Singapore Management University

Institutional Knowledge at Singapore Management University

Dissertations and Theses Collection (Open Access) | Dissertations and Theses

4-2024

Research on futures, profit hedging, and enterprise price risk management in the bulk commodity industry chain — A case study of hot-rolled coil industry chain

Shengxi LIU
Singapore Management University, shengxi.liu.2019@dba.smu.edu.sg

Follow this and additional works at: https://ink.library.smu.edu.sg/etd_coll

Part of the Accounting Commons, and the Finance and Financial Management Commons

Citation

LIU, Shengxi. Research on futures, profit hedging, and enterprise price risk management in the bulk commodity industry chain — A case study of hot-rolled coil industry chain. (2024). 1-121.
Available at: https://ink.library.smu.edu.sg/etd_coll/574

This PhD Dissertation is brought to you for free and open access by the Dissertations and Theses at Institutional Knowledge at Singapore Management University. It has been accepted for inclusion in Dissertations and Theses Collection (Open Access) by an authorized administrator of Institutional Knowledge at Singapore Management University. For more information, please email cherylds@smu.edu.sg.

RESEARCH ON FUTURES, PROFIT HEDGING, AND ENTERPRISE PRICE RISK MANAGEMENT IN THE BULK COMMODITY INDUSTRY CHAIN——A CASE STUDY OF HOT-ROLLED COIL INDUSTRY CHAIN

LIU SHENGXI

SINGAPORE MANAGEMENT UNIVERSITY

2024

Research on Futures, Profit Hedging, and Enterprise Price Risk Management in the Bulk Commodity Industry Chain——A Case Study of Hot-rolled Coil Industry Chain

Liu Shengxi

Submitted to School of Accountancy
in partial fulfillment of the requirements for the
Degree of Doctor of Business Administration
SMU-ZJU DBA (Accounting &Finance)

<u>Dissertation Committee:</u>

ZHANG Liandong (Supervisor / Chair)
Professor of Accounting
Singapore Management University

WEI Jiang (Co-Supervisor)
Professor
Zhejiang University

HU Jianfeng
Associate Professor of Finance
Singapore Management University

Singapore Management University
2024

I hereby declare that this PhD dissertation is my original work

and it has been written by me in its entirety.

I have duly acknowledged all the sources of information

which have been used in this dissertation.

This PhD dissertation has also not been submitted for any degree

in any university previously.

Liushengxi

Liu Shengxi

1st April 2024

Research on Futures, Profit Hedging, and Enterprise Price Risk Management in the Bulk Commodity Industry Chain——A Case Study of Hot-rolled Coil Industry Chain

Liu Shengxi

Abstract

Traditional hedging strategies usually center around a single product, commonly involving companies hedging against the price of their end products or essential production materials. At present, traditional hedging strategies are no longer sufficient to address the production and management requirements of physical enterprises. There is a need to develop hedging strategies aligning with the significant changes in both domestic and international markets.

The thesis presents a new profit hedging model based on product manufacturing processes within the industry chain. This method involves hedging production profits by buying (selling) end products and selling (buying) raw materials according to the proportional relationships in the production process on the futures market. Specifically, this study validates the efficacy of the proposed futures market profit hedging model from both theoretical and practical standpoints.

At the theoretical level, the thesis innovatively integrates futures price factors into the model's mechanism, based on the classic Cournot model. In this process, this study leveraged Bayesian methodology to determine the future price of the commodity through a combination of spot price and futures price. By modifying the original price generation approach, the model is thereby innovated. Subsequently, this study derived an optimal production arrangement for the Cournot model, considering futures market prices on an innovative model. Analyzing the optimal production formula found that companies considering futures market profits can better organize their production to gain a competitive edge.

On a practical level, efforts were made on two dimensions. First, the study employed the classic statistical regression method to test if hot-rolled coil products can be hedged using futures market profits. The findings show that both pure statistical regression and a profit model rooted in actual production processes align with the concept of mean reversion. This implies that hedging hot-rolled coil varieties using futures market profits is entirely viable. This study also constructs two sets of hedging strategies and compares the performance of single-commodity hedging strategies with those based on the market profit from hot-rolled coil futures in each set. Backtesting with historical data, it reveals that hedging strategies based on market profits from hot-rolled futures demonstrate higher opening rates, increased returns on investment (ROI), and lower volatility, surpassing traditional single-commodity hedging strategies in various aspects.

This study further outlines the risk points associated with the hedging strategy involving futures market profits within the industry chain and suggests risk management solutions. The thesis summarizes three types of risks — strategic risk, operational risk, and fundamental risk — and provides corresponding countermeasures.

Keywords: Hot-rolled Coil Industry Chain; Futures Hedging; Cournot Equilibrium; Risk Management

Table of Contents

Acknowledgement

In the process of the completion of this doctoral thesis, I am fortunate to have the support and help of many people. Before the thesis is submitted, I would like to take this opportunity to express my sincerest gratitude to them.

First of all, I would like to express my special thanks to my tutors for their patient guidance and unremitting support throughout the research process. Your rigorous academic attitude and spirit of learning, noble ethics in teaching, profound professional knowledge, simple and approachable personality charm have deeply affected me. When I encounter research problems, your advice and encouragement are always the driving force for me to move forward. What you teach me is not only knowledge, but also the way to learn, the kindness of people and the truth of things.

Secondly, I would also like to thank all the classmates and friends who helped me in the process of completing my thesis, and thank you for your selfless help in the process of learning research methods, designing research schemes, collecting and analyzing data.

Again, a special thank you to my family for their unwavering support and understanding. In the face of academic pressure and challenges in life, you have always been my strong backing, giving me love and encouragement.

Finally, I would like to thank all those who directly or indirectly participated in and supported the completion of this thesis. You have made this academic journey richer and more meaningful.

1 Introduction

1.1 Research background

The thesis provides an overview of the research background from three perspectives. First, it highlights the significant role of the bulk commodity industry chain in our country's national economy; second, it discusses the connection between physical enterprises in the bulk commodity industry chain and the futures market; and finally, it identifies the challenges that physical enterprises encounter when utilizing the futures market for price risk management.

1.1.1 Important position of the bulk commodity industry chain in our country's national economy

Bulk commodities are defined as material goods that are utilized in the industrial and agricultural sectors for production and consumption. They possess the characteristics of goods and are traded in substantial quantities within the non-retail market. In the financial investment market, bulk commodities are tradable, standardized goods widely utilized as fundamental industrial raw materials. Examples include crude oil, steel, iron ore, non-ferrous metals, coal, cotton, soda ash, and more. Bulk commodities play a crucial role in our country's national economy, with numerous varieties impacting both the national economy and people's daily lives. Both production capacity and demand for these commodities rank among the highest globally. However, the production of our country's primary bulk commodities is resource-constrained and holds a passive position in international trade. Hence, given these conditions, vying for pricing power over bulk commodities becomes especially crucial.

In 2021, the Chinese futures market witnessed a record-breaking transaction scale, showcasing substantial growth for three consecutive years. This year, the futures market saw a one-sided trading volume of 7.514 billion lots, with a total turnover of RMB 581.2 trillion, representing year-on-year (YoY) increases of 22.13% and 32.84%, respectively. As per the FIA annual transaction volume statistics, the Zhengzhou Commodity Exchange (ZCE), the Shanghai Futures Exchange (SHFE), the Dalian Commodity Exchange (DCE), and the China Financial Futures Exchange (CFFEX) held the 7th, 8th, 9th, and 27th positions, respectively, in the global futures and options trading volume rankings. In the 2021 global metal variety trading volume rankings, Chinese varieties dominated, securing nine out of the top 10 spots and 13 of the top 20 positions. These varieties included rebar, iron ore, hot-rolled coil, ferrosilicon, and silicomanganese.

Since the onset of the pandemic in 2020, bulk commodity prices have persistently fluctuated at elevated levels. The international bulk commodity market is experiencing tight supply and demand, leading to mounting uncertainty. Consequently, China's trading companies, physical enterprises, and residents' livelihoods have inevitably felt the impact of the price volatility in bulk commodities. Take the hot-rolled coil industry chain as an example. Hot-rolled coils, using slabs as raw materials, are heated in furnaces or homogenized in soaking furnaces. They are then successively rolled into strip steel using rough and finishing rolling units. Finally, the hot strip steel from the last finishing rolling unit is cooled to the desired temperature through laminar flow cooling and coiled into hot-rolled steel strips by a coiling machine. The hot-rolled coil varieties include steel strips, steel coils, and steel sheets that are cut from them.

Based on the material and properties of hot-rolled coils, they can be classified into ordinary carbon structural steel, low-alloy steel, and alloy steel. Based on their specific applications, they can be categorized as corrosion-resistant structural steel, cold-forming steel, mechanical structural steel, structural steel, automotive structural steel, steel for welded gas cylinders and pressure vessels, pipeline steel, and more. Hot-rolled coil products exhibit high strength, excellent toughness, and ease of processing and forming, and find extensive applications in manufacturing sectors including cold-rolled substrates, automobiles, vessels, bridges, and machinery. China, the world's largest producer, consumer, and exporter of hot-rolled coils, introduced hot-rolled coil futures on SHFE in 2014. The launch of hot-rolled coil futures is essential for advancing China's steel industry and serves as a robust strategy to assist steel enterprises in managing price risks effectively. Moreover, it is of great practical significance for our country to perfect the series of ferrous metal futures and strengthen the international influence of steel prices.

Trading variety	**Hot-rolled coil**
Trading unit	10 tons/lot
Quotation unit	Yuan (RMB)/ton
Minimum price fluctuation	RMB 1/ton
Price limit range	Previous trading day
Contract month	January to December
Trading time	9:00-11:30, 13:30-15:00, and other trading hours specified by the exchange
Last trading day	The 15th day of the contract month (postponed in case of national statutory holidays, and the last trading day of months such as the Spring Festival can be adjusted by the exchange and notified accordingly)
Delivery date	Three consecutive working days after the last trading day
Delivery grade	Standard product: Q235B conforming to GB/T 3274-2017 *Hot-rolled Plates and Strips of Carbon Structural Steels and Low-alloy Structural Steels*, SS400 conforming to JIS G 3101-2015 *Rolled Steels for General Structure*, or hot-rolled coils with a thickness of 5.75 mm and a width of 1,500 mm Substitutions: Q235B conforming to GB/T 3274-2017 *Hot-rolled Plates and Strips of Carbon Structural Steels and Low-alloy Structural Steels*; SS400 conforming to JIS G 3101-2015 *Rolled Steels for General Structure*; or hot-rolled coils with a thickness of 9.75 mm, 9.5 mm, 7.75 mm, 7.5 mm, 5.80 mm, 5.70 mm, 5.60 mm, 5.50 mm, 5.25 mm, 4.75 mm, 4.50 mm, 4.25 mm, 3.75 mm, or 3.50 mm, and a width of 1,500 mm
Delivery location	Delivery warehouse designated by the exchange
Minimum transaction margin	4% of the contract value
Delivery method	Physical delivery
Delivery unit	300 tons
Trading code	HC
Listed exchange	Shanghai Futures Exchange

Figure 1.1 Basic information on transactions of hot-rolled coil products at SHFE

Currently, the domestic steel futures industry chain sector has been established, primarily encompassing hot-rolled coil and rebar contracts on SHFE, alongside the three core futures contracts of coking coal, coke, and iron ore on DCE. Additionally, there are the thermal coal, ferrosilicon, and silicomanganese contracts listed on ZCE. Together, they constitute China's steel futures industry chain, refining the futures variety system for the country's coal, coke, and steel sectors. This system is relatively comprehensive, covering key varieties and pioneering an internationally advanced futures hedging chain. This framework presents a significant opportunity for price discovery, risk mitigation, and hedging within China's real economy, providing substantial assistance in risk management and promoting stable development for enterprises in the steel futures industry chain.

