin, Hebei, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, the Hong Kong Special Administrative Region, the Macao Special Administrative Region, and the Guangxi Zhuang Autonomous Region, cover 1,273,200 square kilometres, or 13.26% of China's land area (Yin et al., 2022). These areas, such as Guangdong and Fujian, benefit from a maritime climate that supports agriculture and has led to prosperous ports and advanced cold chain logistics (Bilgin et al., 2023; Arriaga-Lorenzo et al., 2023). The development of modern cold chain facilities has been crucial for maintaining the quality of perishable goods, supporting significant contributions to both domestic and global markets (Arista et al., 2022).

In contrast, inland regions span 8,326,800 square kilometres, making up 86.74% of China's landmass (Yin et al., 2022). Characterized by plateaus, hills, and plains, these areas face a more variable climate and transportation challenges. Despite these difficulties, advancements in cold chain logistics have improved the preservation and transport of agricultural products, enhancing quality and market value (Muhammad, 2020; Pajić et al., 2024). Recent developments in refrigerated storage and transportation are helping to overcome these challenges and boost the region's agricultural export potential (Castelein et al., 2020).



Figure 3.3: Map of China

Source: Constructed by the author, edited from Standard Map Service website.

3.3.2 Data Collection Methods

This study utilized secondary data. After determining relevant variables from an extensive body of literature, historical data related to these variables were collected. The data collection period spanned from 2015 to 2022, with sources obtained from the “China Statistical Yearbook,” and the “Cold Chain Logistics Yearbook.”

3.3.3 Data Analysis Methods

This study employed a quantitative methodology to investigate the cold chain logistics of fresh agricultural products in China. A range of software tools was utilized to support the analysis: CiteSpace was employed for literature analysis, STATA 17 was used to perform static panel data model analysis, and Python was applied to implement the GM (1,1) model for forecasting demand for cold chain logistics across different regions. Additionally, Python was used to calculate the forecasting accuracy of the model, ensuring precise demand predictions.

3.4 Static Panel Data Models

Rizka Zulfikar (2018) categorized panel data models into three types: the Random Effects (RE) model, the Fixed Effects (FE) model, and the Pooled Ordinary Least Squares (Pooled OLS) model. The equations for these models are as follows:

The equation of the Pooled OLS model:

$$y_{it} = \beta_0 + \beta_1 x_{1it} + \beta_2 x_{2it} + \cdots + \beta_n x_{nit} + \varepsilon_{it} \quad \text{Equation 3.1}$$

Description: The variables i and t range from 1 to N and 1 to T , respectively. N represents the quantity of persons or cross sections, while T represents the quantity of time periods. In this model, n represents the number of independent variables, y represents the dependent variable, and x_n represents the n th independent variable. There are no individual or temporal effects included.

The equation of the FE model:

$$y_{it} = \beta_0 + \beta_1 x_{1it} + \beta_2 x_{2it} + \dots + \beta_n x_{nit} + u_i + v_t + \varepsilon_{it} \quad \text{Equation 3.2}$$

Description: The variables i and t are defined as integers ranging from 1 to N and 1 to T , respectively. N represents the quantity of individuals or cross section, while T represents the quantity of time periods. The variable u_i represents an unobservable characteristic specific to each individual, v_t represents an unobservable characteristic that varies over time, and ε_{it} represents other unobservable factors that fluctuate uniquely over time. Either u_i relates to x_n , or v_t is correlated with x_n .

The equation of the RE model:

$$y_{it} = \beta_0 + \beta_1 x_{1it} + \beta_2 x_{2it} + \dots + \beta_n x_{nit} + u_i + v_t + \varepsilon_{it} \quad \text{Equation 3.3}$$

Description: The variables i and t take on values from 1 to N and 1 to T , respectively. Where: N represents the total number of persons or cross sections, and T represents the total number of time periods. There is no correlation between u_i and x_n , or between v_t and x_n .

3.4.1 Model Selection

Rizka Zulfikar (2018) stated that there were several tests available to choose the most appropriate model, these test methods included the Chow test, the Hausman test, and the Breusch-Pagan Lagrange Multiplier (Breusch-Pagan LM) test. These tests can be conducted directly using the STATA17 software.

3.4.1.1 Chow Test

The Chow test is employed to evaluate if the Pooled OLS or the FE model is more appropriate for estimating panel data (Kripfganz & Schwarz, 2015). The test is based on:

H_0 : Select the Pooled OLS model if the probability (p) is more than 0.05.

H₁: Select the FE model if the probability (p) is less than 0.05.

The F -test is computed using the Chow Test formula as described by Baltagi and Yuliadi (2015). Many scholars now use F -test instead of Chow test. The F -test is:

$$F = \frac{(RRSS - URSS)/[(N - 1)(K + 1)]}{URSS/[N(T - K - 1)]} \quad \text{Equation 3.4}$$

where RRSS and URSS are the residual sums of squares of the restricted and unrestricted models, respectively while $[(N - 1)(K + 1)]$ and $[N(T - K - 1)]$ are the degrees of freedom.

3.5.1.2 Hausman Test

The Hausman test is a statistical test utilized to determine the optimal model, either FE or RE to be utilized (Youssef et al., 2023).

H₀: Select the RE model if the p-value is greater than 0.05.

H₁: Select the FE model if the p-value is less than 0.05.

$$H = (\hat{\beta}_{FE} - \hat{\beta}_{RE})' \Sigma^{-1} (\hat{\beta}_{FE} - \hat{\beta}_{RE}) \quad \text{Equation 3.5}$$

$\hat{\beta}_{FE}$: vector estimation of FE parameter; $\hat{\beta}_{RE}$: vector estimation of RE parameter; Σ^{-1} : the inverse variance-covariance matrix $\hat{\beta}_{FE} - \hat{\beta}_{RE}$. The Hausman test statistic is distributed asymptotically as chi-squared with K degrees of freedom under the null hypothesis that u_i is uncorrelated with x_n . The test suggests that RE model is better than the FE model when the null hypothesis is accepted.

3.5.1.3 Breusch-Pagan LM Test

The Breusch-Pagan LM test is employed to assess if the RE model demonstrates superior performance compared to the Pooled OLS model (King'wara, 2020).

H_0 : Select the Pooled OLS model ($p > 0.05$).

H_1 : Select the RE model ($p < 0.05$).

$$Breush - Pagan LM = \frac{NT}{2(T-1)} \left[\frac{\sum_{i=1}^N [\sum_{t=1}^T v_{it}]^2}{\sum_{i=1}^N \sum_{t=1}^T v_{it}^2} - 1 \right]^2 \quad \text{Equation 3.6}$$

The v_{it} is the residual from the Pooled OLS regression. The Breusch-Pagan LM test statistic is distributed as chi-squared with one degree of freedom under the null hypothesis. Acceptance of the null hypothesis means the random effects do not exist.

The following figure depicts the three tests used to select the Estimation Method (see Figure 3.3).

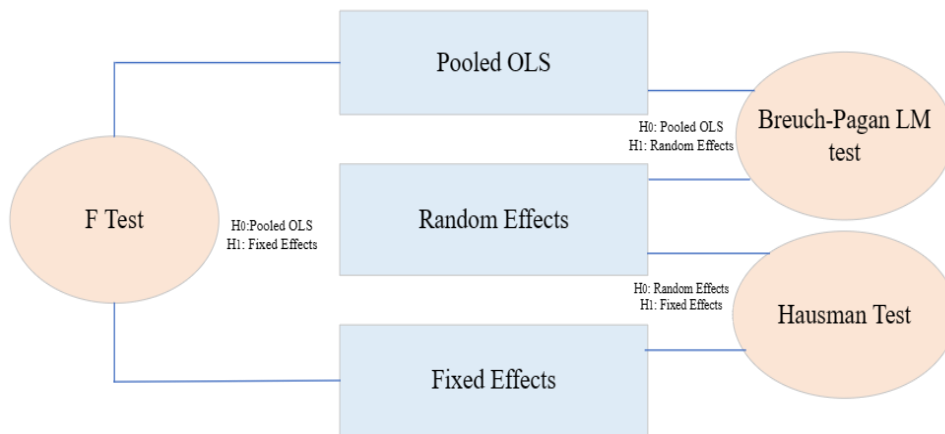


Figure 3.3: Methods of Selecting Panel Data Models

3.4.2 Estimation Static Panel Data Model

In this study, the variable data underwent logarithmic processing to mitigate scale effects. Panel data spanning from 2015 to 2022 were employed to construct a panel regression model, facilitating examination of the relationship between the demand for fresh agricultural products cold chain logistics and the independent variables across China as a whole, as well as the coastal and inland regions separately.

$$\ln Q_{NFAPit} = \alpha_N + \beta_{N1} \ln X_{VPit} + \beta_{N2} \ln X_{FTit} + \beta_{N3} \ln X_{OCGVit} + \beta_{N4} \ln X_{IBSit} + \beta_{N5} \ln X_{COVID-19it} + \varepsilon_{Nit} \quad \text{Equation 3.7}$$

$$\ln Q_{CFAPit} = \alpha_C + \beta_{C1} \ln X_{VPit} + \beta_{C2} \ln X_{FTit} + \beta_{C3} \ln X_{OCGVit} + \beta_{C4} \ln X_{IBSit} + \beta_{C5} \ln X_{COVID-19it} + \varepsilon_{Cit} \quad \text{Equation 3.8}$$

$$\ln Q_{IFAPit} = \alpha_I + \beta_{I1} \ln X_{VPit} + \beta_{I2} \ln X_{FTit} + \beta_{I3} \ln X_{OCGVit} + \beta_{I4} \ln X_{IBSit} + \beta_{I5} \ln X_{COVID-19it} + \varepsilon_{Iit} \quad \text{Equation 3.9}$$

Where $i = 1, 2, \dots, N$; $t = 1, 2, \dots, T$, N represents the number of provinces, T signifies the number of years of research. $\ln Q_{NFAP}$ represents the logarithm of national demand for cold chain logistics of fresh agricultural produce, $\ln Q_{CFAP}$ represents the logarithm of demand for cold chain logistics of fresh agricultural produce in the Coastal region, and $\ln Q_{IFAP}$ represents the logarithm of demand for cold chain logistics of fresh agricultural produce in the Inland region. $\ln X_{nit}$ represents the logarithm of the independent variable. The coefficient is denoted by β_n , and the intercept is denoted by α , and ε_{it} denotes other unobservable that vary individually over time, and α and β_n ($n=1, 2, \dots, 5$) do not vary with the values of i, t . The expected sign of variable $\ln X_{VPit}$ is a positive sign, the expected sign of variable $\ln X_{FTit}$ is a positive sign, the expected sign of variable $\ln X_{OCGVit}$ is either a positive or negative sign, the expected sign of variable $\ln X_{COVID-19it}$ is either a positive or negative sign.

3.5 Spatial Heterogeneity Analysis Method

This study's spatial heterogeneity analysis is conducted by mapping the varying degrees of influence of the same factors on cold chain logistics for fresh agricultural products in China's coastal and inland regions. Specifically, the coefficients of the independent variables in the static panel data model are used to represent these differences. By plotting these coefficients into radar charts, the analysis visually emphasizes the spatial heterogeneity of factors affecting cold chain logistics. This approach effectively highlights how the impact of these determinants varies between coastal and inland regions, providing deeper insights into regional disparities in the logistics of fresh agricultural produce.

3.6 Forecasting

The GM (1,1) model is a commonly used method for time series prediction and data analysis. It is one of the fundamental models in grey system theory, introduced by Professor Deng Julong in 1980. The GM (1,1) model is suitable for nonlinear and non-stationary data sequences with strong trend and periodicity. It is particularly applicable for short-term forecasting, especially when dealing with small, incomplete, or insufficient datasets.

Here's the basic formulae for the GM (1,1) model:

Let $Q_{FAP}^{(0)} = \{Q_{FAP}^{(0)}(i), i = 1, 2, \dots, n\}$ be the original time series data.

Perform the Accumulated Generating Operation (AGO) on the original data to

obtain the accumulated series $Q_{FAP}^{(1)}$:

$$Q_{FAP}^{(1)} = \{Q_{FAP}^{(1)}(k), k = 1, 2, \dots, n\} \quad \text{Equation 3.10}$$

$$Q_{FAP}^{(1)}(k) = \sum_{i=1}^k Q_{FAP}^{(0)}(i), k = 1, 2, \dots, n \quad \text{Equation 3.11}$$

Calculate the first-difference series $Q_{FAP}^{(1)}$ to obtain $\Delta Q_{FAP}^{(1)}$:

$$\Delta Q_{FAP}^{(1)}(k) = Q_{FAP}^{(1)}(k) - Q_{FAP}^{(1)}(k-1) \quad \text{Equation 3.12}$$

The first-order differential equation for GM (1, 1) is:

$$\Delta Q_{FAP}^{(1)}(k) + a * Q_{FAP}^{(1)}(k) = u \quad \text{Equation 3.13}$$

Where a and u are constants, and a represents the development coefficient and u represents the influence degree of the initial value.

The solution of the differential equation is given by:

$$\Delta Q_{FAP}^{(1)}(k) = \frac{u}{a} + (x^{(1)}(1) - \frac{u}{a}) \cdot e^{-a \cdot (k-1)} \quad \text{Equation 3.14}$$

After obtaining $Q_{FAP}^{(1)}(k)$, this study can reconstruct the forecasted values for the original series $Q_{FAP}^{(0)}$:

$$\hat{Q}_{FAP}^{(0)}(k) = Q_{FAP}^{(1)}(k) - Q_{FAP}^{(1)}(k-1) \quad \text{Equation 3.15}$$

These forecasted values $\hat{Q}_{FAP}^{(0)}(k)$ represent the predicted values for the future data points.

3.7 Forecast Accuracy Test

The posterior odds ratio is a statistical measure commonly used in evaluating the accuracy of forecasting models, particularly in the context of cold chain logistics for fresh and perishable agricultural products (Olugbo et al., 2024). This metric allows researchers to assess the model's predictive performance by comparing the probability of the model's

predictions being correct against them being incorrect. Kass and Raftery (1995) provided a comprehensive discussion on the posterior odds ratio in the context of Bayesian model selection, which can further enhance understanding of this metric in applied forecasting scenarios.

Huo (2014) employed the posterior odds ratio as a key metric to evaluate the forecasting accuracy of demand for aquatic products within cold chain logistics. This method provided a quantitative measure to gauge how well the forecasting model aligned with actual outcomes. Zhang (2021) similarly utilized the posterior odds ratio in evaluating the accuracy of demand forecasts for fresh agricultural products in Chongqing City's cold chain logistics sector. Both studies demonstrated that a lower posterior odds ratio corresponds to better forecasting performance, signifying those the model's predictions closely matched the observed data.

In the framework outlined by Huo (2014) and Zhang (2021), the posterior odds ratio serves as an indicator of model precision, with specific thresholds used to categorize accuracy levels. In their work, an accuracy level of one reflects the highest degree of precision, whereas an accuracy level of four indicates model failure. A lower posterior odds ratio suggests a higher likelihood of accurate forecasts, with a value approaching zero indicating optimal model performance. Conversely, a higher posterior odds ratio points to reduced accuracy, necessitating model adjustments or alternative forecasting approaches (see Table 3.1).