1.1.2 The relationship between the production of enterprises in China's bulk commodity industry chain and the futures market

(1) Fluctuations in raw and finished material prices are severe, causing significant uncertainty impacts on hot-rolled coil enterprises

In recent years, the prices of bulk commodities such as hot-rolled coils, iron ore, and coke have shown notable volatility, mainly driven by shifts in domestic and international supply and demand dynamics, alongside macro-control policies. Using the price of hot-rolled coils as an illustration: from 2014 to 2015, it steadily declined to RMB 1,675/ton, rose to RMB 4,400/ton between 2016 and 2017, faced significant fluctuations from 2018 to 2020, and surged to an all-time high of RMB 6,727/ton in 2021. Subsequently, it dropped back to RMB 4,400/ton due to initiatives like "ensuring supply and stabilizing prices". The price performance of the steel industry affects profit margins, rendering profits uncertain and leaving corresponding risk exposure uncompensated. Particularly against the backdrop of policies aimed at peaking carbon emissions and attaining carbon neutrality, events like electricity rationing, production restrictions, and energy consumption controls occur intermittently. Moreover, the intertwined effects of the COVID-19 pandemic and geopolitical tensions have contributed to frequent adjustments and swings in supply and demand dynamics. Therefore, the pressing requirements for companies involve stabilizing profits within the steel sector and ensuring a seamless transition.

Figure 1.2 Continuous futures price of primary contracts for iron ore

Figure 1.3 Continuous futures price of primary contracts for coke

Figure 1.4 Continuous futures price of primary contracts for hot-rolled coil

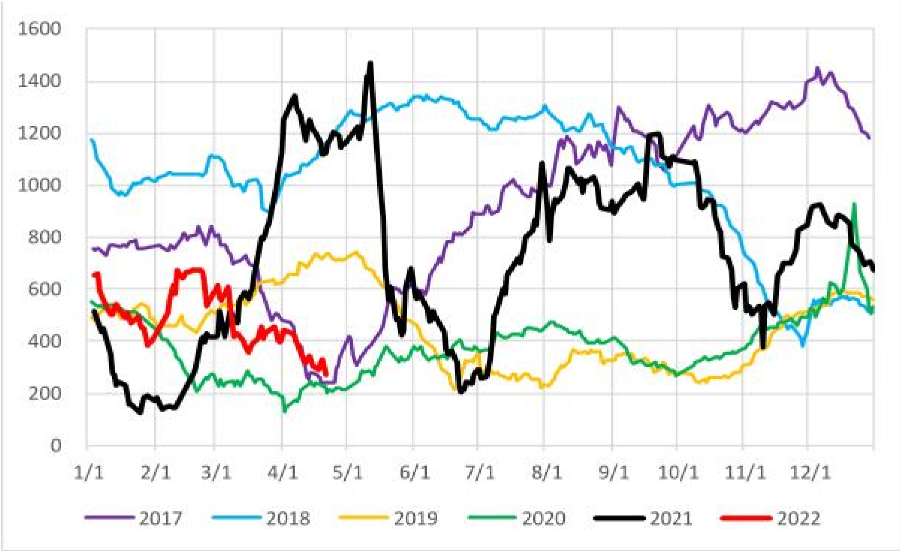

Figure 1.5 Seasonal variations in hot-rolled coil profits

(2) Given the significant price fluctuations, hedging has emerged as a crucial tool for risk management within the steel futures industry chain

Amidst drastic spot and futures commodity price fluctuations, the financialization of industries like coal, coke, and steel is rapidly advancing. Utilizing the futures market for hedging and managing price costs and risks has emerged as a crucial risk management tool for enterprises. These strategies effectively secure corporate profits, fulfilling the crucial aim of stabilizing business development and mitigating risks in industrial operations.

(3) Hot-rolled coil futures can also serve as cross-commodity hedging tools for other related commodity enterprises

The price of hot-rolled coil shows a significant correlation with medium-thick plate, cold-rolled coil, strip steel, ship plate, automotive plate, and other related commodities due to their consistent cost structures. Hence, hot-rolled coil futures can serve as a hedge for these associated products, enabling the creation of cross-commodity hedging strategies. This provides risk management for industries like machinery, automobiles, and shipbuilding, which holds immense importance for the high-quality and stable advancement of China's manufacturing sector.

(4) Both the government and society are promoting the adoption of futures to assist in risk management within the real economy

During his speech commemorating the 30th anniversary of Pudong's development and opening, General Secretary Xi Jinping of the Communist Party of China (CPC) Central Committee emphasized the importance of boosting the impact of prices of essential bulk commodities to effectively support and guide the progress of the real economy. On November 22, 2021, the General Office of the State Council released a notice regarding the enhancement of relief and support for small and medium enterprises (SMEs). The notice emphasized the importance of futures companies offering risk management services to SMEs. This support aims to assist them in utilizing futures hedging tools to mitigate the impact of significant fluctuations in raw material prices and alleviate the cost pressures they face. The *Futures and Derivatives Law of the People's Republic of China*, effective from April 20, 2022, focuses on the core concept of futures services supporting the real economy. It has implemented appropriate institutional measures to facilitate the operation of the futures market.

1.1.3 Pain points of real enterprises in China's bulk commodity industry chain in hedging

While many enterprises are actively hedging underlying assets through the futures market, most lack sophistication in their hedging strategies. This is evident in the following aspects:

(1) There is a need for further enrichment in the hedging strategies for varieties in the industrial supply chain and associated varieties

Currently, most hedging strategies are concentrated on single-commodity hedging and lack comprehensive risk management that considers the interplay between different commodities along the industry chain. This study aims to develop an advanced hedging model for varieties within the industrial supply chain and related varieties. In this model, steel companies strategically engage in futures trading by purchasing or selling coke/coke and iron ore in specific proportions. Simultaneously, they engage in selling or buying hot-rolled coils to hedge production profits effectively. Additionally, they use hot coil futures to hedge against related varieties such as medium and thick plates, cold-rolled coils, strip steel, ship plates, and automobile plates. This innovative approach aligns closely with the risk management requirements of a wider range of companies, thereby enhancing strategic decision-making options for businesses.

(2) The ability to strategize timing selection needs further improvement

Currently, most hedging strategies establish execution thresholds mechanically without fully contemplating macro, meso, and micro perspectives. This approach can result in substantial drawdowns and a limited capacity for strategic timing. This study aims to assist companies in constructing a hedging model capable of selecting the appropriate timing, seizing opportunities, and harnessing momentum.

(3) Risk control capability needs further improvement

Hedging strategies must also establish a stringent risk control system; without a scientific approach to hedging, significant risk exposure can still affect the enterprise. Hedging risk incidents such as the Tsingshan Nickel incident, the Yuanyoubao incident, the China National Aviation Fuel Group incident, and the Zhuzhou Smelter Group incident still occur from time to time. The strategy outlined in the thesis aims to efficiently mitigate potential liquidity risks, position risks, delivery risks, and other such risks that may arise during hedging activities.

1.1.4 Futures market growth facilitating production chain replication

As our country's futures market advances and a wider range of futures options become available, the upstream raw materials needed for producing certain products are now included in the futures market. This inclusion allows for the replication of the production chain for these products through the use of the futures market. For instance, in the scenario of rebar and hot-rolled coil products that necessitate coke and iron ore for production—both currently listed on the futures market—it becomes feasible to mirror the production chain of rebar (or hot-rolled coils) by combining coke, iron ore, and rebar (or hot-rolled coils). There is another example. Live pigs play a pivotal role in influencing our country's Consumer Price Index (CPI). Their upstream essentials, including pig feed like soybean meal and corn, are already listed on the futures market. Similarly, the production chain of live pigs can be mirrored by utilizing soybean meal, corn, and live pigs in sequence.

Leveraging the futures market to replicate the production chain can help businesses better monitor the overall profits generated by their manufactured goods, surpassing mere dependence on product pricing. This will effectively address the limitation of traditional hedging, which typically fixes the price of a single product without considering that manufacturers' profits are influenced by the overall impact of multiple product prices. However, the superiority of futures replication in production profitability over traditional hedging remains a subject open for academic deliberation.

1.2 Research objectives

Traditional hedging strategies usually center around a single product, commonly involving companies hedging against the price of their end products or essential production materials. For businesses, high end product prices do not necessarily guarantee profitability. For example, despite downstream real enterprises implementing price increases on end products due to the rise in bulk commodity prices, a situation persists where product prices have risen while profits have declined. The reason is attributed to the surge in costs at the cost end, which is consuming the profit margin at the product end.

Therefore, for real enterprises, traditional hedging strategies are no longer sufficient to address the production and management requirements of physical enterprises. There is a need to develop hedging strategies aligning with the significant changes in both domestic and international markets. With the ongoing diversification of products in our country's futures market, enterprises can now replicate the products across the upstream and downstream industry chains associated with the production of end products by utilizing a combination of underlying assets in the futures market. For example, live pig producers can utilize corn futures, soybean meal futures, and live pig futures to simulate the end profits in the live pig industry chain. Additionally, hot-rolled coil manufacturers can replicate profits throughout the hot-rolled coil industry chain by using futures in coke, iron ore, and hot-rolled coils.

Considering the limitations of traditional hedging methods and the evolution of profit-oriented hedging enabled by the futures market growth, the thesis aims to investigate whether a hedging strategy based on industry chain profits can better assist manufacturers in organizing their production to enhance price risk management.

The futures market in our country offers a wide array of products, making it impractical to individually verify the profitability of every interconnected industry chain product. Hence, the thesis focuses on the hot-rolled coil industry to investigate whether a hedging strategy based on the profits of the hot-rolled coil futures industry chain can provide better support for real enterprises.