To ensure consistency and standardized measurement in this study, the posterior odds ratio is employed as the primary metric for assessing the accuracy of the cold chain logistics demand forecasting model. This approach aligns with the methodology used by Huo (2014)

and Zhang (2021), enabling a robust evaluation of the model's effectiveness in predicting demand for fresh agricultural products. By incorporating this statistical measure, the study aims to provide a reliable and validated assessment of forecasting accuracy, ensuring that the model's predictive power meets the necessary standards for practical application in logistics planning.

$$e(i) = Q_{FAPi} - \hat{Q}_{FAPi} \quad \text{Equation 3.16}$$

$$\bar{e} = \frac{1}{n} \sum_{i=1}^n e(i) \quad \text{Equation 3.17}$$

$$S_1 = \sqrt{\frac{1}{n} \sum_{i=1}^n (Q_{FAPi} - \bar{Q}_{FAP})^2} \quad \text{Equation 3.18}$$

$$S_2 = \sqrt{\frac{1}{n} \sum_{i=1}^n (e(i) - \bar{e})^2} \quad \text{Equation 3.19}$$

$$C = \frac{S_2}{S_1} \quad \text{Equation 3.20}$$

Where $e(i)$ is the residual; $\bar{e}$ is the mean value of residuals; S_1 is standard deviation of the true dependent variable data; S_2 is standard deviation of forecasting error; C is posterior odds ratio.

Table 3.1: Model Accuracy Descriptions

Accuracy	Class I (good)	Class II (pass)	Class III (barely)	Class IV (fail)
Posterior odds ratio (C)	$C \leq 0.35$	$0.35 < C \leq 0.5$	$0.5 < C \leq 0.65$	$C > 0.65$

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results obtained from the data analysis, focusing on the factors influencing the demand for cold chain logistics of fresh agricultural products in China as a whole, as well as in coastal and inland areas of China by regions. Geographic heterogeneity analysis is conducted to assess the varying levels of influence of these factors across different regions. Predictions are provided for the need for cold chain logistics for fresh agricultural products in China overall, and in coastal and inland areas of China by regions, spanning from 2023 to 2027.

4.2 Descriptive Statistics and Correlation Matrix

This section examines descriptive statistics and correlation matrices for variables pertaining to the cold chain logistics of fresh agricultural produce in China as a whole, as well as in coastal and inland areas of China by regions.

4.2.1 Descriptive Statistics

Table 4.1, Table 4.2, and Table 4.3 display the observed values, means, standard deviations, minimum values, and maximum values of the variables utilized in the static panel data model. These variables include the output of fresh agricultural products, the value added of primary industries, freight turnover, ownership of civilian goods vehicles, internet broadband subscribers, and COVID-19. Moreover, apart from the COVID-19 variable, all other variables demonstrate positive mean, maximum, and minimum values. The COVID-19 variable can take on two values: 0 and 1. A value of 0 signifies the absence of COVID-

19 in the specified year, whereas a value of 1 indicates the presence of COVID-19 in the specified year. The value of COVID-19 is taken as 1 for the years 2020, 2021, 2022 and 0 for the other years.

Table 4.1: Descriptive Statistics for Variables in China

Variables	Obs	Mean	Std. dev.	Min	Max
Q_{FAP} : Production for fresh agricultural products (unit: 10,000 tons)	248	3911.85	3226.71	60.09	14609.56
X_{VP} : Value added of primary industry (unit: 10,000 yuan)	248	22,800,000	15,700,000	936,000	63,000,000
X_{FT} : Freight turnover (unit: 10,000 tons kilometres)	248	62,300,000	66,900,000	1,196,400	341,000,000
X_{OCGV} : Ownership of civilian goods vehicles (unit: 10,000 vehicles)	248	86.88	61.09	12.10	327.00
X_{IBS} : Internet broadband subscribers (unit: 100,00 households)	248	1359.22	1038.70	29.60	4628.70
$X_{COVID-19}$: COVID-19	248	0.38	0.49	0	1

Note: Obs represents the observed values, std. dev. represents standard deviations, min represents minimum values, and max represents maximum values.

Table 4.1 presents the descriptive statistics of variables related to the demand for cold chain logistics in China's fresh agricultural products. These descriptive indicators are derived from a vast dataset spanning 8 years (2015–2022), covering 31 provinces, with a total of 248 data observations. The results in Table 4.1 indicate that the standard deviation of COVID-19 surpasses the mean, suggesting enhanced variability in this variable. Conversely, the standard deviations of fresh agricultural product output, primary industry

value added, freight turnover, civilian goods vehicle ownership, and internet broadband subscriptions are all smaller than their respective means, indicating relatively lower levels of volatility in these variables. The value of COVID-19 is taken as 1 for the years 2020, 2021, 2022 and 0 for the other years.

Table 4.2: Descriptive Statistics for Variables in Coastal Region of China

Variables	Obs	Mean	Std. dev.	Min	Max
Q_{FAP} : Production for fresh agricultural products (unit: 10,000 tons)	88	5055.39	3827.36	345.14	14609.56
X_{VP} : Value added of primary industry (unit: 10,000 yuan)	88	26,200,000	16,800,000	961,000	63,000,000
X_{FT} : Freight turnover (unit: 10,000 tons kilometres)	88	114,000,000	83,800,000	8,640,000	341,000,000
X_{OCGV} : Ownership of civilian goods vehicles (unit: 10,000 vehicles)	88	116.51	82.1	12.70	327.00
X_{IBS} : Internet broadband subscribers (unit: 100,00 households)	88	1883.85	1225.61	149.50	4628.70
$X_{COVID-19}$: COVID-19	88	0.38	0.49	0	1

Note: Obs represents the observed values, std. dev. represents standard deviations, min represents minimum values, and max represents maximum values.

The descriptive statistics of variables related to cold chain logistics for fresh agricultural products in China's coastal regions are presented in Table 4.2. This dataset comprises annual statistical data from 2015 to 2022 for 11 coastal provinces. With 88 observations, this dataset forms the basis of the proposed descriptive statistics. Table 4.2 prominently indicates that the standard deviations of fresh agricultural product output,

primary industry value added, freight volume, civilian truck ownership, and internet broadband users are all lower than their respective means. These five variables demonstrate smaller fluctuations. It is noteworthy that the standard deviation of COVID-19 exceeds the mean, indicating increased variability in the values of this variable. The value of COVID-19 is taken as 1 for the years 2020, 2021, 2022 and 0 for the other years.

Table 4.3: Descriptive Statistics for Variables in Inland Region of China

Variables	Obs	Mean	Std. dev.	Min	Max
Q_{FAP} : Production for fresh agricultural products (unit: 10,000 tons)	160	3282.91	2652.73	60.09	11811.03
X_{VP} : Value added of primary industry (unit: 10,000 yuan)	160	20,900,000	14,800,000	936,000	59,600,000
X_{FT} : Freight turnover (unit: 10,000 tons kilometres)	160	33,700,000	27,800,000	1,200,000	118,000,000
X_{OCGV} : Ownership of civilian goods vehicles (unit: 10,000 vehicles)	160	70.58	36.71	12.10	196.70
X_{IBS} : Internet broadband subscribers (unit: 100,00 households)	160	1070.67	786.12	29.60	3934.80
$X_{COVID-19}$: COVID-19	160	0.38	0.49	0	1

Note: Obs represents the observed values, std. dev. represents standard deviations, min represents minimum values, and max represents maximum values.

Table 4.3 presents the variables pertaining to the demand for cold chain logistics of fresh agricultural products in inland China. The descriptive statistics are derived from data spanning an eight-year period, from 2015 to 2022. The dataset encompasses 160 observations from 20 inland areas. Table 4.3 reveals that the standard deviation of COVID-19 exceeds the mean, indicating a higher variability in the values of this variable. In contrast,

the standard deviations of production of fresh agricultural products, value added of primary industries, freight turnover, ownership of civilian goods vehicles, and internet broadband subscribers, relative to their respective means, are all smaller than the means, indicating relatively minor fluctuations in these variables.

4.2.2 Correlation Matrix

Table 4.4, Table 4.5, and Table 4.6 present the findings of the correlation analysis conducted on variables associated with cold chain logistics for fresh agricultural produce in China as a whole, and coastal and inland areas of China by regions. The results indicate a significant positive association between the cold chain logistics of fresh agricultural produce and the added value of the primary industry, ownership of civilian goods vehicles, and the number of internet broadband subscribers. The demand for cold chain logistics of fresh agricultural produce will also expand with the rise of these independent variables. Furthermore, there is a positive correlation between freight turnover and the demand of fresh agricultural produce cold chains logistics. Similarly, there is a modest positive correlation between COVID-19 and the demand of fresh agricultural products cold chains logistics. The results of the correlation analysis through Tables 4.4 shows that the correlation between Q_{FAP} and X_{VP} is 0.92, and the correlation between X_{OCGV} and X_{IBS} is 0.92, which are both high. The high correlation may lead to some potential problems such as multicollinearity. A similar situation occurs in Table 4.5.

Table 4.4: Correlation Matrix for Variables in China

Variable	Q_{FAP}	X_{VP}	X_{FT}	X_{OCGV}	X_{IBS}	$X_{COVID-19}$
Q_{FAP}	1.00	-	-	-	-	-
X_{VP}	0.92	1.00	-	-	-	-
X_{FT}	0.59	0.48	1.00	-	-	-
X_{OCGV}	0.87	0.87	0.66	1.00	-	-
X_{IBS}	0.84	0.83	0.72	0.92	1.00	-
$X_{COVID-19}$	0.08	0.18	0.07	0.21	0.27	1.00

Table 4.5: Correlation Matrix for Variables in Coastal Region of China

Variable	Q_{FAP}	X_{VP}	X_{FT}	X_{OCGV}	X_{IBS}	$X_{COVID-19}$
Q_{FAP}	1.00	-	-	-	-	-
X_{VP}	0.95	1.00	-	-	-	-
X_{FT}	0.19	0.20	1.00	-	-	-
X_{OCGV}	0.81	0.83	0.50	1.00	-	-
X_{IBS}	0.73	0.83	0.54	0.91	1.00	-
$X_{COVID-19}$	0.09	0.18	0.15	0.19	0.25	1.00

Table 4.6: Correlation Matrix for Variables in Inland Region of China

Variable	Q_{FAP}	X_{VP}	X_{FT}	X_{OCGV}	X_{IBS}	$X_{COVID-19}$
Q_{FAP}	1.00	-	-	-	-	-
X_{VP}	0.88	1.00	-	-	-	-
X_{FT}	0.68	0.59	1.00	-	-	-
X_{OCGV}	0.83	0.87	0.69	1.00	-	-
X_{IBS}	0.85	0.82	0.73	0.89	1.00	-
$X_{COVID-19}$	0.11	0.19	0.05	0.28	0.33	1.00

4.3 Analysis Results of Static Panel Data Model

This section presents empirical findings concerning the demand for cold chain logistics in China for fresh agricultural products. The analysis encompasses China as a whole, as well as coastal and inland regions, utilizing a static panel data model. It offers a comprehensive examination of the factors influencing the demand for cold chain logistics of fresh agricultural products in China, encompassing both coastal and inland areas. Subsection 4.3.1 delves into the empirical findings regarding the demand for cold chain logistics in China's fresh agricultural products industry. Subsection 4.3.2 focuses on the empirical results pertaining to the demand for fresh agricultural products cold chain logistics in China's coastal regions. Lastly, subsection 4.3.3 presents the empirical findings concerning the demand for cold chain logistics in China's inland regions, specifically for agricultural products. Meanwhile, LnX_{VP} represents the natural logarithm of the value added of the primary industry. LnX_{FT} represents the natural logarithm of the freight turnover. LnX_{OCGV} represents the natural logarithm of the ownership of civilian goods vehicles. LnX_{IBS}

represents the natural logarithm of internet broadband subscribers. $X_{COVID-19}$ represents COVID-19.

4.3.1 Analysis Results of Static Panel Data Model in China

This segment explores the correlation between the influencing factors and China's demand for cold chain logistics of fresh agricultural products. The factors considered include COVID-19, the internet broadband subscribers, ownership of civilian goods vehicles, freight turnover, and the value added of primary industry. This subsection also discusses the specific results obtained from the tests conducted to assess multicollinearity, heteroskedasticity, and serial correlation.

Table 4.7: Results of a Static Panel Data Model of the Relationship Between Cold Chain Logistics Demand for Fresh Agricultural Products and Various Influencing Factors in China

Variable	Pooled OLS	Random Effects	Fixed Effects	Random Effects (Robust Standard Errors)
Constant	- 6.88*** (-12.25)	-4.84*** (-6.36)	-2.94** (-2.22)	-6.88*** (-25.04)
LX_{VP}	0.68*** (21.95)	0.61*** (11.53)	0.53*** (7.00)	0.68*** (62.96)
LX_{FT}	0.09*** (2.66)	-0.01 (-0.56)	-0.02 (-0.84)	0.09*** (4.40)
LX_{OCGV}	0.23*** (3.15)	0.22** (2.56)	0.09 (0.7)	0.23*** (8.26)
LX_{IBS}	0.17** (2.44)	0.31*** (5.25)	0.32*** (4.77)	0.17*** (3.68)
$X_{COVID-19}$	- 0.40*** (-4.48)	-0.46*** (-9.30)	-0.37*** (-4.62)	-0.40*** (-16.54)
F test (p -value)			120.23*** (0.00)	
Breusch-Pagan LM Test (p -value)	751.48*** (0.00)		-	-
Hausman Test (p -value)	-	4.21 (0.96)		-
Multicollinearity	-	-	3.55	-
Serial Correlation (p -value)	-	-	89.58*** (0.00)	-
Estimator Shall be Used		RE model		
Observations	248	248	248	248

Notes: Asterisk ***, **, and * represent 1, 5, and 10 percent levels of significance, respectively. The figures in brackets are t-statistics.

Table 4.7 presents the empirical findings derived from employing the static panel data analysis model to investigate the correlation between the demand for cold chain logistics

in the fresh agricultural products and the influencing factors in China. The F -test results in a value of 120.23, which is statistically significant at the 1% level. This indicates rejection of the null hypothesis, suggesting that the RE model is more suitable than the Pooled OLS model.

Following this, a choice between the FE model and the RE model is determined by employing the Hausman test. Table 4.7 reveals that the Hausman test yielded a value of 4.21, which was found to be statistically insignificant at all significance levels. Therefore, this study fails to reject the null hypothesis that the RE model is more appropriate than the FE model. Consequently, it can be concluded that the relationship between the cold chain logistics of fresh agricultural products in China and the various influencing factors is best represented by the RE model.

Subsequently, a battery of tests, including the multicollinearity test, heteroskedasticity test, and serial correlation test, is conducted to verify the robustness of the model. The Variance Inflation Factor (VIF) is employed to assess the presence of multicollinearity in the model. A model is considered to have a multicollinearity problem when the VIF exceeds 10. The empirical findings indicate that the VIF in the model assessing the relationship between the demand for fresh agricultural goods cold chain logistics and the influencing factors in China is 3.55, which is below the threshold of 10. This suggests that there is no issue of multicollinearity between the demand for fresh agricultural products cold chain logistics and the influencing factors in China. This is consistent with the advantages of panel data, which have fewer multicollinearity difficulties compared to time series data.

To ensure the reliability and stability of the empirical findings, a series of robustness tests were conducted. Although the serial correlation test indicated that the null hypothesis

was rejected at a 1% significance level, revealing serial correlation issues, these were addressed by re-estimating the random effects (RE) model using panel-corrected standard errors, following the approach recommended by Arellano (1987). In addition to adjusting for serial correlation, other robustness tests were performed to validate the stability of the results. These tests included re-estimating the model with alternative specifications, such as fixed effects (FE) models, to assess consistency across different methods.

The outcomes of the RE panel-corrected standard error model are displayed in the final column of Table 4.7. The findings of the RE panel-corrected error model indicate that the signs of all the determinants are in line with the anticipated indications. In general, the results firstly show a positive relationship between the independent variables and demand, except for COVID-19.

Table 4.7 demonstrates that the value added of the primary industry has a significant statistical impact at the 1 percent level. It is found to be positively associated with China's demand for fresh agricultural products cold chain logistics. This implies that for every 1 unit increase in the natural logarithm of the value added of the primary industry, the natural logarithm of the China's demand for fresh agricultural products cold chain logistics increases by 0.68 units.