1.3 Research questions

Drawing from the research background outlined above, I found that most companies continue to engage in hedging operations centered on single commodities. Academic research on hedging tends to concentrate on single-commodity hedging. While some studies have explored multi-commodity hedging, these analyses primarily rely on the correlation between futures products, rather than considering the upstream and downstream relationships in production. Therefore, the thesis introduces the concept of profit hedging based on the industry chain and presents it as a pricing management tool. However, the aforementioned discussion is derived from my practical experience and peer exchanges. Is the industry chain profit hedging superior to traditional hedging? How can a company leverage profits from the futures industry chain to manage its production arrangements? To answer the two questions, the thesis examines the hot-rolled coil industry chain and raises three academic questions:

1) Can hot-rolled coil real enterprises utilize fluctuations in futures industry chain profits for hedging purposes?

2) Is profit hedging based on the hot-rolled coil futures industry chain superior to the traditional single-commodity hedging strategy?

3) How can hot-rolled coil real enterprises appropriately handle price risk when utilizing futures to hedge profits in the hot-rolled coil industry chain?

1.4 Research significance

This study exhibits the following significance.

1.4.1 It can contribute to advancing the high-quality development of the bulk commodity industry chain, assisting upstream and downstream enterprises in maintaining supply and price stability

The bulk commodity industry experiences substantial and swift transformations, rife with uncertainties that can originate from the industry or even within individual enterprises. Confronted with uncertainties in production and operations, real enterprises require a certain level of stability to achieve consistent growth. Therefore, establishing a suitable hedging model using the futures market holds great importance for real enterprises. The traditional single-commodity hedging model can meet the basic needs of real enterprises, that is, to buy raw materials at low prices and sell products at high prices. However, single-commodity hedging has certain limitations. In most cases, prices of products within the same industry chain in the futures market tend to move in the same direction. This implies that production-oriented enterprises may encounter scenarios where they make a profit on products but incur losses on raw materials during actual futures market operations. To tackle this challenge, production-oriented enterprises can consider utilizing hedging strategies that involve varieties and related products within the industrial supply chain. This model can be applied flexibly for hedging by leveraging the connections of numerous varieties within the industry chain. It facilitates the analysis of the strengths and weaknesses of various products. When combined with production insights, it safeguards both end products and raw materials, leading to improved risk mitigation and profit protection compared to single-commodity hedging. At present, most manufacturing firms are in the initial phases of implementing hedging practices. Helping establish suitable cross-commodity hedging models for production protection holds great importance for production-oriented enterprises. The thesis will create a cross-commodity hedging model that focuses on timing, opportunity selection, and momentum, presenting innovative insights for corporate hedging strategies.

1.4.2 It is of great significance for the steady and rapid development of the national economy and for competing for international pricing power

Since the initiation of supply-side reforms in the steel industry in 2016, the general price trajectory of steel has transformed from weak to robust, bolstered by the increased utilization of steel in real estate infrastructure. This has notably sparked a significant recovery in the price of construction steel. However, since the second half of 2018, the backing for the reform has somewhat dwindled, leading to a reduced demand for real estate due to policy shifts and economic decline. Consequently, the elevated cost of construction steel has introduced a progressively potent risk factor. As a result, certain production enterprises observed a decline in the marginal benefits of using structural steel and pivoted towards the rolled coil industry which caters to consumer-oriented enterprises. Due to their higher technological sophistication, rolled coil products are priced higher compared to construction steel. From a market standpoint, products associated with rolled coils are essential in manufacturing endeavors spanning from vast projects such as shipbuilding to the creation of smaller household items like air conditioners. At the same time, there exists a wide-ranging international market for rolled coils. Although infrastructure and residential construction in developed nations have peaked, consumer demand persists. Rolled coil production standards are fairly consistent worldwide, unlike rebars that can vary from one country to another. Therefore, the export market for rolled coils holds great potential. From a national perspective, the “going global” strategy was proposed during the Third Session of the Ninth National People’s Congress (NPC), later establishing itself as one of the four new strategies at the Fifth Plenary Session of the 15th CPC Central Committee. Since the listing of hot-rolled coil futures in March 2014, its trading activity has been somewhat weaker compared to rebar. Nonetheless, due to heightened interest from hot rolling-related enterprises and speculators, trading activity has notably improved in recent years. Given the cyclical patterns of bulk commodities such as steel, sectors linked to hot-rolled products have promising prospects, yet their prices carry underlying risks. Therefore, the utilization of hot-rolled futures for hedging products has emerged as a growing concern for enterprises involved in hot-rolled products.

At present, there is a scarcity of research on hedging hot-rolled coils and associated products in China, while foreign exchanges lack suitable futures to guide hot-rolled product hedging. Therefore, the hot-rolled futures offered by SHFE exhibit significant potential. By effectively leveraging hot-rolled futures, Chinese enterprises in this sector can not only shield product prices but also enhance the competitiveness of their products in both domestic and international markets. Through a multiplier effect, they can expand their influence across broader domains, merging with China's manufacturing industry. This strategic approach aids China in securing the pricing power for hot rolling-related products, establishing itself as a pivotal hub in the global steel trade.

1.4.3 The hedging strategy for industrial supply chain products and their derivatives can also be expanded to industry chains like live pig breeding and polyester processing

Steel production, live pig breeding, and polyester processing represent productive sectors where both raw materials and finished products are underpinned by futures contracts within their industry chains. Thus, the hedging model outlined in this study can be effectively applied to the aforementioned industries with a high degree of strategic extension. For production-oriented enterprises, the key areas of management lie in controlling costs at the raw material stage and mitigating risks during production and sales processes. Apart from relatively stable labor and machinery costs, the most fluctuating expense in cost management is the cost of raw materials. Production-oriented enterprises used to manage raw material costs through long-term agreements with suppliers and blending spot market acquisitions under prevailing market conditions. However, the current fluctuation in raw material prices in the futures market provides production-focused enterprises with additional alternatives, particularly in terms of single-commodity hedging strategies as noted before. Likewise, in the production and sales end, production-oriented companies typically engage in long-term contracts with downstream traders to align production with guaranteed sales, thereby reducing sales-related risks. Now, companies also engage in selling on the futures market when there is a premium on their product's futures, thus securing profits and broadening their sales scope. However, in actual operation, while production-oriented enterprises might efficiently address a specific aspect at a given moment, the interconnected nature of industry chains often prevents them from managing multiple facets well concurrently. Therefore, it is of great significance for production-oriented enterprises to synchronize cost management strategies at the raw material end with risk management tactics at the production and sales phases. This coordination, with a full view of the industry chain, can lead to the development of a cross-commodity hedging model.

1.4.4 Risk hedging events arise periodically, and this study is instrumental in circumventing strategic risks

Due to influences like the intensifying conflict between Russia and Ukraine, nickel exports from Russia face limitations. On March 7, 2022, the LME Nickel 03 futures contract experienced a sharp increase, peaking at 55,000 US dollars and closing at an elevated level of 50,300 US dollars, surging by 73% in a single day to reach an all-time high. The upward trend continued on March 8, as the price of the LME Nickel 03 futures contract soared beyond 100,000 US dollars. On the afternoon of March 8, LME announced to suspend all nickel trading and annul transactions post-March 8 UK time and delay March 9 spot nickel deliveries. The "Tsingshan Nickel" incident is a risk event caused by improper hedging of non-standard products. Events such as the Yuanyoubao incident, the China National Aviation Fuel Group incident, and the Zhuzhou Smelter Group incident still occur from time to time. The thesis aims to explore the risk management within hedging strategies to effectively mitigate potential liquidity, position, and delivery risks that could arise during hedging activities.

1.4.5 Applied research on the futures market contributes to enhancing its functional efficacy

Traditional production-oriented enterprises often utilize direct transactions or listings for procuring raw materials and selling products, with pricing largely governed by the trade supply and demand dynamics. Nevertheless, these enterprises are inevitably subject to passive or delayed pricing control due to factors like informational asymmetry. This is primarily because the sources of raw materials are overseas, and China's territory is vast. As a result, leveraging the futures market to revamp and resolve the prevalent challenges and concerns of traditional production-oriented enterprises is important.

First, the futures market offers greater transactional transparency compared to traditional trading. Every trade is conducted on a platform that ensures openness, fairness, and impartiality, thereby circumventing potential fraudulent or monopolistic activities inherent in traditional trading. Second, the futures market boasts a substantial number of participants, encompassing enterprises and speculators. These players bolster market liquidity, alleviating a key constraint in traditional trading. Consequently, price formation in this arena is now characterized by enhanced timeliness, as opposed to the passive and delayed processes of the past. Third, traditional trading is confined by real-time supply and demand dynamics. When companies are positive or negative about future market trends, their tactical options are restricted to hoarding or over-distributing products. In contrast, the nature of forward contracts in the futures market allows market expectations to be expressed in monetary terms through trades. Thus, production-oriented enterprises are empowered to secure favorable pricing directly via the futures market. Finally, considering the aforementioned advantages of the futures market, it is reasonable to view the price of futures contracts as a widely acknowledged and authoritative benchmark. The price can serve as a crucial reference for both production and sales within production-oriented enterprises, and as a tool to secure production profits. Therefore, exploring how production-oriented enterprises utilize futures markets holds great significance for them.

2 Literature Review

2.1 Literature review

Hedging arises from the necessity of individuals at a micro level to mitigate price risks (Zhang Y., Fang, Y., and Huang, K., 2006). It involves trading operations that leverage the futures market for transferring price risks, utilizing futures contracts as interim alternatives for commodities to be exchanged in the prospective spot market, and safeguarding the prices of upcoming commodity purchases(Li, X., 2021). Hedging, an essential function of the futures market meant to facilitate the growth of real enterprises in China, has been thoroughly researched by scholars worldwide. The thesis will sort out the current research findings and conduct a comprehensive review.

2.1.1 Research on hedging model and industry chain hedging

In Xu, H.'s (2021) paper on *Designing Cross-commodity Hedging Strategies for Iron and Steel Enterprises*, a comprehensive set of strategies was developed, including the innovative "virtual steel mill + long-term fixed-price order" scheme. Four econometric analysis methods—OLS, B-VAR, ECM, and GARCH—were used to estimate static and dynamic hedge ratios for rebar, iron ore, and coke. The selection of the optimal hedge ratio focused on mitigating risks. Transaction timing, quantities, and steps were carefully determined by considering industry chain dynamics and historical data. Ultimately, a backtracking test was conducted to analyze the results and effectiveness of the prescribed strategy. Xu's study sheds light on two key points: First, it is effective to employ the cross-commodity hedging approach combining the "virtual steel mill" concept with long-term fixed-price orders in the iron and steel sector. This strategy not only aids in mitigating the risks associated with spot price fluctuations but also enhances the overall profitability of rebar products. Second, within the selected period, the optimal hedge ratio calculated using the OLS-ECM model demonstrated superior risk mitigation benefits in comparison to other models. The hedge ratio for rebar stood at 0.35, while for iron ore, it was 0.53. Furthermore, the regression outcomes for coke varieties from all models examined in the study were suboptimal. Consequently, the research concludes that coke futures may not be an effective hedge against the risks associated with the coke spot market.