The freight turnover exhibits a statistically significant correlation at the 1% level with the demand for cold chain logistics of fresh agricultural products in China. This implies that for every 1 unit increase in the natural logarithm of the freight turnover, there is a corresponding increase of 0.09 units in the natural logarithm of the demand for cold chain logistics of fresh agricultural products in China. The ownership of civilian goods vehicles has a significant statistical impact at the 1% level and is positively associated with the

demand for cold chain logistics of fresh agricultural products in China. This implies that for every 1 unit increase in the natural logarithm of the number of households owning civilian goods vehicles, the natural logarithm of the demand for cold chain logistics of fresh agricultural products in China increases by 0.23 units.

The number of internet broadband subscribers exhibits a statistically significant impact at the 1% level and shows a positive correlation with the demand for cold chain logistics in China's fresh agricultural products. This implies that for every 1 unit increase in the natural logarithm of internet broadband subscribers, the natural logarithm of the demand for cold chain logistics in China's fresh agricultural products increases by 0.17 units. COVID-19 exhibits a statistically significant relationship at the 1% level and shows a favourable correlation with the demand for cold chain logistics of fresh agricultural products in China. The demand for cold chain logistics for fresh agricultural products has a negative correlation, indicating that the presence of COVID-19 in a given year results in a decline of 0.40 units in the natural logarithm of the demand for cold chain logistics for fresh agricultural products in that same year.

The significant contribution of the primary industry to China's value chain positively influences the demand for cold chain logistics for fresh agricultural products. According to the China Bureau of Statistics' 2003 classification of industries, the primary sector encompasses agriculture, forestry, animal husbandry, and fisheries. The close connection between fresh agricultural products and the primary industry means that as the value-added of this sector increases, the production of fresh agricultural products also rises, leading to heightened demand for cold chain logistics. For instance, data from the National Bureau of

Statistics (NBS) indicates that in 2021, China's primary industry contributed over 7% to the GDP, underlining its significant role in the economy and its impact on logistics demand.

Freight turnover is another critical determinant of cold chain logistics demand. As freight turnover increases, so does the market demand for fresh commodities, which necessitates a more robust cold chain logistics system. Cold chain logistics play a crucial role in preserving the quality and safety of fresh agricultural goods throughout the supply chain, given the stringent requirements for transit and storage conditions. The China Logistics Development Report (2022) highlights that the volume of agricultural products transported by cold chain logistics reached 280 million tons in 2021, reflecting the growing market demand driven by freight turnover.

In China, road transport dominates the logistics of fresh agricultural products. The number of civilian goods vehicles directly correlates with the demand for cold chain logistics services. According to the Ministry of Transport, the number of civilian goods vehicles reached 29.17 million in 2021, a 6.1% increase from the previous year. This rise reflects the expanding societal demand for logistics services and the critical need for temperature-controlled logistics systems to maintain the quality of fresh agricultural goods during transportation.

The rapid growth of e-commerce has also significantly influenced the demand for cold chain logistics. With more people shopping online for fresh agricultural products, the need for efficient temperature-controlled logistics has grown. According to the China Internet Network Information Centre, China had over 1 billion internet users by the end of 2022, and e-commerce platforms like JD.com and Alibaba reported a surge in fresh food sales, contributing to the increased demand for cold chain logistics.

The COVID-19 pandemic had a profound impact on the demand for temperature-controlled logistics for fresh agricultural products in China. During the pandemic, the Chinese government implemented strict closure and control measures to curb the virus's spread. As a result, there was a temporary decline in demand for cold chain logistics due to restricted consumer access to fresh agricultural items. The China Cold Chain Logistics Development Report (2021) indicated that while the sector faced disruptions in 2020, the demand for cold chain logistics rebounded quickly as the situation stabilized, driven by increased online grocery shopping and heightened food safety awareness.

4.3.2 Analysis Results of Static Panel Data Model in China's Coastal regions

This section analyses the correlation between the demand for cold chain logistics of fresh agricultural products in the coastal regions of China and the factors influencing it. The factors found to have a significant impact include COVID-19, internet broadband access subscribers, ownership of civilian goods vehicles and the value added by primary industries. This subsection provides an overview of the empirical results obtained from conducting the multicollinearity test, heteroskedasticity test, and serial correlation test.

Table 4.8: Results of a Static Panel Data Model of the Relationship Between Cold Chain Logistics Demand for Fresh Agricultural Products and Various Influencing Factors in China's Coastal Regions

Variable	Pooled OLS	Random Effects	Fixed Effects	Random Effects (Robust Standard Errors)
Constant	-5.50*** (-6.07)	-4.02*** (-4.56)	-3.80** (-2.50)	-5.50*** (-9.82)
LX_{VP}	0.72*** (20.56)	0.64*** (10.49)	0.61*** (6.83)	0.72*** (36.47)
LX_{FT}	0.03 (0.68)	-0.01 (-0.65)	-0.02 (-0.75)	0.03 (1.32)
LX_{OCGV}	0.35*** (4.60)	0.46*** (5.29)	0.50*** (3.76)	0.35*** (13.80)
LX_{IBS}	-0.06 (-0.65)	-0.02 (-0.26)	0.01 (0.09)	-0.06* (-1.92)
$X_{COVID-19}$	-0.29*** (-3.05)	-0.33*** (-5.64)	-0.36*** (-3.71)	-0.29*** (-26.05)
<i>F test</i> (<i>p</i> -value)			98.75 *** (0.00)	
Breusch-Pagan LM Test (<i>p</i> -value)	261.15*** (0.00)		-	-
Hausman Test (<i>p</i> -value)	-	0.75 (1.00)		-
Multicollinearity	-	-	3.85	-
Serial Correlation (<i>p</i> -value)	-	-	12.38*** (0.0055)	-
Estimator Shall be Used		RE model		
Observations	88	88	88	88

Notes: Asterisk ***, **, and * represent 1, 5, and 10 percent levels of significance, respectively. The figures in brackets are t-statistics.

The results of the static panel data analysis model, examining the relationship between influencing factors in China's coastal regions and the demand for cold chain logistics of fresh agricultural products, are presented in Table 4.8. In the beginning, because

the *F*-test yields a value of 98.75, which is statistically significant at the 1% level, leading to the rejection of the null hypothesis, the null hypothesis stating that the Pooled OLS model is the most appropriate model is rejected, suggesting that the RE model is more appropriate.

Subsequently, the FE model and the RE model are compared using the Hausman test. The null hypothesis, stating that the FE model is more suitable than the RE model, is rejected based on the Hausman test value of 0.75 from Table 4.8. This value does not reach statistical significance at any level of significance. Consequently, the study determines that the RE model is the most suitable for explaining the correlation between various factors influencing the cold chain logistics of fresh agricultural items in China's coastal regions.

Following this, a battery of tests, including the multicollinearity test, heteroskedasticity test, and serial correlation test, are conducted to confirm the robustness of the model. The VIF is utilized to assess the presence or absence of multicollinearity in the model. Multicollinearity is observed when the VIF exceeds a threshold of 10. Based on empirical evidence, the VIF in the model describing the relationship between influencing factors in China's coastal regions and the demand for fresh agricultural products in cold chain logistics is 3.85, which falls below 10. This indicates the absence of significant multicollinearity issues among the factors affecting the demand for cold chain logistics for fresh agricultural products in China's coastal regions, aligning with the advantages of panel data, which typically exhibit lower multicollinearity compared to time series data. To address concerns regarding the reliability and stability of the results, a series of robustness tests were conducted. Initially, the serial correlation test results indicated that the null hypothesis was rejected at a 1% significance level, suggesting the presence of serial correlation in the model. To mitigate these issues, as suggested by Arellano (1987), the RE

model was re-estimated using panel-adjusted standard errors to account for potential autocorrelation and heteroskedasticity. Additionally, alternative model specifications were tested, including the FE model, to verify the consistency of the findings across different estimation methods.

The results of the panel-corrected standard error model for China's coastal regions are displayed in the final column of Table 4.8. The findings from the RE panel-corrected error model indicate that the direction of each determinant aligns with the anticipated outcomes. A significant correlation is observed between the increase in primary industry value added and the escalating demand for cold chain logistics in China's coastal regions. Specifically, for every unit increase in the natural logarithm of primary industry value added, the natural logarithm of the demand for cold chain logistics for fresh agricultural produce increases by 0.72 units. This correlation is statistically significant at the 1% level. The statistical analysis further reveals a significant relationship between civilian goods vehicle ownership and the demand for cold chain logistics of fresh agricultural produce in China's coastal regions at a 1% level of significance. Moreover, a positive correlation exists between these two variables. Specifically, when the natural logarithm of civilian goods vehicle ownership increases by one unit, the natural logarithm of the demand for cold chain logistics of fresh agricultural produce increases by 0.35 units.

Internet broadband subscribers exhibit a significant statistical impact at the 10% level and demonstrate a negative correlation with the demand for cold chain logistics in the fresh agricultural produce industry. This suggests that for every one unit decrease in the natural logarithm of internet broadband subscribers, there is a decrease of 0.06 units in the natural logarithm of the demand for cold chain logistics in the fresh agricultural produce industry.

The statistical analysis also reveals that COVID-19 has a significant impact at the 1% level and is negatively correlated with the demand for cold chain logistics of fresh agricultural produce. This suggests that the occurrence of COVID-19 in a particular year leads to a decrease in the natural logarithm of the demand for cold chain logistics of fresh agricultural produce by 0.29 units.

The value-added of the primary industry exhibits a robust and intricate relationship with the demand for cold chain logistics for fresh agricultural produce in coastal regions. Given that these regions predominantly encompass agriculture and fisheries, the level of agricultural output directly influences the demand for cold chain logistics. For example, coastal provinces like Shandong, Zhejiang, and Guangdong are major producers of aquatic products, contributing significantly to China's seafood industry. The escalated need for cold chain logistics stems from the imperative to preserve the freshness of these highly productive agricultural outputs. According to the China Fisheries Statistical Yearbook (2021), coastal provinces account for over 60% of China's total aquatic product output, driving the continuous development and implementation of cold chain logistics systems in these areas.

The demand for cold chain logistics for fresh agricultural products is also significantly shaped by market dynamics in coastal areas, characterized by heightened economic activity and dense populations. Data from the National Bureau of Statistics of China (2022) shows that per capita disposable income in coastal provinces is higher than in inland regions, contributing to an increased demand for high-quality fresh agricultural products. The corresponding improvement in the standard of living has fueled the expansion of cold chain logistics systems to meet this growing demand. During peak harvest seasons, coastal regions experience a surge in fresh agricultural product availability, necessitating a

higher demand for cold chain logistics to maintain product freshness during transportation and storage. The widespread adoption of cold chain technology, as reported in the China Cold Chain Logistics Development Report (2022), has been pivotal in bolstering the connection between the agricultural sector and the necessity for cold chain logistics.

The ownership of civilian goods vehicles in coastal areas also directly influences the demand for cold chain logistics services for fresh agricultural items, establishing a symbiotic relationship between the two. Civilian trucks play a crucial role in transporting fresh agricultural products from farms to markets. As of 2021, the Ministry of Transport reported that coastal regions like Jiangsu and Guangdong had the highest number of civilian freight trucks, contributing to more efficient cold chain logistics services in these areas. The technological sophistication and equipment capabilities of civilian trucks further influence the demand for cold chain logistics. For example, refrigerated trucks equipped with advanced temperature control technologies ensure that fresh agricultural products are delivered at optimal temperatures, minimizing losses and enhancing product quality during transportation. The China Cold Chain Logistics Association (2021) emphasized that the deployment of modern refrigerated vehicles in coastal regions has significantly boosted logistical efficiency and market responsiveness.

Coastal areas, owing to their advantageous geographic positioning, have easier access to a diverse array of fresh aquatic products, which reduces reliance on extensive cold chain logistics for maintaining product freshness. Additionally, residents in coastal regions are more likely to utilize the internet for e-commerce, although their online purchases are often skewed toward non-perishable items. According to the China E-commerce Report (2022), coastal provinces such as Guangdong and Zhejiang lead in e-commerce adoption,

but fresh food purchases remain a smaller segment of overall online transactions. This dynamic potentially yields an inverse relationship between internet broadband access and the demand for cold chain logistics for perishable agricultural goods in coastal regions.

The COVID-19 pandemic precipitated a decline in the demand for cold chain logistics for fresh agricultural products in coastal regions. At first, the surge in global trade uncertainties, embargoes, and restrictions posed challenges for cross-border shipping, impacting the stability of cold chain logistics and disrupting fresh product supply chains. According to the China Cold Chain Logistics Development Report (2021), pandemic-related disruptions led to a temporary downturn in cold chain logistics services, particularly in the early stages of the outbreak. Additionally, consumer preferences shifted towards locally sourced food due to health and safety concerns, reducing the demand for fresh agricultural products sourced from distant locations. The downturn in service sectors, including catering and hospitality, further contributed to the decreased demand for fresh agricultural products, leading to reduced cold chain logistics requirements in coastal regions.

At the same time, the empirical results reveal that the relationship between freight turnover and the demand for cold chain logistics of fresh agricultural products is statistically insignificant in China's coastal regions. This finding warrants further discussion, as it contrasts with expectations.

One possible explanation is that coastal regions in China may already possess well-established logistics networks and infrastructure for fresh agricultural products. Given the advanced logistics capabilities in these areas, increases in freight turnover may not significantly impact the demand for cold chain logistics, as the existing systems are capable of handling fluctuations in demand efficiently.

Another contributing factor could be the proximity of coastal regions to major ports and international trade hubs, which could reduce the reliance on cold chain logistics for domestic transportation. Instead, fresh agricultural products may be directly transported to and from ports with minimal cold chain logistics requirements, further diminishing the influence of freight turnover on cold chain logistics demand in these areas.

This finding highlights the potential differences in logistics infrastructure and needs between coastal and inland regions, underscoring the importance of regional context in shaping demand for cold chain logistics.

4.3.3 Analysis Results of Static Panel Data Model in China's Inland Regions

This section examines the correlation among factors influencing the demand for cold chain logistics of fresh agricultural produce in China's inland regions. The selected influential factors encompass the value added of the primary industry, freight turnover, ownership of civilian goods vehicles, internet broadband subscribers, and the impact of COVID-19. Additionally, this section delves into the specific findings derived from the tests conducted to assess multicollinearity, heteroskedasticity, and serial correlation.

Table 4.9: Results of a Static Panel Data Model of the Relationship Between Cold Chain Logistics Demand for Fresh Agricultural Products and Various Influencing Factors in China's Inland Regions

Variable	Pooled OLS	Random Effects	Fixed Effects	Random Effects (Robust Standard Errors)
Constant	- 6.64*** (-8.56)	-5.38*** (-4.72)	-2.08 (-1.03)	-6.64*** (-21.50)
LX_{VP}	0.56*** (11.23)	0.53*** (6.49)	0.40*** (3.69)	0.56*** (26.21)
LX_{FT}	0.14** (2.46)	0.10 (1.54)	0.08 (1.13)	0.14*** (4.17)
LX_{OCGV}	0.43*** (2.87)	-0.19 (-1.21)	-0.50** (-2.41)	0.43*** (6.55)
LX_{IBS}	0.17* (1.78)	0.58*** (6.40)	0.62*** (6.13)	0.17*** (2.68)
$X_{COVID-19}$	- 0.44*** (-3.47)	-0.53*** (-7.11)	-0.37*** (-3.08)	-0.44*** (-13.21)
<i>F test</i> (<i>p</i> -value)			131.13*** (0.00)	
Breusch-Pagan LM Test (<i>p</i> -value)	480.31*** (0.00)		-	-
Hausman Test (<i>p</i> -value)	-	7.75 (0.74)		-
Multicollinearity	-	-	3.99	-
Serial Correlation (<i>p</i> -value)	-	-	72.51*** (0.00)	-
Estimator Shall be Used		RE model		
Observations	160	160	160	160

Notes: Asterisk ***, **, and * represent 1, 5, and 10 percent levels of significance, respectively. The figures in brackets are t-statistics.

The results of the static panel data analysis model, investigating the relationship between influencing factors in China's inland regions and the demand for cold chain logistics of fresh agricultural products, are outlined in Table 4.9. Originally, the data of the *F*-test, which yields a value of 131.13 at the 1% level, consequently rejecting the null hypothesis, indicates a preference for the RE model over the Pooled OLS model. Subsequently, the Hausman test introduces an additional dimension, offering a choice between the FE and RE models. Table 4.9 illustrates that the Hausman test produces a statistic of 7.75, which is statistically insignificant across all levels of significance. Consequently, the null hypothesis asserting the superiority of the RE model over the FE model remains unchallenged.

Following this, a battery of diagnostic tests, including assessments for multicollinearity, heteroskedasticity, and serial correlation, are conducted to affirm the robustness of the model. The VIF is employed to evaluate the presence or absence of multicollinearity within the model. Multicollinearity becomes problematic when the VIF surpasses a threshold of 10. Empirical findings reveal a VIF of 3.99 in the model scrutinizing the relationship between influencing factors in China's inland regions and the demand for fresh agricultural products in cold chain logistics, comfortably below the designated threshold. This suggests an absence of multicollinearity between the factors influencing China's demand for cold chain logistics of fresh agricultural products and the demand itself, consistent with the inherent advantages of panel data, which typically exhibit lower levels of multicollinearity relative to time series data.

To validate the reliability and stability of the results, a series of robustness tests were incorporated into the analysis. Although the serial correlation test results indicated a rejection of the null hypothesis at a 1% significance level, pointing to the presence of serial

correlation issues in the model, these concerns were addressed by re-estimating the RE model using panel-adjusted standard errors, following the method proposed by Arellano (1987). In addition to correcting for serial correlation, further robustness tests were conducted. These included re-estimating the model with alternative specifications, such as the FE model, to assess the consistency of results across different econometric methods.

The results of the RE panel-corrected standard error model are depicted in the final column of Table 4.9. According to the findings, all determinant signs align with the anticipated outcomes. Specifically, Table 4.9 reveals that the value added of the primary industry exhibits a statistically significant impact at the 1 percent level and is positively associated with the demand for cold chain logistics for fresh agricultural produce in China's inland regions. In essence, for every unit increase in the natural logarithm of the value added of the primary industry, the natural logarithm of the demand for cold chain logistics for fresh agricultural products in China's inland regions increases by 0.56 units.

Likewise, there exists a significant positive correlation between freight turnover and the demand for cold chain logistics of fresh agricultural produce in China's inland regions, significant at the 1% level. For every one unit increase in the natural logarithm of the freight turnover, the natural logarithm of the demand for cold chain logistics of fresh agricultural produce in China's inland regions increases by 0.14 units. Moreover, a robust and positive correlation is observed between the ownership of civilian goods vehicles and the demand for cold chain logistics of fresh agricultural products in China's inland regions, significant at the 1% level. Specifically, for every one unit increase in the natural logarithm of ownership of civilian goods vehicles, the natural logarithm of the demand for cold chain logistics of fresh agricultural produce in China's inland regions increases by 0.43 units.

Similarly, the natural logarithm of the demand for cold chain logistics of fresh agricultural produce in China's inland regions demonstrates a significant correlation with the number of internet broadband subscribers, significant at the 1% level. With every increase of one unit in the natural logarithm of the number of internet broadband subscribers, the natural logarithm of the demand for cold chain logistics of fresh agricultural produce in China's inland regions increases by 0.17 units. Conversely, COVID-19 displays a statistically significant relationship at the 1 percent level, inversely connected with the demand for fresh agricultural products. The presence of COVID-19 in a given year is associated with a reduction in the natural logarithm of the demand for cold chain logistics for fresh agricultural products by 0.44 units in that same year in China's inland areas.

The escalation in the value added of the primary industry in inland regions of China has positively impacted the demand for cold chain logistics for fresh agricultural produce in multiple dimensions. The increased levels of production in agriculture, forestry, animal husbandry, and fisheries have notably augmented the output and diversity of agricultural products in these areas. According to the National Bureau of Statistics of China (2022), inland provinces like Henan, Sichuan, and Hunan have seen significant growth in the primary industry, which necessitates enhanced cold chain logistics to ensure optimal transportation conditions. Furthermore, the emergence of specialized industries in inland regions, driven by unique climatic and soil conditions, has underscored the need for cold chain logistics systems to preserve the quality and flavour of these specialized agricultural goods. For example, Sichuan's pepper and Hunan's rice are highly valued and require efficient cold chain systems to maintain their quality during transportation to distant markets.

As the value added in the primary industries increases, there is potential for inland agricultural markets to expand into more remote regions. This expansion requires cold chain logistics systems to maintain product quality and extend market reach. The proliferation of the primary industry has also bolstered the consistent availability of seasonal agricultural products. The adoption of cold chain logistics has extended the shelf life of these products, ensured year-round availability, and fortified the long-term sustainability of the agricultural market. Reports from the China Cold Chain Logistics Association (2022) highlight the growing adoption of cold chain technologies in inland areas to support this expansion.

The amplification of freight turnover in inland areas is poised to drive a heightened demand for cold chain logistics for fresh agricultural items. Maintaining appropriate temperature and humidity levels during transportation is crucial to preserving the quality and freshness of agricultural products. Cold chain logistics systems are designed to meet this exigency, creating optimal conditions for transporting perishable goods. Inland provinces like Hubei and Shaanxi have seen significant increases in freight turnover, driven by urbanization and rising consumption levels, as reported by the Ministry of Transport (2022). The escalation in freight turnover signals increased commercial and trade activities between cities, leading to greater distances travelled by agricultural products, further intensifying the demand for cold chain logistics systems.

Moreover, the advent of e-commerce has strengthened the link between freight volume and cold chain logistics demand. The rapid growth of online grocery sales in China, particularly in inland regions, has necessitated faster and more reliable logistics services to meet consumer expectations for the prompt delivery of fresh goods. Cold chain logistics systems are essential for ensuring that fresh goods remain of high quality throughout the

supply chain. According to the China E-commerce Report (2022), e-commerce platforms are playing a critical role in connecting inland agricultural producers with broader markets, increasing the demand for cold chain logistics to support the online sale and distribution of fresh agricultural products.

The proliferation of civilian goods vehicles in inland regions is another key factor driving the growth of the cold chain logistics market for fresh agricultural products. The surge in vehicle ownership has expanded the resources available for transporting fresh agricultural products, making it a predominant mode of transportation. According to the National Bureau of Statistics (2022), the number of civilian goods vehicles in inland provinces like Sichuan and Hubei has seen substantial growth, underscoring the need for cold chain logistics solutions to ensure the freshness and quality of agricultural products during transit. This increase in vehicle ownership is a direct result of economic advancement and urban expansion in inland regions, which has also fuelled demand for fresh agricultural products. Urban residents, especially those with higher incomes, are driving demand for cold chain logistics due to their preference for a diverse range of high-quality food goods that must meet strict freshness criteria.

The widespread adoption of internet broadband in inland China has also fostered the growth of cold chain logistics for fresh agricultural produce. According to the Ministry of Industry and Information Technology (2022), internet penetration in inland provinces has significantly improved, enhancing the speed and accuracy of information transmission. This improvement has made cold chain logistics more intelligent and precise by enabling real-time monitoring and data transmission, which optimizes agricultural product production,

transportation, and storage, ensuring that goods are maintained in optimal conditions throughout the entire supply chain.

The proliferation of internet broadband has also catalysed the growth of e-commerce and online transactions involving agricultural goods. Consumers in inland regions can now conveniently purchase fresh food online, which necessitates the rapid and secure delivery of these products using cold chain logistics systems. The China Internet Network Information Centre (2022) reported a notable increase in online grocery purchases from inland consumers, further driving the demand for cold chain logistics.

The onset of the COVID-19 outbreaks likely exerted a modest downturn on the market for fresh agricultural products in inland China. First of all, the pandemic disrupted the supply chain, leading to transportation, logistical, and labour-related challenges that impeded the accessibility of newly harvested agricultural goods. Simultaneously, consumer behaviour shifted, with a decline in demand for fresh agricultural products stemming from reduced social outings and communal gatherings, particularly as the restaurant and food service industries faced significant setbacks. According to the China Cold Chain Logistics Development Report (2021), the pandemic-induced disruptions led to temporary declines in cold chain logistics demand for fresh agricultural products in inland areas. The resulting economic instability further impacted consumer expenditure, curbing the demand for premium fresh agricultural products during this period.

4.4 Analysis of Spatial Heterogeneity

This subsection produces a radar chart illustrating the magnitudes of coefficients associated with factors influencing the demand for cold chain logistics in China's fresh agricultural products, encompassing both coastal and inland regions. The radar chart delineates the relative significance of these influencing elements across diverse geographical locations, as demonstrated in Figure 4.1.

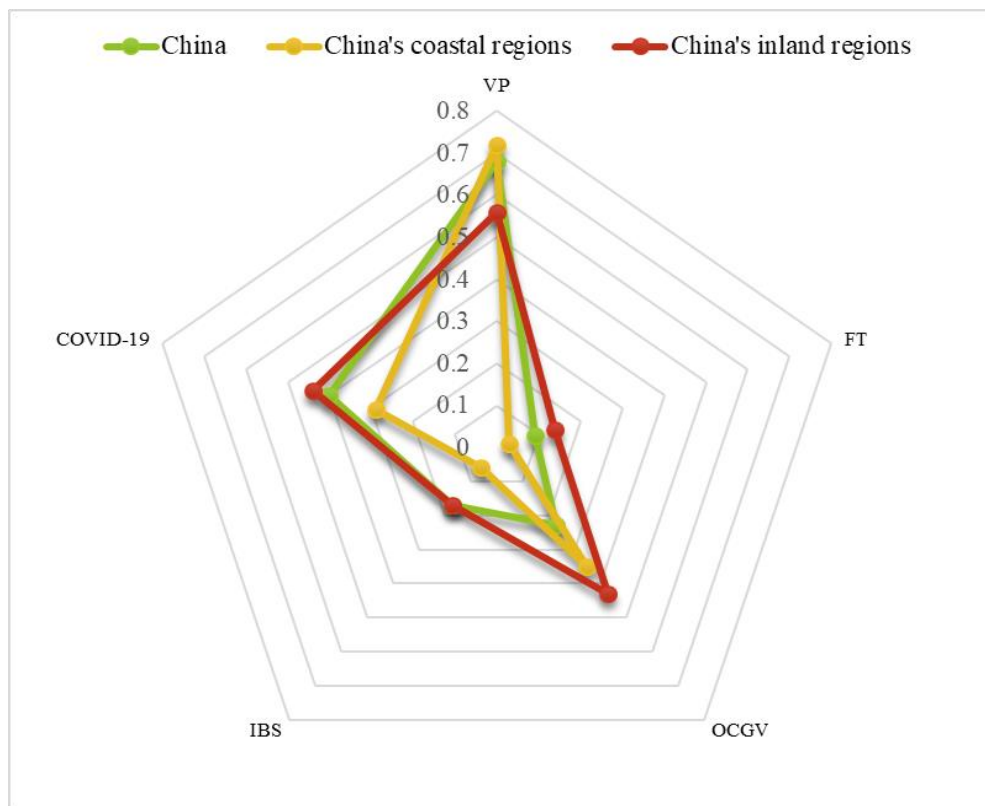


Figure 4.1: Magnitude of Impacts of the Same Impact Factor under Different Regions

Figure 4.1 illustrates that the need for cold chain logistics of fresh agricultural produce in China's coastal areas is primarily influenced by the value added of the primary industry. This underscores the significant impact of primary industry development on the demand for fresh agricultural products in coastal regions. Additionally, the ownership of civilian goods vehicles exerts a noteworthy influence on the demand for cold chain logistics

of fresh agricultural products in coastal areas, indicating a positive correlation suggestive of increased ownership contributing to the growth of fresh agricultural products. The prevalence of cold chain logistics in China is largely attributed to its heavy reliance on road transport. However, the need for cold chain logistics for fresh agricultural products has been significantly affected by the COVID-19 pandemic, thereby impeding its growth to a certain extent. This pandemic-induced impact hinders the progress of cold chain logistics to some degree.

In China's coastal regions, the presence of internet broadband access in households has a minor restraining impact on the need for cold chain logistics for fresh agricultural products. This observation could be attributed to the tendency of residents in these areas to purchase fresh seafood offline, given their proximity to the sea. The impact of freight turnover on the demand for cold chain logistics for fresh agricultural products in China's coastal areas is negligible. Overall, the impact of cold chain logistics for fresh agricultural products in coastal areas is determined by several factors, including the value added of the primary industry, freight turnover, ownership of civilian goods vehicles, the number of households with internet broadband access, and the COVID-19 situation. These factors are ranked in descending order of their influence on cold chain logistics as follows:

$$VP > OCGV > COVID-19 > IBS > FT$$

Figure 4.1 illustrates that the need for cold chain logistics of fresh agricultural produce in inland areas of China is primarily driven by the value added of the primary industry. This is attributed to the fact that fresh agricultural products originate from the primary industry, and an increase in its value-added leads to heightened production of fresh agricultural goods. Consequently, the demand for cold chain logistics of fresh agricultural

products experiences a corresponding increase. The COVID-19 pandemic has exerted a significant impact on the growth of cold chain logistics in inland regions, resulting in a decline in the demand for such services. Furthermore, the ownership of civilian trucks emerges as a contributing factor in the advancement of cold chain logistics for fresh agricultural products in inland areas.

In contrast to the coastal region, the proliferation of the internet has had a notable impact on the demand for cold chain logistics of fresh agricultural produce in inland areas. This phenomenon can be attributed to the increased accessibility to fresh seafood and enhanced knowledge about it among residents, facilitated by the development of the internet. Consequently, inland areas have witnessed a surge in demand for cold chain logistics to ensure the freshness of agricultural products. Simultaneously, the movement of goods has also played a pivotal role in driving the local demand for efficient transportation and storage of perishable goods. The influencing variables of fresh agricultural products and cold chain logistics in the inland area are ranked in descending order as follows:

$$VP > COVID-19 > OCGV > IBS > FT$$

Figure 4.1 illustrates that the value-added factor of the primary industry exerts a more pronounced influence on the demand for cold chain logistics of fresh agricultural products in coastal areas compared to inland areas. Several factors contribute to this observation:

Coastal areas typically benefit from superior transportation infrastructure, including ports and well-developed sea and land transport networks, which facilitate the efficient import and export of fresh agricultural produce. According to the Ministry of Transport (2022), China's coastal provinces like Guangdong, Zhejiang, and Shandong have developed advanced transportation systems that link them to global markets. These regions have greater

connectivity, enabling efficient logistics operations for both domestic and international trade. Fluctuations in the added value of the primary industry, particularly in agriculture, can lead to shifts in import and export patterns, directly impacting the demand for cold chain logistics. Cold chain logistics is crucial for preserving the freshness of agricultural products in international trade, as evidenced by research from the China Cold Chain Logistics Association (2022).

Moreover, coastal areas tend to exhibit a higher degree of industrial diversification, with a greater reliance on industry and service sectors compared to agriculture. However, agriculture still contributes significantly to their overall output value. Fluctuations in the value added of the primary industry can substantially affect the entire economic landscape, including the demand for cold chain logistics. Urbanization is another contributing factor, with coastal regions experiencing higher levels of urbanization, greater population densities, and larger market sizes. The National Bureau of Statistics of China (2022) reports that the urbanization rate in coastal provinces is significantly higher than in inland regions, leading to increased demand for fresh produce and consequently driving up the need for cold chain logistics. Coastal supply chains are typically more extensive, involving a greater number of intermediary stages, making cold chain logistics even more critical for maintaining product quality throughout these complex networks.