Third, the study suggests that the optimal timing to initiate cross-hedging positions is when the spot gross profit reaches RMB 440 per ton.

In Zhang, L.'s (2018) paper, *Research on Cross-commodity Futures Arbitrage of 'Virtual Steel Mills' in China*, a detailed analysis of the price relationship among rebar, iron ore, and coke was conducted by examining the production inputs of actual steel mills and utilizing mathematical statistical analysis methods. Additionally, Zhang identified the profit margin for cross-commodity futures arbitrage, setting operational upper and lower limits with a 90% margin of safety. When the price spread exceeds the upper limit, it signals a profitable opportunity for shorting the steel mill. In such instances, one can engage in selling rebar futures and purchasing iron ore and coke futures until the spread normalizes, subsequently using hedging techniques to close the positions. If the price spread contracts below the lower limit, investors are advised to purchase rebar futures while offloading iron ore and coke contracts. It is prudent to await the price spread's recovery to a rational level before employing suitable strategies to individually liquidate the positions, at which point they can obtain considerable profits and exit the market. Drawing on theoretical insights, econometric analysis, and industry expertise, the researcher devised a "virtual steel mill" arbitrage model, which underwent backtesting validation utilizing pertinent industrial data from 2016. The test results demonstrate that the "virtual steel mill" model exhibits a lower drawdown rate and superior profit performance. Additionally, the study introduces a fundamental analysis method for single commodity spot trading, providing a secure basis for entering into futures arbitrage positions.

In the study titled *Research on Hedging in the Steel Futures Industry Chain - An Analysis of Price Linkages among Combined Varieties*, Su, P. (2017) examined the correlation coefficients between different prices based on the varieties and their production relationships within the industry. Building upon hedging theory and Copula connection functions, the research evaluated the correlation coefficients between futures and spot varieties. Taking into account the time-varying and volatility clustering characteristics of financial time series, the study utilized a GARCH model to process the time series of returns. Moreover, by applying the VaR minimum variance theory, the dynamic hedging ratio of a single commodity was determined. Moreover, Su established a hedging research framework within the steel futures industry chain, integrating spot varieties and four futures portfolios. Su's study explored the correlation among various futures varieties, elucidated principles like hedging risk aggregation and return rates of multi-variety portfolio futures in detail, and employed multiple GARCH-BEKK models to dynamically assess the covariance of return rates. The research demonstrates that implementing comprehensive hedging across portfolio varieties achieves price risk diversification and significantly enhances futures hedging income.

From the existing research on hedging, it is evident that most studies are confined to analyzing single commodities. They primarily rely on the correlation between spot and futures prices to develop hedging strategies. While some studies have crafted futures portfolios for hedging purposes, these portfolios tend to be mechanistic and lack integration into a more cohesive and purposeful futures portfolio.

2.1.2 Research on hot-rolled coil futures

China is the world's largest producer, consumer, and exporter of hot-rolled coils. The enterprises engaging hot-rolled coils in China exhibit a significant need for hedging and risk hedging. Additionally, in contrast to long products, hot-rolled coils have a higher degree of internationalization as a steel variety. The introduction of hot-rolled coil futures can align with hot-rolled coil spot markets, bolstering pricing capabilities, and elevating the global influence of China's hot-rolled coil production enterprises. At present, the research on hot-rolled coil futures lags behind that of rebar futures. Nonetheless, the existing literature has made significant contributions to this field of study.

In Cao, W.'s (2019) *Empirical Analysis of Factors Affecting the Futures Price of Hot-Rolled Coils*, an empirical study was carried out on hot-rolled coil futures, focusing on cost factors and supply and demand factors. Cao applied the Granger causality test to illustrate the strong connection between futures and spot prices of the hot-rolled coil. Furthermore, a stepwise regression model was employed to illustrate the direction and extent of various factors influencing the futures prices of hot-rolled coils. The analysis particularly highlighted the close connection between the futures prices of hot-rolled coils and the prices of raw material futures within their associated industry chain, notably focusing on the price of iron ore futures.

In the study titled *Research on the Dynamic Relationship Between Hot-Rolled Coil Futures Prices and Spot Prices in China*, Cui, C.(2015) emphasized the crucial role of hot-rolled coil futures in the financialization process of China's steel industry. Additionally, Cui delved into the equilibrium and cointegration relationships between futures and spot prices for hot-rolled coils, while also suggesting a guiding relationship between the two. The Vector Autoregression (VAR) model was applied to depict the fluctuations in two prices, while the Johansen cointegration test was employed to examine the VAR model. The analysis revealed the existence of an equilibrium relationship between the futures price and the spot price of hot-rolled coils. Upon conducting the Granger causality test to scrutinize the VAR model, it was discovered that a bidirectional guiding relationship exists between the futures price and the spot price of hot-rolled coils, with the futures price exerting a stronger guiding influence. The findings from the impulse response method indicate that initially, the impact of futures price and spot price on the hot-rolled coil is minor. However, this effect gradually amplifies over time before stabilizing.

Wang, M. (2018) studied rebar futures and hot-rolled coil futures in the paper *Study on Price Fluctuations and Influencing Factors of Steel Futures in China*. Wang, M. began by exploring the theory behind the formation of steel futures prices, including supply and demand theory, basis difference theory, and cost-of-carry theory. She outlined the formation mechanism of steel futures prices. Furthermore, she categorized the potential influencing factors of futures prices into macroeconomic factors, market supply and demand factors, cost components, and other factors. Based on this classification, she further divided these factors into long-term, medium-term, and short-term categories for empirical analysis. Research shows that in the medium term, industrial value-added has the most significant impact on the prices of hot-rolled coil futures. In the short term, the cost-plus index exerts the most notable influence on hot-rolled coil futures prices. In the long term, it is crucial to pay attention to factors such as the Purchasing Managers' Index (PMI), import iron ore prices, and policy implications.

Wu, P. (2018) emphasized the significant impact of price fluctuations in bulk commodities on national economic security and corporate operations in *Convenience Yield Analysis and Spot-Futures Arbitrage: An Empirical Test Based on Hot-Rolled Coil.* The thesis used the convenience yield as a special variable in commodity futures pricing, comparing the added value spot goods retain over futures with the risks in price fluctuations. This approach led to a more profound comprehension of the price correlation between hot-rolled coil futures and spot goods. Besides, the thesis selected three factors—inventory, marginal costs in actual transactions, and the volatility of spot prices—to conduct regression analysis. It adopted the ARMA (p,q) model to describe the trend of convenience yields and used the GARCH model to model and analyze the volatility of hot-rolled coil futures, thereby reflecting the risk mitigation role that the interaction between hot-rolled coil spot and futures plays in corporate production and management.

Zhang, Y. (2014) in *Research on Risk Management of Raw Material Hedging Projects for Hot-rolled Coils for China-Myanmar Pipelines* emphasized that iron ore, as the raw material for hot-rolled coils, significantly impacts hot-rolled coil futures. The thesis studied the characteristics and extent of the impact of iron ore futures on hot-rolled coil futures. Based on the industrial chain relationship and degree of association, the author proposed to hedge against the production costs of hot-rolled coils using iron ore futures. Additionally, the thesis clarified the differences between hot-rolled coil futures and hot-rolled coil spot goods, including that the prices are not always in sync. It provided risk management measures corresponding to these differences.

Chen, Li, and Yu (2021) introduced methods for steel companies to gauge hedging strategies through the directional fluctuations of steel futures prices, highlighting the importance of examining the influencing factors. They created a GARCH econometric model for empirical analysis. However, their focus was not on the impact of iron ore prices on hot-rolled coil futures as mentioned by researchers in previous literature, but rather on the influence of the transaction volume of hot-rolled coil futures, the amount of capital involved, and the cost of capital on hot-rolled coil price volatility. They concluded that the price volatility persistence for hot-rolled coil futures driven by individual events is not significant.

Li, Y. (2017) used BASIS and Value at Risk (VaR) to measure the risk of hedging steel futures in his paper titled *Research on the Nonlinear Characteristics and Hedging Strategy of China's Steel Futures Market*. Combined with publicly available market data, the thesis defined the calculation methods for risk premium and relative risk premium. The thesis highlighted that traders in hot-rolled coil futures within the steel futures market exhibit the highest level of risk aversion. Furthermore, the study compared optimal hedging ratios for steel futures, analyzing speculative and pure hedging demands. It discovered that the speculative sentiment surrounding hot-rolled coil futures surpasses that of other steel futures products. The thesis introduced an LPM-based GARCH model, with empirical testing validating the aforementioned conclusions.

Based on the literature mentioned above, hot-rolled coil futures, introduced to the market in 2014, have garnered rich research results. However, existing studies predominantly focus on factors influencing hot-rolled coil futures prices, the correlation between hot-rolled coil futures and spot goods prices, and hedging involving hot-rolled coil futures. Limited research exists on the cross-commodities related to the hot-rolled coil industry chain, with only discussions on hedging. Compared to rebar futures, research on hot-rolled coil futures remains relatively scarce, leading to the lack of empirical tests and comprehensive, multi-dimensional analyses. Particularly, there is limited research on integrating rebar and hot-rolled coil industry chains. This gap is addressed in this study. Furthermore, there is a notable absence of studies analyzing the hedging benefits of hot-rolled coil futures for hot-rolled processed products. However, in the spot market, a significant need for hedging exists in terms of hot-rolled processed products. Therefore, addressing this research gap in the context of hot-rolled coil futures is a pressing concern.

2.1.3 Research on commodity correlation hedging

Currently, there are close to 70 futures types listed on different futures exchanges in China, encompassing the primary categories of bulk commodities in the country and including some index futures. This breadth of offerings to some extent fills the gaps in the country’s financial market. Futures contracts chosen and formulated by exchanges typically represent significant portions of various industrial sectors in the country. Nonetheless, the goods utilized or traded by enterprises in practical production activities may not always align perfectly with the futures contracts available in the market, while these enterprises exhibit substantial demand for hedging. As a result, research on cross-hedging or hedging with substitute commodities has consistently been a key focal point in the hedging domain.