In contrast, the increase in freight turnover tends to have a more direct impact on the demand for logistics, particularly in inland regions, where this influence is more pronounced. Inland provinces like Henan, Sichuan, and Shaanxi have seen significant growth in freight turnover as part of the national "Go West" development strategy, which aims to enhance the economic development of China's interior. According to the Ministry of Commerce (2022),

higher freight turnover is typically associated with improved supply chain efficiency in inland regions, driving the need for cold chain logistics to ensure the preservation and quality of perishable goods. Additionally, a rise in freight turnover often signifies increased market demand for perishable goods, necessitating the implementation of cold chain logistics to meet the growing demand and maintain product excellence. This growth in freight turnover indicates the need to expand market coverage, necessitating the development of suitable cold chain logistics infrastructure for expanding inland markets. Collaborative efforts among different sectors of the supply chain are essential for meeting the heightened demand for logistics and enhancing overall efficiency in these regions.

The level of civilian vehicle ownership exerts a more substantial influence on cold chain logistics in inland regions compared to coastal regions. According to the China Statistical Yearbook (2022), inland areas have experienced a notable increase in civilian goods trucks, which are critical conduits for transporting fresh agricultural products from production to consumption sites. The proliferation of car ownership contributes to the expansion and efficacy of the logistics network, reducing transit times and enhancing the preservation of perishable goods that require controlled-temperature environments. This expansion is particularly critical in inland areas, where civilian trucks play a pivotal role in transporting agricultural products over longer distances. The swift and efficient conveyance of these goods helps preserve their freshness and quality, and a surge in civilian trucks would further escalate the demand for cold chain logistics, improving the overall efficiency of the supply chain.

Regarding internet broadband access, the demand for cold chain logistics of fresh agricultural products in inland regions exhibits a positive correlation, while in coastal regions,

this factor has a relatively minor and even negative correlation. The disparity can be attributed to the fact that interior regions, owing to their remoteness from primary markets and manufacturing hubs, rely more extensively on internet broadband for immediate access to market information and streamlined transactions. The China Internet Network Information Centre (2022) notes that internet penetration in inland regions has significantly improved, allowing agricultural supply chains to adapt more dynamically to market demand. This expansion of internet connectivity has also catalysed the growth of online sales and e-commerce platforms tailored to the distribution of fresh produce in non-coastal regions. Agricultural producers and suppliers have increasingly leveraged online channels to sell their products, prompting a surge in demand for cold chain logistics to ensure the freshness and quality of products during transit.

Furthermore, the availability of high-speed internet access has bolstered the utilization of digital management and tracking technologies within cold chain logistics. Inland areas are increasingly adopting sophisticated tracking systems, sensors, and data analytics tools to monitor temperature control and quality management throughout the transportation process, enhancing the efficiency of the cold chain logistics network. This digital transformation has been further facilitated by the proliferation of internet broadband, which fosters supply chain collaboration and information sharing, improving the overall efficiency of agricultural logistics in inland regions.

The demand for cold chain logistics for fresh agricultural produce in inland areas has been more adversely affected by the COVID-19 pandemic compared to coastal regions. According to the China Cold Chain Logistics Development Report (2021), inland areas faced greater logistical and transportation challenges due to containment policies and their distance

from production bases. These challenges exacerbated the impact of the pandemic on the demand for fresh agricultural products and cold chain logistics in inland regions. In contrast, coastal regions, with their modern transportation systems and shorter transportation distances, were better equipped to mitigate the adverse effects of the pandemic on cold chain logistics. Coastal provinces like Guangdong and Zhejiang demonstrated resilience in maintaining their cold chain logistics operations, despite the disruptions caused by COVID-19, as highlighted by the Ministry of Transport (2021).

4.5 Forecasting Results of the Demand for Fresh Agricultural Products Cold Chain Logistics

In 2023, the Chinese government introduced the “Implementation Plan for the High-Quality Development of Cold Chain Logistics (2023–2027).” This strategic roadmap outlines China’s aspiration to establish a comprehensive cold chain logistics network by 2027. This network is envisioned to seamlessly connect production and distribution centres, encompassing urban and rural regions, and facilitating integration into both domestic and international markets. Furthermore, the plan aims to develop a cold chain logistics infrastructure tailored to China’s unique national circumstances and industrial landscape, effectively meeting the demands of economic and social progress. This section seeks to forecast the demand for cold chain logistics pertaining to fresh agricultural produce across China, including both coastal and inland areas, for the period from 2023 to 2027. The goal is to contribute to the realization of China’s development objectives in the domain of cold chain logistics.

4.5.1 Forecasting Results of the Demand for Fresh Agricultural Products Cold Chain Logistics in China's Coastal Regions

The forecasted demand for cold chain logistics in the coastal region of China from 2023 to 2027, focusing on 11 provinces, is presented in Table 4.10. The projections were generated utilizing the GM (1,1) model and computed using Python software. The *OV* represents the original value, *FV* represents the forecasted value, $e(i)$ denotes the residual, *C* signifies the posterior odds ratio, *P* represents province, *V* represents values, and *Y* represents year.

Table 4.10: Results of the Demand for Fresh Agricultural Products Cold Chain Logistics in China's Coastal regions (Unit: 10,000 tons)

$\begin{matrix} P \\ Y \backslash V \end{matrix}$	Fujian				Guangdong				Guangxi			
	OV	FV	$e(i)$	C	OV	FV	$e(i)$	C	OV	FV	$e(i)$	C
2015	2993.4	2993.4	0	0.0008	5730.9	5730.9	0	0.0013	5305.1	5305.1	0	0.002
2016	3003.5	3008.9	5.4	-	5816.6	5821.7	5.1	-	5649.9	5565.9	84.0	-
2017	3129.1	3137.4	8.3	-	6046.2	6073.7	27.5	-	5956.3	5974.3	18.0	-
2018	3274.2	3271.3	2.9	-	6344.9	6336.6	8.3	-	6338.7	6412.6	73.9	-
2019	3430.7	3411.0	19.8	-	6630.5	6610.9	19.6	-	6864.4	6883.1	18.6	-
2020	3557.7	3556.6	1.1	-	6925.9	6897.1	28.8	-	7380.6	7388.2	7.6	-
2021	3711.7	3708.4	3.3	-	7216.4	7195.6	20.8	-	8004.5	7930.3	74.2	-
2022	3856.9	3866.7	9.8	-	7469.5	7507.1	37.6	-	8502.0	8512.2	10.2	-
2023	-	4031.8	-	-	-	7832.0	-	-	-	9136.7	-	-
2024	-	4203.9	-	-	-	8171.0	-	-	-	9807.1	-	-
2025	-	4383.3	-	-	-	8524.7	-	-	-	10526.7	-	-
2026	-	4570.5	-	-	-	8893.7	-	-	-	11299.1	-	-
2027	-	4765.6	-	-	-	9278.7	-	-	-	12128.2	-	-

$\begin{matrix} P \\ Y \backslash V \end{matrix}$	Hainan				Hebei				Jiangsu			
	OV	FV	$e(i)$	C	OV	FV	$e(i)$	C	OV	FV	$e(i)$	C
2015	1241.0	1241.0	0	0.1081	7865.1	7865.1	0	0.1758	7548.7	7548.7	0	0.1532
2016	1239.5	1206.1	33.4	-	7795.6	7664.6	131.0	-	7620.8	7501.7	119.1	-
2017	1223.2	1234.1	10.9	-	7779.3	7770.4	8.9	-	7565.3	7582.4	17.1	-
2018	1257.7	1262.7	5.0	-	7841.5	7877.7	36.2	-	7611.3	7663.8	52.5	-
2019	1272.3	1292.1	19.8	-	7831.6	7986.4	154.8	-	7660.6	7746.2	85.6	-
2020	1296.5	1322.0	25.5	-	8015.2	8096.7	81.5	-	7755.5	7829.5	74.0	-
2021	1350.7	1352.7	2.0	-	8187.0	8208.4	21.4	-	7921.2	7913.6	7.6	-
2022	1414.7	1384.1	30.6	-	8477.1	8321.7	155.4	-	8101.9	7998.6	103.3	-
2023	-	1416.2	-	-	-	8436.6	-	-	-	8084.6	-	-
2024	-	1449.1	-	-	-	8553.1	-	-	-	8171.5	-	-
2025	-	1482.7	-	-	-	8671.1	-	-	-	8259.3	-	-
2026	-	1517.1	-	-	-	8790.8	-	-	-	8348.1	-	-
2027	-	1552.4	-	-	-	8912.2	-	-	-	8437.8	-	-

Table 4.10 continued

$\begin{matrix} P \\ Y \backslash V \end{matrix}$	Liaoning				Shandong				Shanghai			
	OV	FV	$e(i)$	C	OV	FV	$e(i)$	C	OV	FV	$e(i)$	C
2015	4323.9	4323.9	0	0.2142	13181.1	13181.1	0	0.2103	476.8	476.8	0	0.0815
2016	4016.8	3845.4	171.4	-	13270.6	13017.7	252.9	-	426.9	436.5	9.6	-
2017	3823.1	3912.9	89.8	-	13340.4	13230.5	109.9	-	424.1	420.1	4.0	-
2018	3898.1	3981.6	83.5	-	13369.0	13446.8	77.78	-	425.1	404.4	20.7	-
2019	3970.8	4051.5	80.7	-	13226.9	13666.6	439.7	-	387.7	389.2	1.5	-
2020	4120.4	4122.6	2.2	-	13652.6	13890.0	237.4	-	362.5	374.6	12.1	-
2021	4228.6	4195.0	33.6	-	14251.0	14117.0	134.0	-	345.1	360.6	15.5	-
2022	4321.0	4268.7	52.4	-	14609.6	14347.8	261.8	-	361.4	347.1	14.3	-
2023	-	4343.6	-	-	-	14582.3	-	-	-	334.1	-	-
2024	-	4419.8	-	-	-	14820.7	-	-	-	321.6	-	-
2025	-	4497.4	-	-	-	15063.0	-	-	-	309.5	-	-
2026	-	4576.4	-	-	-	15309.2	-	-	-	297.9	-	-
2027	-	4656.7	-	-	-	15559.5	-	-	-	286.8	-	-

$\begin{matrix} P \\ Y \backslash V \end{matrix}$	Tianjin				Zhejiang				-	-	-	-
	OV	FV	$e(i)$	C	OV	FV	$e(i)$	C	-	-	-	-
2015	512.6	512.6	0	0.2519	3556.6	3556.6	0	0.1569	-	-	-	-
2016	502.2	481.7	20.5	-	3358.2	3366.2	8.0	-	-	-	-	-
2017	467.4	471.0	3.6	-	3421.1	3378.5	42.6	-	-	-	-	-
2018	450.4	460.6	10.2	-	3373.4	3390.8	17.4	-	-	-	-	-
2019	423.6	450.4	26.8	-	3367.2	3403.1	35.9	-	-	-	-	-
2020	451.9	440.4	11.5	-	3431.9	3415.6	16.3	-	-	-	-	-
2021	417.2	430.6	13.4	-	3408.2	3428.0	19.8	-	-	-	-	-
2022	443.3	421.1	22.2	-	3462.7	3440.5	22.2	-	-	-	-	-
2023	-	411.8	-	-	-	3453.1	-	-	-	-	-	-
2024	-	402.7	-	-	-	3465.7	-	-	-	-	-	-
2025	-	393.7	-	-	-	3478.3	-	-	-	-	-	-
2026	-	385.0	-	-	-	3491.0	-	-	-	-	-	-
2027	-	376.5	-	-	-	3503.7	-	-	-	-	-	-

Table 4.10 displays the original values of the demand for cold chain logistics concerning fresh agricultural products in each province of the coastal region spanning from 2015 to 2022, alongside the projected demand for the years 2023 to 2027. Additionally, it includes the residuals and the posterior odds ratio for each province. Upon scrutinizing the

results, it is observed that all values of the posterior odds ratio C are below 0.35. As illustrated in Table 3., this indicates a high degree of forecasting accuracy, thereby satisfying the predetermined standards.

The forecasted values of the demand for cold chain logistics concerning fresh agricultural products in the coastal region for the period 2023–2027 were derived by aggregating the projected values for each of the 11 coastal areas as outlined in Table 4.10. These aggregated values are summarized in Table 4.11.

Table 4.11: Demand for Fresh Agricultural Products Cold Chain Logistics in China’s Coastal regions (Unit: 10,000 tons)

Year	2023	2024	2025	2026	2027
Demand of China’s Coastal Regions	62062.8	63786.2	65589.7	67478.8	69458.1

4.5.2 Forecasting Results of the Demand for Fresh Agricultural Products Cold Chain Logistics in China’s Inland Regions

Table 4.12 presents the forecasted demand for cold chain logistics pertaining to fresh agricultural products in the inland region of China spanning from 2023 to 2027, encompassing 20 provinces. The table offers comprehensive data on the existing and projected demand for cold chain logistics of fresh agricultural products across each province in the inland region. It encompasses the original values spanning from 2015 to 2022, the forecasted values spanning from 2023 to 2027, residuals, and the a posteriori difference ratio for each province. OV represents the original value, FV represents the forecasted value, $e(i)$ denotes the residual, C signifies the posterior odds ratio, P represents province, V represents values, and Y represents year.

Table 4.12: Results of the Demand for Fresh Agricultural Products Cold Chain Logistics in China's Inland Regions (Unit: 10,000 tons)

$\begin{matrix} P \\ Y \backslash V \end{matrix}$	Anhui				Beijing				Gansu			
	OV	FV	$e(i)$	C	OV	FV	$e(i)$	C	OV	FV	$e(i)$	C
2015	4559.1	4559.1	0	0.0018	412.9	412.9	0	0.3283	1730.4	1730.4	0	0.0094
2016	3337.8	3308.9	28.9	-	362.4	318.6	43.8	-	1810.9	1785.4	25.5	-
2017	3443.7	3455.9	12.2	-	315.2	306.2	9.0	-	1998.1	1940.9	57.2	-
2018	3597.8	3609.4	11.6	-	254.8	294.3	39.5	-	2059.1	2110.0	50.9	-
2019	3756.7	3769.8	13.1	-	233.9	282.8	48.9	-	2261.2	2293.8	32.6	-
2020	3922.7	3937.3	14.6	-	252.0	271.8	19.8	-	2446.4	2493.7	47.3	-
2021	4140.9	4112.2	28.7	-	270.7	261.3	9.4	-	2764.7	2710.9	53.8	-
2022	4294.3	4294.9	0.6	-	298.5	251.1	47.4	-	2959.7	2947.1	12.6	-
2023		4485.8	-	-	-	241.3	-	-	-	3203.8	-	-
2024		4685.1	-	-	-	231.9	-	-	-	3482.9	-	-
2025		4893.2	-	-	-	222.9	-	-	-	3786.3	-	-
2026		5110.6	-	-	-	214.2	-	-	-	4116.2	-	-
2027		5337.7	-	-	-	205.9	-	-	-	4474.8	-	-

$\begin{matrix} P \\ Y \backslash V \end{matrix}$	Guizhou				Henan				Heilongjiang			
	OV	FV	$e(i)$	C	OV	FV	$e(i)$	C	OV	FV	$e(i)$	C
2015	2314.9	2314.9	0	0.0143	10976.3	10976.3	0	0.3811	1974.2	1974.2	0	0.7712
2016	2522.4	2615.9	93.5	-	11353.9	11248.8	105.1	-	1872.6	1803.4	69.2	-
2017	2807.3	2862.7	55.4	-	11487.2	11307.9	179.3	-	1933.5	1812.0	121.5	-
2018	3245.0	3132.8	112.2	-	11137.5	11367.3	229.8	-	1679.6	1820.7	141.1	-
2019	3435.3	3428.4	6.9	-	11264.4	11427.0	162.6	-	1701.8	1829.4	127.6	-
2020	3803.2	3751.9	51.3	-	11477.4	11487.0	9.6	-	1782.5	1838.1	55.6	-
2021	4220.8	4105.8	115.0	-	11462.2	11547.4	85.2	-	1892.0	1846.9	45.1	-
2022	4359.8	4493.2	133.4	-	11811.0	11608.0	203.0	-	1944.3	1855.7	88.6	-
2023	-	4917.2	-	-	-	11669.0	-	-	-	1864.5	-	-
2024	-	5381.1	-	-	-	11730.3	-	-	-	1873.4	-	-
2025	-	5888.8	-	-	-	11791.9	-	-	-	1882.4	-	-
2026	-	6444.4	-	-	-	11853.9	-	-	-	1891.4	-	-
2027	-	7052.4	-	-	-	11916.1	-	-	-	1900.4	-	-

Table 4.12 continued

$\begin{matrix} P \\ Y \backslash V \end{matrix}$		Hubei				Hunan				Jilin			
		OV	FV	$e(i)$	C	OV	FV	$e(i)$	C	OV	FV	$e(i)$	C
2015		5694.3	5694.3	0	0.0454	5222.1	5222.1	0	0.0069	907.4	907.4	0	0.0973
2016		5786.7	5725.1	71.6	-	5377.5	5348.1	29.4	-	884.0	890.0	6.0	-
2017		5856.5	5868.0	11.5	-	5522.0	5533.2	11.2	-	879.3	926.8	47.5	-
2018		6035.6	6014.5	21.1	-	5739.1	5724.7	14.4	-	1019.2	965.1	54.1	-
2019		6107.8	6164.7	56.9	-	5866.3	5922.9	56.6	-	1027.7	1005.0	22.7	-
2020		6168.1	6318.6	150.3	-	6099.1	6127.9	28.8	-	1034.5	1046.5	12.0	-
2021		6534.2	6476.4	57.8	-	6414.3	6340.0	74.3	-	1091.6	1089.8	1.8	-
2022		6709.9	6638.1	71.8	-	6543.0	6559.5	16.5	-	1122.2	1134.8	12.6	-
2023		-	6803.8	-	-	-	6786.5	-	-	-	1181.7	-	-
2024		-	6973.7	-	-	-	7021.5	-	-	-	1230.5	-	-
2025		-	7147.8	-	-	-	7264.5	-	-	-	1281.4	-	-
2026		-	7326.3	-	-	-	7516.0	-	-	-	1334.3	-	-
2027		-	7509.2	-	-	-	7776.1	-	-	-	1389.5	-	-

$\begin{matrix} P \\ Y \backslash V \end{matrix}$		Jiangxi				Inner Mongolia				Ningxia			
		OV	FV	$e(i)$	C	OV	FV	$e(i)$	C	OV	FV	$e(i)$	C
2015		2685.5	2685.5	0	0.0293	2621.3	2621.3	0	0.3672	917.8	917.8	0	0.0516
2016		2705.8	2685.9	19.9	-	2615.2	2434.4	180.8		939.7	927.0	12.7	
2017		2791.9	2769.1	22.8	-	2321.1	2390.4	69.3		977.4	966.0	11.4	
2018		2859.6	2855.0	4.6	-	2172.7	2347.2	174.5		982.5	1006.7	24.2	
2019		2898.1	2943.5	45.4	-	2283.7	2304.8	21.1		1071.1	1049.2	21.9	
2020		2973.7	3034.8	61.1	-	2265.4	2263.2	2.2		1050	1093.4	43.4	
2021		3160.6	3128.8	31.8	-	2207.4	2222.3	14.9		1141.1	1139.4	1.7	
2022		3255.7	3225.9	29.9	-	2279.8	2182.1	97.7		1209.2	1187.5	21.7	
2023			3325.9		-		2142.7				1237.5		
2024			3429.0		-		2104.0				1289.6		
2025			3535.3		-		2066.0				1344.0		
2026			3644.9		-		2028.7				1400.6		
2027			3757.9		-		1992.0				1459.6		

Table 4.12 continued

$\begin{matrix} P \\ Y \backslash V \end{matrix}$	Qinghai				Shanxi				Shaanxi			
	OV	FV	$e(i)$	C	OV	FV	$e(i)$	C	OV	FV	$e(i)$	C
2015	219.4	219.4	0	0.0807	1940.5	1940.5	0	0.1279	3706.7	3706.7	0	0.0183
2016	224.6	223.9	0.7	-	1886.9	1791.0	95.9	-	3820.5	3788.6	31.9	-
2017	223.5	225.6	2.1	-	1928.6	1877.9	50.7	-	3953.1	3916.4	36.7	-
2018	226.9	227.4	0.5	-	1853.9	1969.1	115.2	-	3945.6	4048.5	102.9	-
2019	232.0	229.1	2.9	-	1989.4	2064.6	75.2	-	4208.2	4185.0	23.2	-
2020	231.2	230.9	0.3	-	2104.1	2164.8	60.7	-	4325.1	4326.2	1.1	-
2021	231.7	232.6	0.9	-	2339.1	2269.8	69.3	-	4467.0	4472.1	5.1	-
2022	234.0	234.4	0.4	-	2422.3	2379.9	42.4	-	4643.8	4622.9	20.9	-
2023	-	236.2	-	-	-	2495.4	-	-	-	4778.9	-	-
2024	-	238.0	-	-	-	2616.5	-	-	-	4940.1	-	-
2025	-	239.8	-	-	-	2743.5	-	-	-	5106.7	-	-
2026	-	241.6	-	-	-	2876.6	-	-	-	5278.9	-	-
2027	-	243.5	-	-	-	3016.1	-	-	-	5457.0	-	-

$\begin{matrix} P \\ Y \backslash V \end{matrix}$	Sichuan				Xizang				Xinjiang			
	OV	FV	$e(i)$	C	OV	FV	$e(i)$	C	OV	FV	$e(i)$	C
2015	5960.1	5960.1	0	0.007	60.1	60.1	0	0.0126	2732.6	2732.6	0	0.1465
2016	6130.8	6055.2	75.6	-	130.4	132.13	1.73	-	3704.4	3537.2	167.2	-
2017	6272.9	6295.4	22.5	-	142.6	138.1	4.5	-	3645.9	3579.3	66.6	-
2018	6550.0	6545.1	4.9	-	138.3	144.3	6.0	-	3374.5	3621.8	247.3	-
2019	6721.5	6804.7	83.2	-	151.2	150.9	0.3	-	3495.9	3664.8	168.9	-
2020	7028.9	7074.6	45.7	-	160.5	157.7	2.8	-	3805.5	3708.4	97.1	-
2021	7398.1	7355.2	42.9	-	169.5	164.8	4.7	-	3748.2	3752.5	4.3	-
2022	7683.4	7646.9	36.5	-	167.8	172.2	4.4	-	3887.3	3797.0	90.3	-
2023	-	7950.2	-	-	-	180.0	-	-	-	3842.2	-	-
2024	-	8265.5	-	-	-	188.2	-	-	-	3887.8	-	-
2025	-	8593.4	-	-	-	196.7	-	-	-	3934.0	-	-
2026	-	8934.2	-	-	-	205.6	-	-	-	3980.8	-	-
2027	-	9288.5	-	-	-	214.8	-	-	-	4028.1	-	-

Table 4.12 continued

$\begin{matrix} P \\ Y \backslash V \end{matrix}$	Yunnan				Chongqing				-	-	-	-
	OV	FV	$e(i)$	C	OV	FV	$e(i)$	C	-	-	-	-
2015	3236.6	3236.6	0	0.0286	2392.9	2392.9	0	0.0072	-	-	-	-
2016	3299.7	3170.9	128.8	-	2479.3	2440.8	38.5	-	-	-	-	-
2017	3431.1	3395.1	36.0	-	2543.5	2547.8	4.3	-	-	-	-	-
2018	3600.9	3635.1	34.2	-	2645.6	2659.6	14.0	-	-	-	-	-
2019	3729.7	3892.2	162.5	-	2750.8	2776.2	25.4	-	-	-	-	-
2020	4060.3	4167.3	107.0	-	2870.0	2898.0	28.0	-	-	-	-	-
2021	4555.4	4462.0	93.4	-	3039.6	3025.1	14.5	-	-	-	-	-
2022	4848.7	4777.4	71.3	-	3181.2	3157.8	23.4	-	-	-	-	-
2023	-	5115.2	-	-	-	3296.3		-	-	-	-	-
2024	-	5476.8	-	-	-	3440.9		-	-	-	-	-
2025	-	5864.0	-	-	-	3591.8		-	-	-	-	-
2026	-	6278.6	-	-	-	3749.3		-	-	-	-	-
2027	-	6722.5	-	-	-	3913.8		-	-	-	-	-

Based on the data presented in Table 4.12, the posterior odds ratio of the forecasting results for the inland region consistently remains below 0.65, with the exception of Heilongjiang Province. According to Northeast Rice Live Streaming Technology (2018), Heilongjiang Province faced adverse weather conditions, including drought and gale disasters in the spring of 2018, followed by torrential rains in July, resulting in a significant decline in crop production. The production of fresh agricultural products in the province dropped from 19.34 million tons in 2017 to 16.80 million tons in 2018, before showing signs of recovery thereafter. Overall, the projections for the next five years regarding cold chain logistics for fresh agricultural products in the inland region demonstrate considerable precision.

Table 4.13 illustrates the forecasted demand for cold chain logistics of fresh agricultural products in the inland region of China, spanning from 2023 to 2027. This forecast is derived by aggregating the projected values of the 20 provinces in the inland

region from Table 4.12. It is evident from the table that the demand for cold chain logistics of fresh agricultural products in the inland region of China is projected to exhibit steady growth during the period from 2023 to 2027, reaching a total of 876.56 million tons by 2027.

Table 4.13: Demand for Fresh Agricultural Products Cold Chain Logistics in China's Inland Regions (Unit: 10,000 tons)

Year	2023	2024	2025	2026	2027
Demand of China's Inland Regions	75754.1	78486.8	81374.4	84427.1	87655.9

4.5.3 Forecasting Results of the Demand for Fresh Agricultural Products Cold Chain Logistics in China

The anticipated demand for cold chain logistics of fresh agricultural produce in China is detailed in Table 4.14. This demand is calculated by aggregating the demand for cold chain logistics of fresh agricultural produce in the inland region from 2023 to 2027 with the demand for the same items in the coastal region over the same period. The data reveals a gradual increase in the demand for cold chain logistics of fresh agricultural goods in China from 2023 to 2027, culminating in a total of 1,571.14 million tons by the end of that timeframe.

Table 4.14: Demand for Fresh Agricultural Products Cold Chain Logistics in China (Unit: 10,000 tons)

Year	2023	2024	2025	2026	2027
Demand of China	137816.9	142273.0	146964.1	151905.9	157114.0

Based on the analysis results presented above, this study has generated a line chart depicting the predicted values of cold chain logistics demand for fresh agricultural products

in China, its coastal areas, and inland regions over the next five years (2023–2027). This visualization is illustrated in Figure 4.2.

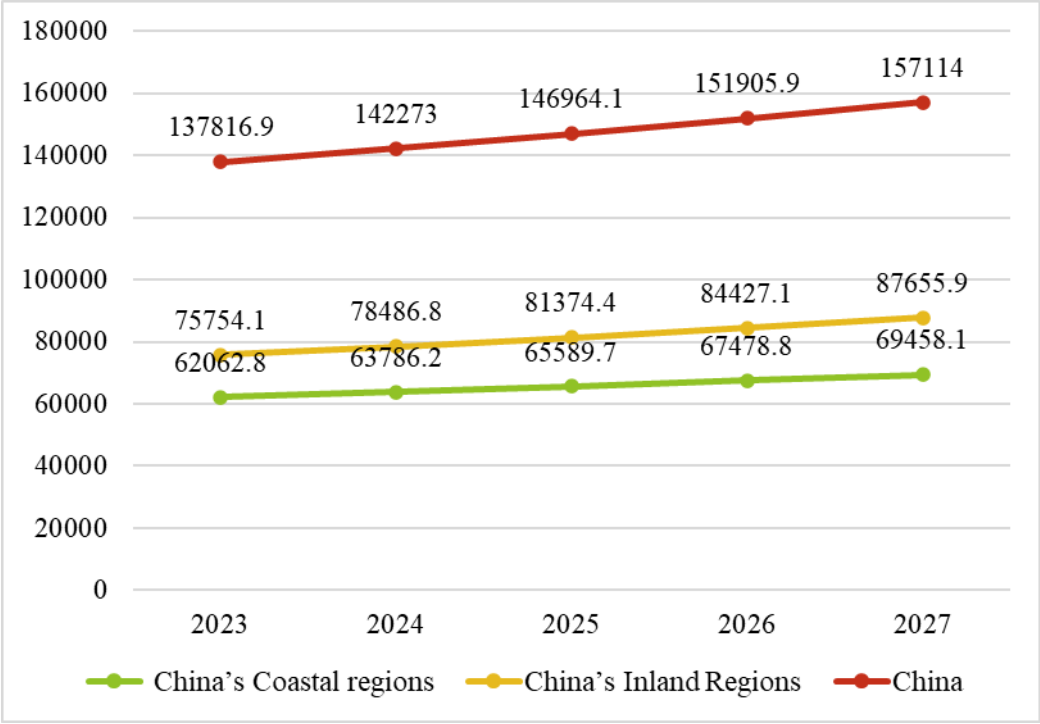


Figure 4.2: Forecast Value of Fresh Agricultural products Cold Chain Logistics Demand (Unit: 10,000 tons)

Figure 4.2 illustrates a linear growth trend in the demand for cold chain logistics for fresh agricultural products in both China’s coastal and inland regions over the next five years (2023–2027). Furthermore, it is apparent that the demand for cold chain logistics in inland areas surpasses that in coastal regions, a phenomenon attributed to various underlying factors.

The higher demand for cold chain logistics for fresh agricultural products in inland regions compared to coastal areas stems from a multitude of complex factors. Firstly, disparities in geographic distribution result in inland areas being situated farther from ports, necessitating longer transportation durations and thus a heightened reliance on reliable cold chain logistics systems to preserve product freshness. Secondly, inland areas often experience more extreme climatic conditions, necessitating stringent temperature control

measures to safeguard agricultural produce from the adverse effects of climatic variability. Moreover, the diverse nature of market demands in inland regions contributes to increased logistics requirements, owing to the expansive geographical expanse and dispersed market demands. Additionally, the length of the supply chain is a critical consideration, with inland supply chains typically being longer and thus requiring robust cold chain logistics to maintain product quality throughout transportation. Furthermore, variations in the seasonality of agricultural produce across different regions necessitate year-round cold chain support, particularly in inland areas reliant on seasonal agricultural products. Finally, population density and consumption patterns in inland areas significantly influence the demand for cold chain logistics, with fragmented markets necessitating broader coverage and heightened consumption levels driving the demand for premium-quality, fresh agricultural products. Taken collectively, these factors underscore the heightened demand for cold chain logistics for fresh agricultural products in inland areas relative to coastal regions. However, it is essential to acknowledge that the specifics of this demand are contingent upon various factors, such as regional characteristics, levels of economic development, and industrial structures.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

Chapter 5 of this thesis delves into the conclusions, recommendations, and limitations stemming from the study's findings. Section 5.1 furnishes a concise summary of Chapter 5, while Section 5.2 delves into an in-depth analysis of the study's findings. In Section 5.3, policy recommendations are delineated based on the insights gleaned from the research, and Section 5.4 elucidates the study's inherent limitations.