In 2013, Chinese iron ore futures were introduced on the DCE. Prior to this launch, Chinese traders engaged in iron ore trading were limited to the options of the Singapore Exchange’s iron ore swaps or the Indian Commodity Exchange’s iron ore futures for hedging purposes. As highlighted by Han and Mao in *An Exploration on Cross Hedging Method of Chinese Steel Enterprises for Spot Iron Ore and Enlightenments*, the trading volume of these two contracts was insufficient to facilitate extensive hedging activities. Consequently, a considerable number of domestic iron ore buyers turned to rebar futures listed on the SHFE to hedge their transactions. The study utilized efficiency tests and correlation analyses to empirically investigate the price linkage between rebar futures and iron ore spot prices, validating the viability of hedging with these substitute commodities. Regression analysis was employed to confirm the association between factors impacting rebar futures prices and iron ore spot prices.

Besides cross-hedging in black commodity futures, oils within the agricultural product sector are also significant candidates for cross-hedging strategies. In their study titled *Research on Edible Oil Hedging Substitution*, Yan, X.,et al highlighted the absence of futures types for corn oil, sunflower seed oil, and peanut oil in current Chinese futures exchanges, which hinders direct hedging opportunities. The study utilized software to conduct correlation analyses between spot prices and futures prices of various types. Both Pearson and Spearman correlation coefficients in their research findings revealed that edible oils lacking direct futures types could utilize soybean oil futures for hedging activities during relevant months. Their study indicated a strong price correlation between soybean oil futures and these edible oils, and opting for soybean oil for hedging endeavors was shown to facilitate enhanced risk mitigation against spot prices compared to other alternatives.

Non-ferrous metals represent a significant aspect of futures contracts, yet there are spot commodities that do not align with listed futures contracts. For example, in their study titled *Examining the Use of Copper Futures for Hedging in lieu of Lead*, Guo, W. and Liu, Y. proposed that lead, a primary material in the lead-acid battery industry, lacks a futures type for direct hedging. Large lead-acid battery manufacturers require thousands of tons of lead monthly, and given lead's substantial price volatility, hedging becomes imperative for these firms. While the London Metal Exchange (LME) offers lead futures, Chinese enterprises encounter challenges due to foreign exchange regulations when transferring funds overseas, and pricing deviations exist. Consequently, I proposed cross-hedging with other non-ferrous metals within the country. Data review suggested that copper, aluminum, lead, zinc, and tin generally exhibit similar trends in major cycles. The thesis employed a multiple regression model to support this observation. Nonetheless, the thesis stressed the necessity of managing alternative hedging by controlling position size strictly and opting for far-month contracts to mitigate risks associated with abrupt shifts in near-month market conditions and delivery concerns.

In China, steel mills are categorized into long-process and short-process steel mills. Short-process steel mills utilize electric furnaces and rely heavily on scrap steel that is subject to significant price fluctuations for production. The SHFE is gearing up to introduce corresponding futures contracts. In advance of this development, the steel material team at *Capital Futures highlighted in their publication Utilizing Steel Futures for Hedging in the Scrap Steel Market* that rebar futures could serve as a hedge for scrap steel. The study tested the hedging ratios of the two using the ordinary least squares (OLS) method and the error correction method, and it showed that the appropriate futures type and contract month should be selected based on the market conditions at the time of hedging actions to achieve better hedging effects.

Xu, C. (2022) highlighted in the study of *An Examination of Hedging Strategies Using Commodity Substitution* that achieving a 100% correlation between spot and futures markets is unattainable due to disparities in supply-demand dynamics and price expectations, leading to inevitable basis risk in any hedging endeavor. The study advised against rigid hedging when selecting futures contracts, even in the presence of directly corresponding futures types, recommending instead an approach incorporating market conditions and trends to inform decision-making. The thesis classified substitutions—based on both commodity and financial attributes—into three categories: positively correlated, uncorrelated, and negatively correlated. A positive correlation indicates a similarity between financial and commodity attributes, allowing for substitution when supply-demand conditions shift. Uncorrelation indicates items of different classifications, typically chosen for short-term conditions when a macro impact exists. Negative correlation denotes instances where commodity and financial attributes diverge entirely, often serving as hedging options when macro and fundamental influences conflict. Moreover, the thesis stressed the attention to the hedge ratio and near-month delivery when opting for substitution in hedging practices, underscoring the importance of maintaining hedge persistence.

Futures boast a long historical presence in global markets, with the practice of hedging through substitute commodities being a recurrent strategy among bulk commodity producers and traders. Lim and Peter (2016) delved into the efficacy of hedge strategies for aviation fuel using heating oil, Brent crude oil, WTI, and diesel as substitutes in the study titled *Airline Fuel Hedging: Do Hedge Horizon and Contract Maturity Matter?* The study argued that utilizing these four futures contracts for aviation fuel hedging yields positive results in most cases, with heating oil identified as the optimal substitute. However, the volatile nature of petroleum commodities introduces substantial risks for airlines, underscoring the necessity of considering impacts potentially brought by hedging and contract duration, along with monitoring the trends in spot prices, when engaging in hedging activities.

Hao (2019) used the Elman Neural Network model to construct a hedging model for the Chinese soybean market. This model proved that within an appropriate price cycle, choosing futures contracts of the same type from different countries for hedging spot transactions was equally effective. Sometimes, compared to direct hedging, selecting overseas contracts for international type hedging can yield greater hedging profits. However, it is also necessary to pay attention to the fundamental trends of both contracts, properly allocate proportions, and be mindful of exchange rate fluctuations.

Zhao and Barry (2012) employed Copula models to discuss the use of corn futures contracts to cross hedge grain sorghum and the use of Kansas wheat futures contracts to cross hedge barley. The rationale for selecting these substitute commodities stems from the interchangeable demand characteristics between corn and sorghum, as well as between wheat and barley in their respective spot markets. Notably, sorghum and barley lack direct futures contracts for hedging. The study emphasized a significant correlation among these commodities, establishing a robust risk management framework to mitigate price risk. However, it explicitly acknowledged the inevitability of hedging losses attributable to disparities in commodities.

The above literature review elucidates that cross-hedging with substitute commodities is a prevalent practice in bulk commodity hedging, underpinned by a robust theoretical framework. By analyzing spot and futures prices, grasping the fundamental knowledge of bulk commodities, and acknowledging macro conditions, researchers can discern cyclical patterns in price trends and disparities among substitute commodities, enabling the development of effective hedging strategies for substitute commodities. It is vital to consider delivery risks and extreme market conditions possibly faced by these substitute commodities. I noted the existence of a substantial body of research on hedging using substitute commodities of agricultural products. For instance, Hayenga and DiPietre (1982) explored the benefits of live pig futures for hedging pork products in the previous century. Nevertheless, there is a dearth of research on hedge substitutes in black commodity futures, particularly in China, which indicates a crucial area worthy of further research.

2.1.4 Research on empirical methods

Research on Cournot models is extensive. Wang, R. (2009) used China's electric power industry as a case study to examine the influence of electricity options on the equilibrium of the electricity market and the competitive strategies of power plants in an oligopolistic electricity market setting. The study developed a two-stage Cournot model that incorporated power plants engaging in strategic physical call option trading and investigated the effects of strategic physical call option trading on the competitive behaviors of power plants in the spot market. The study validated the model's rationale and algorithm efficiency through a duopolistic example. Additionally, it analyzed the impact of factors like option strike price, load volatility, and production costs on power plants' strategies for physical call option trading. Xing, W. et al. (2016) utilized China's construction machinery manufacturing sector as a study case, opting for a duopoly manufacturer Cournot model incorporating dual sourcing. They formulated three competition structures predicated on the risk management strategies (spot trading strategy and hedging strategy) chosen by the two manufacturers. The research revealed that the magnitude of end-market demand profoundly influences the competition structure. In instances of asymmetric competition, low forward contract prices do not invariably prompt both manufacturers to adopt forward contracts for raw material procurement. Zhang, H. and Yin, X.(2020) examined China's soybean industry chain to investigate the quantity competition equilibrium between upstream and downstream enterprises within the soybean industry chain under an oligopolistic market structure. The study indicated that by focusing solely on the partial equilibrium of the edible soybean market, tariffs could potentially result in a scenario where the imported soybean price is lower than that of domestic soybeans. The soybean market is intricately linked to the soybean oil market, with the equilibrium in the soybean oil market playing a role in determining the demand for soybeans utilized in oil extraction. Compared to free trade, as oligopoly equilibrium is established in both upstream and downstream markets, the imposition of increased import tariffs on upstream products leads to a more pronounced decline in profits for downstream firms. Yan, J. (2022) developed a duopoly dynamic game model based on consumer surplus within the realm of corporate social responsibility. The study delved into the presence and stability criteria of equilibrium points and, through numerical simulations, concluded that companies benefiting from suitable consumer surplus parameters are better positioned for long-term growth in the market. Zhou, X. et al. (2022) devised a game model focusing on a closed-loop supply chain with one manufacturer and two rival retailers. Their research delved into decision-making processes and contract selection matters within the supply chain, considering government remanufacturing subsidies. Findings revealed that the competitive dynamics between retailers contribute to elevated optimal retail prices, decreased rates for recovering used products, and diminished maximum profits for the supply chain.

Hedging is a crucial topic in domestic and international derivatives hedging research, with numerous scholars dedicating substantial efforts to exploring this domain. The existing literature predominantly reflects two primary approaches in model selection and hypothesis testing for hedging strategies. The first approach involves leveraging diverse statistical regression models to extract parameters from historical data, which subsequently determine future hedging methods. The alternative approach considers the industry chain, establishing a price model grounded in the cost-profit relationship within the supply chain, and subsequently employing pertinent statistical methodologies for hypothesis testing.

Peng, H. and Ye, Y.(2007) employed a modified ECM-GARCH model to ascertain the hedging ratio of copper futures, contrasting its result with that of the ECM-GARCH and B-GARCH models. The study revealed that, within China's futures market, the modified ECM-GARCH model exhibited superior hedging capabilities. Tong, M.(2011) also utilized the modified ECM-GARCH model to assess the hedging concerning the CSI 300 futures. Compared to the GARCH model, the conventional OLS model has gained favor among scholars due to its simple idea and practicality. For instance, Jing, T. and Yang, J. (2022) computed the dynamic hedging ratio of the CSI 300 futures using the OLS model. Likewise, Liu, X. et al. (2022) adopted this method to analyze hedging and capacity expansion behaviors in agricultural products. Scholars such as Gao, W. and Zhao, J. (2007) similarly undertook research utilizing this method. While some researchers have compared the efficacy of various hedging models, their findings often differ. Liang, B. et al. (2009) explored the CSI 300 futures' hedging effectiveness using methods like OLS, VAR, and ECM models, discovering that dynamic hedging outperforms static hedging, albeit with insignificant advantages and disadvantages among these models. Additionally, Wang, J. et al (2005) compared OLS, ECM, B-VAR, and ECM-GARCH models, revealing that ECM and EC-GARCH models demonstrate superior hedging performance, a finding replicated in out-of-sample assessments.