5.2 Conclusion

This study provides valuable insights into the development of cold chain logistics for fresh agricultural products in China, with a particular focus on coastal and inland regions. Through the application of a static panel data model, the research identified key factors influencing the demand for cold chain logistics in these distinct geographical areas.

The empirical findings highlight significant regional variations in the impact of specific factors. On a national level, the value added by the primary industry, freight turnover, ownership of civilian goods vehicles, internet broadband access subscribers, and the effects of COVID-19 all play a substantial role in shaping the demand for cold chain logistics in China's fresh agricultural produce. However, the influence of these factors varies between coastal and inland regions.

In coastal regions, the primary industry and ownership of civilian goods vehicles are the most prominent drivers of cold chain logistics demand. On the other hand, inland regions are more sensitive to the effects of COVID-19, freight turnover, and internet broadband access subscribers. These differences underscore the importance of region-specific strategies and policies to promote the effective development of cold chain logistics across China.

Additionally, the study provides demand projections for the cold chain logistics sector in the fresh agricultural products over the next five years. By 2027, China's overall demand for cold chain logistics in fresh agricultural products is expected to reach 1,571.14 million tons, with 694.58 million tons attributed to coastal areas and 876.56 million tons in inland regions.

Based on these findings, the study offers tailored policy recommendations to support the continued growth of cold chain logistics for fresh agricultural products in both coastal and inland areas. By addressing region-specific challenges and leveraging the factors identified in this research, policymakers and industry stakeholders can enhance the efficiency, sustainability, and resilience of the cold chain logistics system in China.

5.3 Policy Recommendations

This section aims to offer policy recommendations aimed at bolstering the sustainability of China's fresh agricultural products cold chain logistics industry, drawing upon the insights gleaned from the empirical study elucidated in the preceding chapter.

5.3.1 Recommendations for China's Coastal regions

Recommendations for improving cold chain logistics for fresh agricultural products in coastal regions are delineated into two main categories. The initial segment provides

suggestions concerning the primary variables that influence the demand for cold chain logistics of fresh agricultural products in the region. Subsequently, the second segment furnishes proposals aimed at ensuring harmonization with the burgeoning expansion of cold chain logistics for fresh agricultural products in the region.

5.3.1.1 Recommendations for Determining Factors

The Value Added of Primary Industry

The empirical findings from Chapter 4 underscored a positive correlation between the development of cold chain logistics for fresh agricultural produce in China's coastal areas and the variable of added value within the primary industry. To foster the advancement of cold chain logistics in these regions, it is recommended to augment the added value within the primary industry through the following strategies:

The adoption of cutting-edge agricultural technologies is paramount for enhancing agricultural productivity and quality. Techniques such as advanced planting, breeding, irrigation, and fertilization technologies can optimize production processes, reduce costs, and elevate the value of agricultural products. For instance, the deployment of sophisticated planting methods can bolster crop yields, mitigate pest infestations, and expedite growth cycles, thereby enhancing overall productivity and quality.

Cultivating strong brand identities for agricultural products is pivotal to augmenting their market value and competitiveness. By fortifying brand development initiatives and intensifying marketing endeavours, it is possible to bolster market recognition and consumer trust. Establishing agricultural product brands that embody local attributes and uphold high-quality standards can significantly elevate product prices and bolster farmer incomes.

Moreover, robust branding efforts instil consumer confidence in product quality and safety, thus stimulating market demand and fostering industry growth.

Diversifying the agricultural industry chain can enhance the value proposition of agricultural products by facilitating downstream processing and refinement. Through the establishment of comprehensive industry chains, agricultural products can undergo value-added processing, resulting in higher market competitiveness and increased profitability for farmers. Processing agricultural goods into semi-finished or finished products prolongs their market shelf life and enhances their overall value. Additionally, expanding the agricultural by-products processing sector promotes resource efficiency and contributes to rural economic diversification.

Prioritizing the conservation of agricultural ecosystems is imperative for preserving product quality and enhancing value. Initiatives aimed at enhancing ecological protection and promoting organic farming practices contribute to product safety and quality standards. Implementation of eco-friendly production techniques, such as bio-pesticides and organic fertilizers, reduces chemical residues and pollution levels, thereby enhancing product safety and market desirability. Furthermore, investments in farmland infrastructure, such as water conservation and soil conservation measures, bolster soil fertility and agricultural productivity, thereby elevating the value of agricultural outputs.

Promoting innovation and investment in agricultural research and development drives technological advancements that elevate the value proposition of agricultural products. By fostering innovation in crop breeding, genetic improvement, and agronomic practices, it is possible to develop resilient crop varieties with improved yield and quality attributes. Implementation of precision agriculture technologies, including efficient irrigation and

fertilizer application methods, optimizes resource utilization and production efficiency, resulting in cost savings and enhanced product value. Consequently, prioritizing innovation in agricultural science and technology facilitates the modernization and sustainability of the agricultural sector, thereby enhancing its overall value proposition.

Ownership of Civilian Goods Vehicles

The surge in cold chain logistics for fresh agricultural products in China's coastal regions has been directly correlated with the rise in ownership of civilian goods vehicles, which has played a crucial role in meeting the escalating demand for fresh agricultural products. To enhance the growth of demand for cold chain logistics, comprehensive measures from various perspectives are necessary.

The government can facilitate the growth of demand for temperature-controlled logistics by providing multi-level financial assistance, such as by creating dedicated funds, offering loan subsidies, and granting tax incentives. These measures aim to encourage enterprises to boost their investments in civilian cargo vehicles. Simultaneously, the government should provide guidance to enterprises in technological innovation and promote the upgrading of temperature-controlled equipment to enhance its sophistication, energy efficiency, and environmental sustainability. The provision of extensive support can significantly decrease the expenses associated with enterprise investment, encourage more businesses to participate in the cold chain logistics sector, and improve the efficiency and manageability of the entire supply chain.

To maintain professionalism in the cold chain logistics process, the government can promote and provide assistance for a comprehensive training system that enhances the skills of drivers and logistics professionals in operating cold chain equipment and deepens their

knowledge of food safety. Furthermore, the establishment of cold chain logistics infrastructure is of utmost importance. To enhance the coverage and transportation efficiency of the entire temperature-controlled logistics network, it is imperative for the government and enterprises to collaborate and allocate more resources towards investing in temperature-controlled infrastructure. Standardization and digitization are essential components of contemporary logistics. The government should develop standardized criteria for cold chain logistics and implement a digital regulatory framework to enhance the transparency and quality traceability of the entire cold chain logistics system.

Promoting collaboration and the exchange of resources among businesses is crucial for enhancing the efficiency of cold chain logistics. Sharing resources such as cold chain equipment and transport networks can lead to a reduction in logistics costs, an improvement in resource utilization, and the promotion of sustainable development in the cold chain logistics industry. To guarantee the quality and safety of cold chain logistics, it is imperative for the government to enhance the regulation of this sector and establish a comprehensive regulatory framework. This should include monitoring the quality of cold chain equipment and conducting compliance inspections of transport vehicles. Enterprises will face penalties if they do not comply with regulations, in order to incentivize them to prioritize the quality and safety of cold chain logistics. This will help establish a more effective and long-lasting supply chain for fresh agricultural products in coastal areas.

COVID-19

The empirical results in Chapter 4 revealed a negative correlation between the factor of COVID-19 and the development of cold chain logistics for fresh agricultural produce in China's coastal areas. To mitigate the adverse effects of public health events like COVID-

19 on the cold chain logistics of fresh agricultural products, the following measures can be implemented:

It is essential to enhance health protection measures at cold chain logistics nodes, such as ports and terminals located in coastal areas. Regular and meticulous disinfection of sites and facilities, particularly areas and equipment frequently touched, such as cargo loading and unloading areas and transport vehicles, is crucial to ensure the effective eradication of viruses. In addition, conducting health surveillance for employees engaged in cold chain logistics, including regular temperature and health assessments, as well as providing essential protective equipment such as masks and gloves, is necessary to ensure their personal safety and well-being.

To promptly identify and address potential irregularities in cold chain logistics, it is essential to establish a flawless information monitoring system. This system should continuously monitor and log the temperature, humidity, and other important data of imported and exported goods in real-time. It will enable the system to promptly issue alarms and implement appropriate measures when any abnormalities are detected. Simultaneously, establishing an information sharing mechanism to facilitate the exchange of data with relevant departments and enterprises will enable comprehensive data monitoring and management, thereby enhancing capacity and effectiveness in responding to emergencies.

Ensuring the safety of cold chain logistics transport requires effective safety management of both vehicles and facilities involved in the process. To guarantee the safety of cold chain logistics transport, it is imperative to enhance the oversight and control of transportation vehicles and facilities, ensuring their adherence to health standards and safety regulations. Conducting routine inspection and maintenance of vehicles and facilities to

ensure they are in optimal working condition is important. Providing practitioners with pertinent training to enhance their focus on transport safety and conscientiousness is also crucial. By enhancing the safety management of logistics and transportation, it is possible to effectively prevent cross-infection and ensure the safety and stability of cold chain logistics and transportation.

Cold chain logistics in transnational transport involve numerous intricate factors, and enhancing international cooperation is a crucial approach to addressing the risk of epidemics. Coastal regions ought to collaborate with countries in order to formulate epidemic prevention standards and measures, establish mechanisms for cross-border collaboration, and collectively address the risks of epidemics in cross-border cold chain logistics. To enhance the sharing and exchange of information, stay updated on the current state of the epidemic and the preventive and control measures implemented by each country. Implement standardized epidemic prevention measures to ensure the safe functioning of cold chain logistics. By engaging in international collaboration, the likelihood of epidemics can be significantly diminished, and the uninterrupted and secure transportation of cold chain logistics can be ensured.

Facilitating the digitalization of the cold chain logistics sector is a crucial step in enhancing emergency response capabilities. By enhancing information management and achieving complete traceability of the cargo flow process, potential safety risks can be identified and tracked promptly, leading to improved emergency response capabilities. Simultaneously, employing big data and artificial intelligence technology to analyse and forecast the cold chain logistics process allows for the development of proactive response strategies to mitigate the impact of emergencies on cold chain logistics. By advocating for

digital transformation, the effectiveness and security of cold chain logistics can be enhanced, ensuring the reliable and stable operation of cold chain logistics.

The rapid development of the internet in coastal areas in recent years has posed challenges to the growth of demand for cold chain logistics for fresh agricultural products. While the internet has facilitated market expansion and information exchange, it has also introduced complexities such as information asymmetry, a lack of transparency in transportation processes, and shifts in traditional distribution methods. In response to these challenges, it is imperative to develop strategies that foster healthy collaboration between fresh agricultural products temperature-controlled logistics and the internet.

The Internet Broadband Subscribers

Utilizing information technology is paramount to leveraging the positive interaction between the internet and cold chain logistics for fresh agricultural products. Establishing a real-time monitoring system through the use of the internet and Internet of Things (IoT) technology enables comprehensive tracking of the cold chain process, ensuring product quality and safety during transportation. Additionally, the creation of mobile applications or online platforms facilitates instantaneous information exchange among agricultural producers, wholesalers, and retailers, enhancing supply chain transparency. This not only mitigates information asymmetry but also improves market efficiency, ensuring consumers receive safer and more reliable fresh agricultural products.

Cooperation and integration are fundamental strategies for promoting the seamless integration of the internet and cold chain logistics for fresh agricultural produce. Collaborating with e-commerce platforms expands sales channels and enhances shopping convenience through online payment and streamlined delivery services, enticing more

consumers to purchase agricultural products online. Concurrently, investment in cold chain logistics infrastructure development ensures a comprehensive logistics network, enabling swift and dependable circulation of agricultural products between production and consumption locations. Cutting-edge cold chain technology further enhances transportation effectiveness and reliability, establishing a solid foundation for the secure conveyance of perishable goods.

Training and policy support are vital components for effectively integrating the internet and fresh agricultural products cold chain logistics. Providing training courses on optimal cold chain logistics methods for farmers and practitioners enhances their knowledge and skills. Moreover, enhancing product packaging and handling criteria ensures the preservation of product quality during transportation. Government-level policies, including tax incentives, loan support, and measures to facilitate market access, are essential for promoting the growth of temperature-controlled logistics for fresh agricultural goods. Advocating for the adoption of renewable energy sources and eco-friendly transportation methods by businesses helps mitigate negative environmental effects.

Lastly, leveraging big data analytics and artificial intelligence technology enables accurate market demand forecasting and optimization of supply chain management. Efficient inventory management minimizes food waste, while data analysis enhances transportation route effectiveness, reducing transport time and costs. These comprehensive measures establish a strong foundation for seamless integration of the internet and cold chain logistics for fresh agricultural products, facilitating their joint and sustainable development.

5.3.1.2 Recommendations for Cold Chain Logistics Development Scale in Coastal Regions

The projected increase in demand for cold chain logistics of fresh agricultural products in China's coastal areas, expected to reach 694.58 million tons by 2027, necessitates strategic measures aligned with existing national policies to effectively manage this growth. The following recommendations aim to address this demand while connecting to China's current cold chain logistics policies:

In line with China's National Cold Chain Logistics Development Plan (2021-2025), which emphasizes the need for enhancing cold chain infrastructure, it is crucial to establish a compact and effective cold chain network. Forming strategic partnerships with agricultural cooperatives, wholesale markets, and retailers is recommended to create efficient cold chain routes and storage strategies, ensuring cooperation throughout the supply chain. Additionally, regional centralized cold storage systems should be developed to improve efficiency by leveraging economies of scale, minimizing resource waste, and ensuring adaptable cold chain services that align with national goals.

Consistent with the Chinese government's emphasis on innovation, particularly in agricultural modernization and logistics, investing in research and development for advanced cold chain technology is essential. National policies encourage the adoption of energy-efficient, environmentally sustainable solutions. Therefore, allocating resources to develop advanced preservation, packaging, and cooling technologies tailored to the specific needs of diverse agricultural products will support policy goals aimed at reducing spoilage and enhancing supply chain sustainability.

To align with China's focus on digital transformation, as highlighted in the Digital China initiative, integrating intelligent supply chain management is necessary. This includes advanced route optimization, real-time tracking, and intelligent warehousing systems. Training programs should be developed to ensure personnel are proficient in these systems, contributing to enhanced efficiency and reduced operational costs. This aligns with the government's push towards using technology to modernize logistics and improve food safety standards.

Coastal areas serve as key foreign trade routes, and enhancing international cooperation, as supported by the Belt and Road Initiative, is crucial for developing robust cold chain logistics. Collaborating with international organizations and neighbouring countries to establish global benchmarks for cold chain logistics will enhance network flexibility, reduce trade barriers, and facilitate global agricultural product movement. Diversifying trade routes, including expanding land and air transportation options, will strengthen system resilience and align with China's broader goals of expanding its influence in global supply chains.

By aligning these recommendations with China's current policies, coastal regions can effectively manage the increasing demand for cold chain logistics of fresh agricultural products. This approach ensures not only the quality and efficiency of cold chain logistics but also the competitiveness of China's agricultural products in the global market.

5.3.2 Recommendations for China's Inland Regions

The development recommendations for cold chain logistics of fresh agricultural products in inland areas are primarily categorized into two sections. The initial section focuses on the key factors that influence the demand for cold chain logistics of fresh

agricultural products in the region. The subsequent section provides recommendations regarding the projected growth of regional cold chain logistics demand for fresh agricultural products over the next five years.