Concerning the second method, some scholars have concentrated their research on the price volatility attributes of the underlying futures, investigating related studies from a variance perspective. Wu, C. et al (1998) undertook a comparative analysis between the minimum variance risk hedging and maximum utility hedging methods. Qi, M. (2004) explored a comparison between minimum variance hedging and traditional hedging approaches. Lin, X. (2004) expanded the minimum variance hedging method to include considerations of risk-benefit ratios. In addition to minimal risk hedging, an increasing number of scholars have started to investigate long-term equilibrium relationships among futures. Cointegration tests and error correction models (ECM) are the primary methods employed for analyzing these relationships. Initially proposed by Engle and Granger (1987), these models have evolved through the contributions of numerous scholars globally and domestically, emerging as a prevalent method in academic literature. Pan, C. and Zhao, H. (2004) extensively discussed the intercept and trend terms of this method using Eviews. Yuan, X. et al (2003) utilized cointegration tests to assess the cointegration relationship between futures and spot prices. Shi, J. et al (2006) delved into testing the stationarity and cointegration relationships of copper futures and spot data, comparing various hedging models. Wang, H. and Xie, Y. (2011) investigated the cointegration relationship between futures and spot data of five commodities in China—soybeans, cotton, copper, aluminum, and fuel oil—finding that cointegration relationships are generally established.

2.2 Discussion

After summarizing and organizing existing literature, I have identified the following drawbacks within the research domain of profit hedging in the futures industry chain:

First, regarding research subjects, current hedging research remains restricted to individual commodities, primarily focusing on the correlation between spot and futures when formulating hedging strategies. While some studies incorporate the utilization of futures product portfolios for hedging, these portfolios are often inflexible, relying solely on the correlation between futures products and disregarding the upstream and downstream interconnections in real-life production processes. Consequently, such studies fall short of constructing underlying futures portfolios that hold greater practical significance.

Second, concerning research methodologies, the Cournot model boasts a robust theoretical underpinning, featuring a well-established model framework with broad practical utility. Existing hedging investigations predominantly revolve around statistical regression models and spot-futures analyses, neglecting cross-commodity futures examinations, particularly the long-term equilibrium relationships among futures in the industrial chain. Furthermore, the research predominantly accentuates backtesting simulations, which inadequately capture the real hedging process, thus struggling to adequately showcase the merits of the hedging strategies.

Third, within the category of hot-rolled coils, listed as a product in 2014, hot-rolled coil futures have garnered a wealth of research outcomes. However, existing studies predominantly focus on factors influencing hot-rolled coil futures prices, the correlation between hot-rolled coil futures and spot goods prices, and hedging involving hot-rolled coil futures. Limited research exists on the cross-commodities related to the hot-rolled coil industry chain, with only discussions on hedging. Compared to rebar futures, research on hot-rolled coil futures remains relatively scarce, leading to the lack of empirical tests and comprehensive, multi-dimensional analyses. Particularly, there is limited research on integrating rebar and hot-rolled coil industry chains. This gap is addressed in this study. Furthermore, there is a notable absence of studies analyzing the hedging benefits of hot-rolled coil futures for hot-rolled processed products. However, in the spot market, a significant need for hedging exists in terms of hot-rolled processed products. Therefore, addressing this research gap in the context of hot-rolled coil futures is a pressing concern.

3 Research Framework

3.1 Research framework

Building upon the aforementioned research topics, the thesis has structured and formulated the following research framework

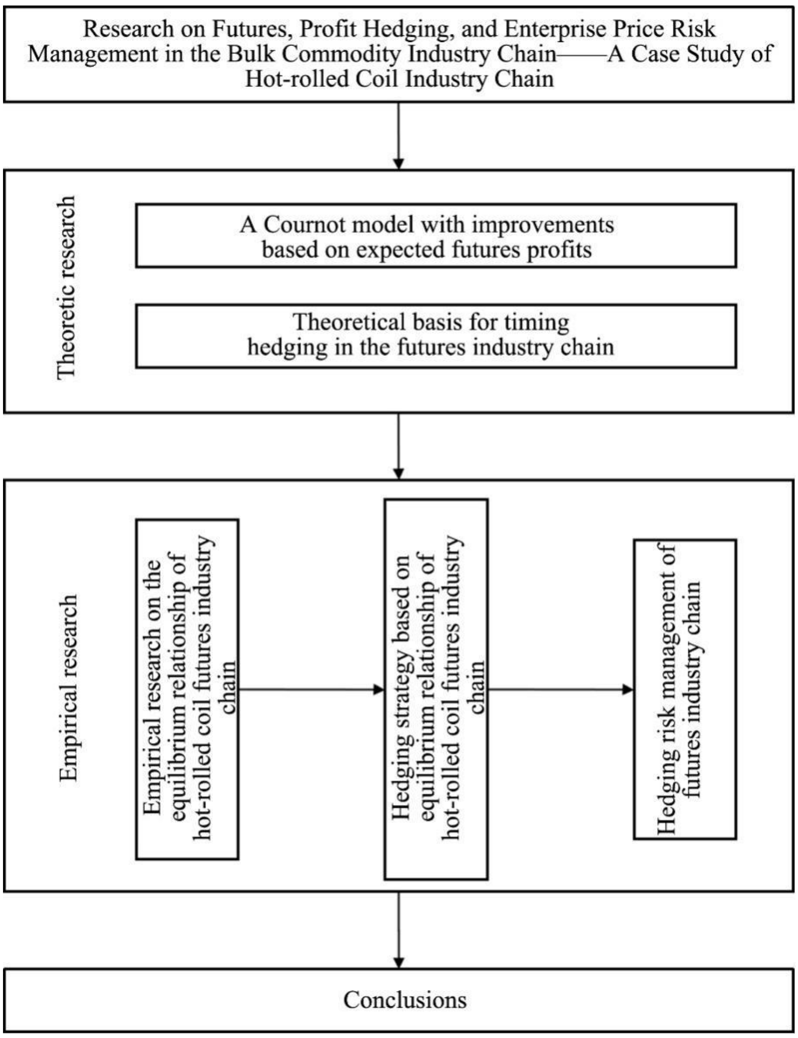

Figure 3.1 Technology roadmap

The research framework of the thesis traverse from theory to practical application.

First, the theoretical part established a Cournot model based on future price expectations to delineate that firms adjust their anticipations of forthcoming product prices and optimize their production decisions by monitoring futures price fluctuations. This part discussed the distinctions in firm behaviors across diverse belief systems. Then, the deductive method was used to provide the theoretical basis for market timing hedging within the supply chain of the futures industry.

Transitioning to the empirical part, the study first delved into real-world conditions. By utilizing actual futures trading data and employing a robust statistical regression method, it tested the equilibrium price formula for the hot-rolled coil industry chain futures supply chain. Subsequently, building on the formula, the thesis devised four distinct cross-commodity futures hedging strategies and conducted historical backtesting to evaluate the performance of these strategies. Lastly, by assessing the risks associated with these strategies, the thesis performed case analyses on historical phases with notable backtesting results to refine the potential risks entailed by these strategies, culminating in designing an effective risk mitigation framework.

3.2 Research methods

This section delineates the research methods of the thesis from two vantage points: theoretical research and empirical research.

3.2.1 Theoretical research methods

In the theoretical section, the thesis initially established a Cournot model based on future price expectations to delineate that firms adjust their anticipations of forthcoming product prices and optimize their production decisions by monitoring futures price fluctuations. This part discussed the distinctions in firm behaviors across diverse belief systems. Then, the deductive method was used to provide the theoretical basis for hedging for commodities within the industrial supply chain and related commodities. In other words, companies track alterations in the futures market and employ hedging to secure their production profits. When futures market profits surpass actual production profits substantially, companies are motivated to hedge a portion of the surplus profits via the futures market, prompting futures market prices to converge toward an equilibrium price.

3.2.2 Empirical research methods

In the empirical research section, the thesis initially applied pertinent statistical arbitrage methods to evaluate whether the cross-commodity prices within the hot-rolled coil industry chain align with theoretical equilibrium prices. Subsequently, standardized steps for strategy backtesting were implemented to craft four distinct cross-commodity hedging strategies for futures, followed by conducting backtesting assessments on the efficacy of these strategies. Lastly, employing a case study approach, the thesis scrutinized anomalous phases with notable drawdown results in futures cross-commodity hedging strategies. Through a comprehensive analysis of these anomalous phases, a corresponding risk management framework for futures cross-commodity hedging strategies was formulated.

3.3 The structure of the thesis

The structure of the thesis is as follows:

Chapter 1: Introduction. This chapter elucidates the research background and significance of the thesis outlining the primary research content and methods employed while expounding on the contributions of this study.

Chapter 2: Literature Review. The literature review encompasses three main areas: research about firms' output competition, research focusing on hedging within the futures market, and research on risks in hedging in the futures market faced by physical enterprises. The conclusions and deficiencies of the existing research are evaluated.

Chapter 3: Research Framework. The thesis's research framework includes nine chapters: the introduction, literature review, research framework, contributions, theoretical model, two empirical testing chapters, risk management, and conclusion, for the reader's convenience.

Chapter 4: Contributions. The thesis highlights several innovations, including the introduction of a new Cournot model that integrates futures prices into firms' production choices as the extension of the conventional Cournot model. It proceeds by introducing standard testing methods to validate the feasibility of hedging grounded in futures market profits. Subsequently, it presents diverse investment strategies and engages in a backtesting examination to assess the viability of hedging market futures profits within the industrial chain. Finally, from the vantage point of corporate price risk management, it offers essential insights and considerations for managing risk associated with hedging industrial chain profits.

Chapter 5: Theoretical Model. The thesis initiates by setting up a Cournot model grounded in future price expectations. Subsequently, employing the deductive method and real-world firm scenarios, it lays down the theoretical groundwork for timing market hedging within the futures industry supply chain. Lastly, building on the outcomes derived from the theoretical model, the thesis outlines the research design for the forthcoming empirical section.

Chapter 6: Empirical Tests. Empirical tests are conducted on the profit-cost curve of the hot-rolled coil industry supply chain in the futures market to validate the alignment of production profit costs simulated in the futures market with actual firms' production.

Chapter 7: Strategy Formulation. The thesis develops and conducts backtesting for hedging strategies tailored to the hot-rolled sheet industry supply chain, proposing four distinct futures hedging strategies for the hot-rolled coil industry chain. Leveraging historical futures trading data, backtesting is executed for these strategies, followed by an analysis of the backtesting results to evaluate the adaptation of these strategies across various scenarios.

Chapter 8: Risk Management. This chapter identifies the risk factors associated with hedging plans for futures market profit within the industrial chain, puts forth relevant risk management strategies to address these risks, and concludes by outlining the essential aspects of hedging for enterprises.

Chapter 9: Conclusions and Outlook. This chapter initially encapsulates the research findings, scrutinizes the shortcomings through analysis, and provides an outlook on future research directions.

4 Contributions

The thesis has the following contributions:

1) Innovatively incorporating futures prices as future price information into the Cournot model to extend the application depth of the model;

2) Elaborating on the theoretical basis for the production profit curve in the futures industry supply chain as a contribution to existing theories;

3) Addressing the research gaps in hedging within industrial supply chains associated with hot-rolled coils despite existing academic studies on rebar-related hedging;

4) Proposing four different hedging strategies featuring a broadened range and enhanced risk resistance based on existing futures trading;

5) Expanding the research subject from traditional underlying futures to spot products, exploring hedging strategies based on the correlation between spot products and futures products from a risk control perspective, and providing practical significance for the production cost management of corporate entities not directly related to futures;

6) Examining potential strategy risks and providing comprehensive risk management measures through case studies.

5 Theoretical Model: A Cournot Model with Improvements Based on Expected Futures Profits

The Cournot model, a classic economic competition model, pertains to oligopolies participating in competition by adjusting their output levels.

5.1 Assumptions and model settings

The traditional Cournot model is predicated on several pivotal assumptions:

1) Firms partake in oligopolistic competition without collusion;

2) Firms' decisions are rational;

3) Products from different firms are identical, with no variable costs for firms;

4) Market capacity is confined, and market price is a decreasing function of total product quantity (i.e. market price decreases as total product quantity increases);

5) Firms seek to maximize profits, with the objective function centered on maximizing profits at period T+1;

6) Spot inventory for firms at period T+1 originates from unsold products from period T not purchased by consumers (i.e., product demand). Production by firms in period T and consumer demand are endogenously ascertained within the Cournot model.

Assuming the outlined hypotheses are valid, the thesis establishes a model where production firms compete with each other. The model is set up as follows:

1) In a market with three firms, the cost of producing a single product is a fixed value denoted as Ci, where i=1, 2, 3;

2) The spot price at time T+1 is formulated as:

$$P_{T+1} = P_0 - a(Q_1 + Q_2 + Q_3 + D_{T+1})$$

Given that firms frequently leverage futures market prices and market profits to refine their anticipations of future market demand, assumption 3) is made:

3) It is postulated that certain firms in the market base their spot output for period T+1 on the futures market price at period T, while also assuming the exogeneity of the futures market price. These assumed conditions aim to explore from a theoretical standpoint whether firms considering futures market profits can secure a competitive edge over those disregarding such profits.

In these hypotheses, Q_i represents the firm's output, D_{T+1} represents the spot inventory in period T+1, a is the output-to-price conversion coefficient, and P_0 is the extreme price of the product when there is no supply of the product on the market, which is unobservable in practice.

Note: The output-to-price conversion coefficient $a$reflects the sensitivity of output to price. If a product displays output sensitivity, resulting in a substantial price decline with a minor output rise, the value of α will be relatively elevated. For instance, during the COVID-19 pandemic in Shanghai, there was a surge in vegetable prices. However, as the vegetable supply increased, prices swiftly regressed to regular levels. This indicates that the price conversion coefficient α for vegetables was notably high.

Based on the three model settings mentioned above, two types of optimal production schemes for enterprises are provided in theoretical research:

1) Optimal output based on Cournot equilibrium (classical model);
2) Optimal output based on futures market profits (improved model).

5.2 Traditional Cournot model

Regarding the Cournot equilibrium, the firm's profit formula is:

$$Profit_{T+1} = (P_0 - a(Q_1 + Q_2 + Q_3 + D_{T+1}) - c_i) * (Q_i), \ i = 1,2,3$$

The equilibrium output solving process using the traditional Cournot model is as follows:

1) Use the Lagrange multiplier method, take the derivative of each company's profit function concerning production quantity, set it to zero, and find the stationary points (also known as the first-order condition of equilibrium):

$$\frac{\partial Profit_{T+1,1}}{\partial Q_1} = (P_0 - aD_{T+1} - a(Q_1 + Q_2 + Q_3) - c_1) - a(Q_1) = 0$$

$$\frac{\partial Profit_{T+1,2}}{\partial Q_2} = (P_0 - aD_{T+1} - a(Q_1 + Q_2 + Q_3) - c_2) - a(Q_2) = 0$$

$$\frac{\partial Profit_{T+1,3}}{\partial Q_3} = (P_0 - aD_{T+1} - a(Q_1 + Q_2 + Q_3) - c_3) - a(Q_3) = 0$$

2) Simultaneously create the first-order partial derivative equations of the three firms for solution:

$$Q_1 = \frac{P_0 - aD_{T+1} - (3c_1 - c_2 - c_3)}{4a}$$

$$Q_2 = \frac{P_0 - aD_{T+1} - (3c_2 - c_1 - c_3)}{4a}$$

$$Q_3 = \frac{P_0 - aD_{T+1} - (3c_3 - c_1 - c_2)}{4a}$$

3) The optimal equilibrium output for each firm is:

$$Q_{i,opti} = \frac{P_0 - aD_{T+1} - \left(3c_i - \sum_{i \neq j} c_j\right)}{4a}, \ \ i = 1,2,3$$

In the traditional Cournot model, the pricing elements of futures are excluded, but in practical scenarios, firms utilize futures market prices to steer their production decisions. Furthermore, firms with distinct risk preferences have varying perspectives regarding the futures market. This shortfall in the traditional model will be addressed in the following sections.

5.3 A Cournot model considering futures market prices and profits

Previously, the thesis delved into the traditional Cournot model and highlighted its absence of consideration for futures market price factors, rendering the model incongruent with real-world dynamics. Our research integrates these factors into the traditional Cournot model, thus presenting an innovative facet of our thesis.

Specifically, the utilization of futures market prices by the firm can be described as follows:

1) Firms solely monitor end product prices to shape their projections of future prices;

2) Firms not only monitor end product prices but also, from an industrial supply chain standpoint, amalgamate futures market prices of upstream raw materials and production endpoints to compute future market profits of the end products. This approach assists in formulating expectations regarding future revenues.

Based on research and practical experience, we conclude that the second scenario aligns more closely with reality. The price of the end product does not equate to its profit. In cases where the end product price rises, if the prices of upstream raw materials also manifest an upward trend surpassing the end product's rising price, then the production profit of the end product markedly diminishes. Hence, the futures market profit serves as a more significant gauge for firms.

Building on the preceding discourse, we posit that the futures market profit in the current period is denoted as P_f. For firms, a higher futures market profit signifies a greater level of optimism about the future, fostering a willingness to secure a segment of production profits through the futures market. Consequently, this results in an increase in the extreme price constraint expectation P. Therefore, we assume that the firm's extreme price constraint expectation P is determined by the following formula:

$$P = f(P_0, P_f)$$

As the futures market profits rise, firms exhibit increased optimism about the future. Conversely, when these profits decline, they tend to become pessimistic about what lies ahead. Therefore, $f(\cdot)$ should be an increasing function about P_f. In mathematical language, this means that the first-order derivative of $f(\cdot)$ with respect to P_f is a number greater than or equal to 0, that is:

$$\frac{\partial f(P_0, P_f)}{\partial P_f} \geq 0$$

In cases where the firm adopts an aggressive stance and the futures market profits are increasing, the value of the aforementioned equation will increase accordingly. Conversely, if the equation yields a value of 0, it indicates that the firm disregards such profits entirely, which means that the model aligns with the traditional Cournot model.

For the Cournot model considering futures market profits, the firm's profit formula is:

$$Profit_{T+1} = (P_i - a(Q_1 + Q_2 + Q_3 + D_{T+1}) - c_i) * (Q_i)$$

Where$P_i = f(P_0, P_f)$

Various firms, encountering equal futures market profits, harbor disparate future expected extreme prices. Consequently, the value of each firm's future expected limit price P will vary. For computational simplicity, the thesis posits that the expected function $f(P_0, P_f)$ of future extreme price P remains constant.

Building on the above discourse, to maintain the generalizability of the research findings, we assume that Firm 1 incorporates futures market profit considerations, whereas Firm 2 and Firm 3 do not. Subsequently, the profit formulas for the firms are outlined below:

$$Profit_{T+1,1} = (P_1 - a(Q_1 + Q_2 + Q_3 + D_{T+1}) - c_1) * (Q_1)$$

$$Profit_{T+1,2} = (P_0 - a(Q_1 + Q_2 + Q_3 + D_{T+1}) - c_2) * (Q_2)$$

$$Profit_{T+1,3} = (P_0 - a(Q_1 + Q_2 + Q_3 + D_{T+1}) - c_3) * (Q_3)$$

1) Use the Lagrange multiplier method, take the derivative of each company's profit function concerning production quantity, set it to zero, and find the stationary points (also known as the first-order condition of equilibrium):

$$\frac{\partial Profit_{T+1,1}}{\partial Q_1} = (P_1 - aD_{T+1} - a(Q_1 + Q_2 + Q_3) - c_1) - a(Q_1) = 0$$

$$\frac{\partial Profit_{T+1,2}}{\partial Q_2} = (P_0 - aD_{T+1} - a(Q_1 + Q_2 + Q_3) - c_2) - a(Q_2) = 0$$

$$\frac{\partial Profit_{T+1,3}}{\partial Q_3} = (P_0 - aD_{T+1} - a(Q_1 + Q_2 + Q_3) - c_3) - a(Q_3) = 0$$

2) Simultaneously create the first-order partial derivative equations of the three firms for solutions of the optimal equilibrium output of each firm:

$$Q_1 = \frac{3P_1 - 2P_0 - aD_{T+1} - (3c_1 - c_2 - c_3)}{4a}$$

$$Q_2 = \frac{2P_0 - P_1 - aD_{T+1} - (3c_2 - c_1 - c_3)}{4a}$$

$$Q_3 = \frac{2P_0 - P_1 - aD_{T+1} - (3c_3 - c_1 - c_2)}{4a}$$

Where $P_1 = f(P_0, P_f)$. For Firm 2 and Firm 3, as they do not take futures market profits into account, the value of P_1 is relatively stable and unaffected by itself.