5.3.2.1 Recommendations for Determining Factors

The primary determinants influencing the demand for cold chain logistics of fresh agricultural products in China's coastal regions, ranked in descending order, are the value added of the primary industry, the impact of COVID-19, the ownership of civilian goods vehicles, the number of households with internet broadband access, and the freight turnover. For each of these five factors, the following recommendations are provided:

The Value Added of the Primary Industry

The empirical findings in Chapter 4 demonstrated a direct relationship between the increase in value of the primary industry and the progress of cold chain logistics for fresh agricultural products in China's inland regions. Thus, enhancing the value added by the primary industry can effectively promote the development of cold chain logistics for fresh agricultural produce in inland regions.

Inland regions should adapt their agricultural industry structure based on geographical and climatic conditions, with a focus on cultivating advantageous agricultural products that are well-suited to the region's characteristics. This approach will enhance the value of the products. To enhance the market competitiveness of agricultural products, it is important to carefully choose crop varieties based on the soil type and climate characteristics of different regions. Additionally, it is crucial to optimize the planting structure. Furthermore, cultivating agricultural product brands with local characteristics and a high-quality image,

in line with market demand and consumption trends, can significantly increase the added value of the products.

Encouraging the efficient functioning of the agricultural sector is a highly effective strategy for enhancing the economic value of primary industries in inland regions. Inland regions have the potential to adopt new operational strategies, such as large-scale and cooperative operations, to enhance the scale, standardization, and intensification of agricultural production. This can be achieved by integrating resources, optimizing layout, and improving management practices. The ultimate goal is to enhance agricultural production efficiency and increase the value of agricultural products. This business model has the potential to decrease agricultural production expenses, enhance economic productivity, and augment farmers' income.

Rural regions have the potential to establish a robust agricultural product processing industry in order to enhance the value of agricultural products through processing and further refinement. Processing agricultural products can enhance their shelf life, boost their value, and cater to the diverse demands of various consumer segments. Simultaneously, efforts will be made to enhance the development of marketing channels in order to broaden the market reach and enhance the market competitiveness of processed agricultural products. The value-added of agricultural products in inland areas can be achieved by implementing agricultural product processing and marketing strategies, thereby enhancing the overall value of the primary industry.

It is important for inland regions to prioritize ecological environmental protection, promote the growth of eco-agriculture, and cultivate green, organic, and high-quality agricultural products in order to enhance the value of these products. Eco-agriculture

prioritizes the harmonized advancement of the ecological environment and agricultural production. It places emphasis on safeguarding and sustainably utilizing land resources, employing pollution-free and environmentally conscious production techniques, and yielding agricultural products that possess enhanced market competitiveness and added value. Eco-agriculture can facilitate the sustainable development of agriculture, thereby generating increased economic advantages for residents in inland regions.

Rural regions should enhance their investment in agricultural science and technology, foster the adoption of advanced agricultural techniques such as efficient water-saving irrigation and precise fertilizer application, and enhance the quality and productivity of agricultural products to boost farmers' income. By implementing and advocating for cutting-edge agricultural technologies and management strategies, we can enhance the efficiency of agricultural production, lower production costs, and increase the value of products. Simultaneously, it can enhance the scientific and technological education of farmers, enhance their capacity to utilize new technologies, stimulate the innovation and advancement of agricultural science and technology, and invigorate the added value of the primary industry in inland regions.

COVID-19

Chapter 4 presented empirical results showing that the development of cold chain logistics for fresh agricultural products in China's inland areas is negatively influenced by the COVID-19 factor. To mitigate the adverse impact of public health events such as COVID-19 on the transportation and storage of fresh agricultural products, the following strategies can be implemented:

In the face of public health crises like COVID-19, it is crucial for inland regions to enhance border control measures, particularly in regulating and monitoring the origins and quantities of imported cold chain products. This necessitates the establishment of a rigorous regulatory framework, which includes evaluating the risk of epidemics in the countries from which cold chain goods are imported, as well as building quarantine and testing facilities at import ports and harbours. Regulating the origin and volume of imported cold chain goods is a crucial step in safeguarding inland regions from the spread of epidemics through imports. To effectively prevent the spread of epidemics through temperature-controlled logistics and protect the health and safety of residents in inland areas, it is crucial to prioritize the safety of imported cold chain goods.

To address potential safety risks in the transportation and storage of temperature-sensitive goods, it is crucial for inland regions to develop a thorough emergency response strategy. This involves elucidating the accountable departments and disposal procedures, as well as establishing an emergency response mechanism, to ensure that prompt actions can be taken to dispose of cold chain goods once safety hazards are identified. In order to ensure a prompt and efficient response to emergencies, the development of the emergency plan should take into account a range of potential scenarios, such as the presence of contaminated goods, breakdown of transport vehicles, and other unforeseen emergencies. It is crucial to devise appropriate disposal programs and measures that are tailored to each situation, ensuring that the emergency response is both timely and effective. The inland areas can only achieve a rapid and effective response to emergencies and minimize potential losses by implementing a well-designed emergency plan.

Inland regions should enhance the surveillance and examination of cold chain commodities, establish a robust quarantine system, and implement rigorous inspections of imported cold chain goods. This involves the surveillance of temperature, humidity, and other crucial parameters of cold chain commodities, as well as the examination for potential pathogens to guarantee compliance with health regulations for imported cold chain goods. Simultaneously, it is imperative to enhance the surveillance and assessment of cold chain logistics transportation vehicles and facilities to guarantee their adherence to safety regulations. The timely detection of potential safety hazards in inland areas, effective implementation of corrective measures, and ensuring the secure functioning of cold chain logistics can only be achieved through the enhancement of monitoring and testing efforts.

It is necessary to enhance the training and education of practitioners in inland areas to enhance their understanding of epidemic prevention and control and their proficiency in operational skills. This involves providing training to cold chain logistics practitioners on epidemic prevention and control knowledge and operational skills, enabling them to acquire proficiency in implementing appropriate protective measures and operational procedures. Simultaneously, it is imperative to enhance the health surveillance and supervision of professionals to ensure their well-being and mitigate the potential hazards of infections. Enhancing personnel training in inland areas can enhance the proficiency of practitioners in managing epidemic outbreaks and ensure the safety and stability of cold chain logistics and transportation.

Inland regions should prioritize the promotion and education of cold chain logistics practitioners and related enterprises to increase their awareness and vigilance towards epidemic prevention and control efforts. This involves disseminating the significance of

epidemic prevention and control to practitioners through diverse forms of publicity and educational initiatives, as well as enhancing their safety consciousness and sense of accountability. Simultaneously, it is imperative to enhance the dissemination and instruction of pertinent enterprises to facilitate the execution of epidemic prevention protocols and guarantee the security and dependability of cold chain logistics and transportation. By enhancing publicity and education efforts, inland regions can increase awareness of epidemic prevention among cold chain logistics practitioners and relevant enterprises, thereby reducing the risk of epidemic transmission and ensuring the public health and safety of inland regions.

The Ownership of Civilian Goods Vehicles

Transportation is crucial for establishing cold chain logistics in inland regions, and the ownership of civilian goods vehicles directly affects the fulfilment of this requirement. As inland areas become more urbanized and the rural economy develops, there is a growing need for civilian trucks. This not only enhances the transportation capability of agricultural products but also creates a wider market for the development of cold chain logistics. To effectively enhance the coverage and transport efficiency of cold chain logistics for fresh agricultural products in inland areas, it is necessary to increase the input of civilian cargo vehicles.

To enhance the temperature-controlled logistics of fresh agricultural products in inland areas, it is recommended that the government augment its assistance for civilian cargo vehicles. This can be achieved by directing enterprises to boost their investment through favourable policies and expediting the upgrade of transportation methods. Simultaneously, businesses are urged to embrace sophisticated temperature-controlled technologies in order

to enhance transportation efficiency and minimize losses. Furthermore, it is advisable to enhance the training of professionals involved in cold chain logistics and enhance their expertise to guarantee the safety and quality of operations during temperature-controlled transportation.

The Internet Broadband Subscribers

There is a direct relationship between the expansion of cold chain logistics for fresh agricultural produce in China's inland regions and the number of households that had access to high-speed internet. Thus, the subsequent tactics can be employed to promote the advancement of cold chain logistics for fresh agricultural products in the inland regions:

The establishment of internet infrastructure is vital for the advancement of cold chain logistics in landlocked regions. Primarily, the government ought to augment its investment in the development of internet broadband infrastructure to guarantee universal access to fast and reliable internet connectivity in both urban and rural areas of the inland region. This will not only fulfil the requirements of residents' daily activities and employment but also offer essential network assistance for cold chain logistics. Furthermore, it is imperative to establish impeccable internet access infrastructure, encompassing optical fibre and wireless networks, in order to adequately cater to the diverse requirements of various regions and users. Furthermore, the government can incentivize internet service providers to construct networks in inland regions by implementing policies that offer support and financial subsidies. This will facilitate the expeditious growth of internet infrastructure.

Expanding agricultural product e-commerce is a crucial method for stimulating the need for temperature-controlled logistics in inland regions. The government can promote and facilitate the growth of agricultural product e-commerce in inland areas by implementing

favourable policies. Policy support, such as providing tax incentives and financial subsidies, can be implemented to decrease the operational expenses of agricultural produce e-commerce platforms. Simultaneously, the government can enhance the oversight of agricultural produce e-commerce, safeguard consumer rights and interests, and bolster consumer confidence in agricultural produce e-commerce. Furthermore, the government can foster collaboration between agricultural product e-commerce firms and temperature-controlled logistics enterprises to collectively advance the development of temperature-controlled logistics networks and enhance the quality of service and operational efficiency.

The utilization of internet technology is essential for improving the efficiency and quality of service in temperature-controlled logistics in inland regions. The government can incentivize cold chain logistics enterprises to implement cutting-edge technologies such as the Internet of Things (IoT), big data analysis, and cloud computing. This will allow for the optimization of logistics and distribution routes, as well as improved management of warehousing. Additionally, it will enhance the capabilities of product tracking and tracing. Simultaneously, the government can also facilitate cold chain logistics enterprises by establishing online platforms that offer convenient ordering and payment services to enhance the consumer experience. Furthermore, the government can bolster the cultivation and recruitment of internet technology experts to enhance the technological proficiency and innovation potential of inland regions, thereby facilitating the growth of the cold chain logistics industry.

Freight Turnover

The freight turnover in inland areas serves as a significant measure of the level of regional economic activity, and it plays a crucial role in facilitating the cold chain logistics

of fresh agricultural products. Given the geographical characteristics of inland regions, agricultural goods must travel longer distances to reach the market. Therefore, it is essential to enhance freight turnover to minimize transport time and decrease product loss in cold chain logistics. Nevertheless, the present transportation of goods in inland regions continues to encounter certain obstacles, necessitating the implementation of measures to enhance it.

Increased freight turnover decreases the duration between production and distribution of goods, thereby minimizing quality variations and losses during transportation. Increased freight turnover also motivates cold chain logistics service providers to prioritize inland regions and enhance cold chain facilities and services. Enhanced freight turnover will additionally entice a greater number of investors to engage in the cold chain logistics sector in the inland region, thereby stimulating the industry to more effectively cater to the growing need for fresh agricultural products.

To enhance freight turnover in the inland area, it is recommended that the government augment investment in infrastructure development, streamline the transport network, and enhance transport efficiency. By constructing additional transportation hubs and enhancing road and railway infrastructure, it is possible to decrease logistics expenses and enhance the velocity of freight turnover. Furthermore, businesses can be incentivized to implement sophisticated logistics management systems to enhance the intelligence of their logistics operations and further optimize the efficiency of freight turnover.

5.3.2.2 Recommendations for Cold Chain Logistics Development Scale in Inland Regions

The demand for cold chain logistics of fresh agricultural products in China's inland areas is projected to reach 757.54 million tons in 2023 and grow to 876.56 million tons by 2027. Considering the specific characteristics and scale requirements of regional development, the following suggestions, connected to national policies, are proposed for advancing cold chain logistics in these areas:

In line with China's National Cold Chain Logistics Development Plan (2021-2025), which emphasizes expanding cold storage infrastructure, investment in modern cold storage facilities in inland cities is essential. These facilities should meet international standards, ensure adequate storage capacity, and utilize advanced preservation technology. National policy also supports upgrading cold chain transportation infrastructure, making it crucial to allocate resources for acquiring refrigerated trucks, rail transport, and advanced transportation modes like drones and driverless vehicles, especially in remote areas. These initiatives directly contribute to improving food safety and economic efficiency in inland regions.

Inland regions experience diverse seasonal climate variations, which align with the government's emphasis on addressing logistical challenges through innovative technology. Implementing flexible cold chain technologies, including novel temperature-regulated equipment and intelligent packaging, is necessary to manage these climate fluctuations. National initiatives such as Made in China 2025 encourage innovation in logistics technology. By adopting adaptable environmental control systems, inland regions can optimize storage conditions across varying climates and seasons, ensuring the secure transportation and storage of agricultural goods in line with national modernization goals.

China's agricultural policies promote the development of tailored logistics solutions that meet the diverse needs of different regions. In inland areas, where agricultural output varies widely, it is essential to customize cold chain logistics services. This involves creating adaptable transportation strategies and storage systems based on market research and data analysis. The government's push for enhanced food safety regulation can be supported by implementing categorized supervision of agricultural products, using advanced labeling and tracking technologies. Customized services, including precise temperature and humidity control, will ensure the quality and safety of each batch of produce, in line with national food safety standards.

The Chinese government's Rural Revitalization Strategy highlights the importance of building skilled talent pools in less-developed regions. Inland areas require professionals with expertise in cold chain logistics management, maintenance, and emergency response. To align with this strategy, partnerships should be established between cold chain industry experts and higher education institutions to provide specialized training programs. Additionally, technical training for cold chain system enhancement is crucial. Personnel should be trained in the use of new technologies and equipment, as well as in handling emergency situations. These initiatives will help build a skilled workforce that can support the efficient operation of cold chain logistics in inland regions, in line with national goals of rural revitalization and regional economic development.

By aligning these recommendations with China's current policies, inland regions can better manage the increasing demand for cold chain logistics of fresh agricultural products. This approach supports not only the development of regional cold chain networks but also the overall goal of national food safety, technological advancement, and rural revitalization.

5.4 Limitations of the Study

This study employed annual data spanning from 2015 to 2022 to scrutinize the determinants influencing the demand for cold chain logistics within China's fresh agricultural products sector, encompassing both coastal and inland regions. The differential impacts of these determinants on cold chain logistics demand in the coastal and inland regions were also examined. However, the absence of more granular data, such as quarterly or monthly data, potentially limits the depth of analysis, thus affecting the precision of the findings. Additionally, this study may be susceptible to biases when forecasting cold chain logistics demand for the transportation of fresh agricultural products in both coastal and inland regions of China.

5.5 Suggestions for Future Study

5.5.1 Utilizing More Granular Data

Future research should consider incorporating more granular data, such as quarterly or monthly statistics, to provide a more detailed analysis of cold chain logistics demand. This approach would allow for the examination of seasonal patterns, supply chain disruptions, and short-term fluctuations, leading to more precise forecasting models. Such data can also help capture the effects of policy changes, market shocks, and consumer behavior on cold chain logistics.

5.5.2 Exploring Advanced Forecasting Methods

Given the potential biases in demand forecasting, future studies could explore advanced forecasting methods, such as machine learning algorithms or time series analysis techniques, to improve accuracy. These methods can account for complex, nonlinear

relationships between variables and adjust to emerging trends more effectively. Combining these approaches with granular data could yield more accurate and reliable forecasts.

5.5.3 Investigating Intra-Regional Variations

To gain a deeper understanding of cold chain logistics demand, future research should investigate intra-regional variations within coastal and inland regions. This could involve case studies or region-specific analyses that consider local factors, such as infrastructure development, policy implementation, and economic conditions. Such an approach would provide more nuanced insights into how different areas within the same region may experience varying levels of demand for cold chain logistics services.

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