If all firms consider futures market profits, for any one of them, the expected profit function in period T+1 is:

$$Profit_{T+1} = (P_i - a(Q_1 + Q_2 + Q_3 + D_{T+1}) - c_i) * (Q_i)$$

$$P_i = f_i(P_0, P_f)$$

Similar to Item 2), we can also employ the Lagrange multiplier method to determine the optimal output at the Cournot output competition equilibrium for each firm, outlined as follows:

$$\frac{\partial Profit_{T+1,1}}{Q_1} = (P_1 - a(Q_1 + Q_2 + Q_3 + D_{T+1}) - c_1) - a(Q_1) = 0$$

$$\frac{\partial Profit_{T+1,2}}{Q_2} = (P_2 - a(Q_1 + Q_2 + Q_3 + D_{T+1}) - c_2) - a(Q_2) = 0$$

$$\frac{\partial Profit_{T+1,3}}{Q_3} = (P_3 - a(Q_1 + Q_2 + Q_3 + D_{T+1}) - c_3) - a(Q_3) = 0$$

Add the three simultaneous equations to obtain:

$$P_1 + P_2 + P_3 - 3a(Q_1 + Q_2 + Q_3 + D_{T+1}) - (c_1 + c_2 + c_3) = a(Q_1 + Q_2 + Q_3)$$

Further:

$$a(Q_1 + Q_2 + Q_3) = \frac{P_1 + P_2 + P_3 - 3aD_{T+1} - (c_1 + c_2 + c_3)}{4}$$

Hence, the optimal output of the firm is:

$$Q_{i,opti} = \frac{3P_i - \sum_{i \neq j} P_j - aD_{T+1} - \left(3c_i - \sum_{i \neq j} c_j\right)}{4a}$$

Furthermore, calculate the first-order partial derivative of the current futures market profit P_f concerning the firm's optimal output Q_i:

$$\frac{\partial Q_{i,opti}}{\partial P_f} = \frac{3}{4a} \times \frac{\partial f(P_0, P_f)}{\partial P_f} \geq 0$$

A simple deduction indicates that the firm's optimal output Q_i is an increasing function of the current futures market profit P_f. In other words, the higher the current futures market profit, the more inclined firms are to ramp up their output. However, it is essential to note that escalating output, especially beyond the optimal equilibrium level, increases raw material consumption. Consequently, raw material suppliers may seek higher returns by enhancing raw material prices to a certain extent over a specific period. This scenario could result in a substantial decline in firms' profits, subsequently leading to a moderate reduction in prices.

At this time, the total output of all manufacturers is:

$$Q_{total} = \frac{\sum_i P_i - 3aD_{T+1} - \sum_i c_i}{4a}, i = 1,2,3, P_i = f_i(P_0, P_f)$$

5.4 Model inference

Based on the results derived from the classic Cournot model and the improved Cournot model, the thesis can obtain optimal production schemes for two types of enterprises: enterprises considering futures market profits and those not considering futures market profits. Without loss of generality, the thesis assumes that all enterprises consider the production methods of other enterprises according to their pricing methods, that is, enterprises that do not consider futures market profits also do not believe that other enterprises consider futures market profits.

$$Q_{i,opti} = \frac{P_0 - aD_{T+1} - \left(3c_i - \sum_{i \neq j} c_j\right)}{4a}, \quad i = 1,2,3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5.1)}$$

$$Q_{i,opti} = \frac{3P_i - \sum_{i \neq j} P_j - aD_{T+1} - \left(3c_i - \sum_{i \neq j} c_j\right)}{4a} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5.2)}$$

The difference between formula (5.1) and formula (5.2) lies in the different total market price ceilings. Enterprises not considering the futures market price set it as P_0, while those considering the futures market price set it as P_i. If the futures market profit is high, then $P_i > P_0$. Enterprises considering futures market profits will produce more products based on formula (5.2), while enterprises not considering futures market profits will maintain the original production volume.

Next, the thesis will discuss the situation of only one enterprise considering futures market profits in arranging production and that of all enterprises considering futures market profits in arranging production.

If there is only one enterprise considering futures market profits in the market, then the total output for the T+1 period in the market is:

$$Q_{total} = \frac{P_1 + 2P_0 - 3aD_{T+1} - \sum_i c_i}{4a}$$

The product price is:

$$Price_{T+1} = \frac{2P_0 - (P_1 + aD_{T+1} - \sum_i c_i)}{4}$$

If the three enterprises in the market all consider futures market profits and adopt a consistent pricing model, then the total output for the T+1 period in the market is:

$$Q_{total} = \frac{3P_1 - 3aD_{T+1} - \sum_i c_i}{4a}$$

The product price is:

$$Price_{T+1} = \frac{4P_0 - (3P_1 + aD_{T+1} - \sum_i c_i)}{4}$$

Inference 1 can be drawn through the comparison of the two formulas:

[Inference 1] If the futures market profit is high and there are enterprises considering futures profits in the market, then the total industrial output will be higher than the equilibrium total output under the classic Cournot model.

Further analysis depends on the ability of the futures market to predict future output D_{T+1}. Here we first discuss the case where the futures market is effective, which means that the higher the futures market profits are, the lower the future inventory D_{T+1} will be and the higher the future market price will be. In such a situation, enterprises that appropriately increase production capacity can sell more products at the same price in the next period, thereby gaining a higher market share and bolstering their competitiveness.

On the contrary, if the futures market lacks the ability to predict future inventory D_{T+1}, then the general market price constraint is ineffective, which will lead to an increase in overall production, further reducing future equilibrium prices and harming the utility of market participants. Enterprises that increase their production volume will have excessive inventory. From this, Inference 2 can be drawn:

[Inference 2] If futures market profits can reflect future inventory, then enterprises that adjust production capacity by observing futures market profits will produce more products while ensuring balanced supply and demand, thereby gaining higher profits and securing larger market shares.

Further, if [Inference 2] holds true, and all enterprises in the market gradually observe the predictive capability of futures market profits on product supply and use futures market profits to guide their production arrangements, then the product supply in the market will increase by $3(P_1 - P_0)$. If the increase in product supply exceeds the expected decrease in inventory, there will be an excess supply in the market, resulting in inventory accumulation. This will drive down the market equilibrium price, causing an increase in enterprises' inventory and a reduction in their market share and utility. From this, Inference 3 can be drawn:

[Inference 3] Based on [Inference 2], if all enterprises in the market rely on futures market profits to guide their production, the total output Q will be too high when the futures profit is high, which will lead to an increase in spot inventory in the following period. This will affect the spot price in the future T+1 period, potentially resulting in losses for manufacturers.

Actually, the overall increase in industrial output can conversely influence the fluctuations in futures prices. In the theoretical model of this chapter, the futures price is set as an exogenous variable, thus neglecting the impact of the industry on futures prices. This represents a shortcoming of the model in the thesis and is also a direction for future improvement.

5.5 Theoretical basis for timing hedging in the futures industry chain

Based on the results derived from the above model, the thesis draws the following inferences:

1) If the current futures market profit is high, enterprises focusing on futures will raise their expectations for future price ceilings, thereby producing more products;

2) If other manufacturers do not consider futures market profits and adopt static price ceilings due to a lack of professional knowledge or talent reserves, or considering cost factors, manufacturers observing futures market prices can achieve higher production volume and profits through futures hedging in the bull market (when futures profits are high); and produce less products in the bear market (when futures prices are low) to avoid losses, thereby gaining a competitive edge;

3) If all manufacturers focus on futures market profits and ignore the

equilibrium price ceiling, then when the market profit is high, the total production volume Q will be too high, resulting in an increase of D_{T+1} in spot inventory for the next period. This will affect the spot price for the T+1 period and even lead to losses for the manufacturers.

Therefore, based on the derivation of the improved Cournot model, we find that enterprises considering futures market profits can better arrange their production, thereby mitigating cyclical price fluctuations. Additionally, enterprises that can correctly utilize profit information in the futures industry chain will gain a large competitive edge. This also explains the increase in the number of physical enterprises participating in hedging in recent years. Next, the thesis will take an empirical approach to verify the superiority of the futures hedging strategy in the industry chain.

6 Research on the equilibrium relationship of the futures supply chain in the hot-rolled coil industry chain

In the previous chapters, the thesis has argued from the perspectives of enterprises and industries that leveraging futures market profits for hedging is superior and can effectively reduce risks while enhancing profits. However, the above analysis remains at the level of theoretical analysis. In practice, the issues regarding whether the actual market operation conforms to the assumptions of the theoretical model, whether leveraging futures market profit for hedging can increase enterprises' profits, and how to use and develop futures market profit hedging strategies still require empirical research and analysis. In the following chapters, the thesis will conduct empirical research on these issues one by one and provide solutions.

This chapter studies the equilibrium relationship of the futures supply chain in the hot-rolled coil industry chain and utilizes classical statistical research analysis methods to verify whether futures market profits can satisfy hedging conditions.

6.1 Research design

The purpose of this section is to verify whether there is an equilibrium relationship in the profit of the futures supply chain in the hot-rolled coil industry chain. This question can be refined as to whether the futures market profits of the hot-rolled coil industry chain satisfy the characteristics of mean reversion. If the futures market profit of the hot-rolled coil industry chain satisfies the characteristics of mean reversion, it means that the strategy of short-selling when the market profit is exceptionally high and the strategy of going-long when the market profit is exceptionally low will be effective.

To answer this question, the thesis verifies it from two perspectives: 1) The thesis will verify whether the hot-rolled coil futures market profits generated by the process proportion equation in the hot-rolled coil industry chain have long-term equilibrium characteristics, that is, check whether the hot-rolled coil futures market profits derived from this calculation formula satisfy the mean reversion characteristic; 2) For pure statistical tests, the thesis will derive the parameters of the formula for the hot-rolled coil futures market profits from the regression equation and check whether the hot-rolled coil futures market profits derived from this formula satisfy the characteristic of mean reversion.

6.2 Research methods

This study employs the Augmented Dickey-Fuller (ADF) test method to determine whether the residuals of the regression equation satisfy the mean reversion characteristic.

The ADF test is an extended form of the DF test, which can only be used to test time series with first-order lag. For time series with higher-order lag, the ADF test should be used. Therefore, the ADF test is an extension of the DF test in higher-order lag cases.

Commonly used models such as ARMA and ARIMA require that the time series studied be stationary in studying specific time series. Therefore, before the study of a given time series, it is first necessary to determine if the series is stationary. The commonly used method to test the stationarity of time series is the ADF test, also known as the unit root test.

The specific principle is: In the autoregressive process, if there is a root equal to 1 in the equation $y_t = by_{t-1} + a + \epsilon_t$, then the equation is said to have a unit root. The unit root test is to check whether a time series is a "unit root process (non-stationary series)", that is, for a characteristic equation with a root of 1, if a unit root exists, the series is a random walk. If not, the series is stationary (characterized by mean reversion).

Therefore, the null hypothesis H0 of the ADF test posits that the series contains a unit root. Through mathematical derivation, the test statistics at confidence levels of 10%, 5%, and 1% correspond to rejection of the null hypothesis at 90%, 95%, and 99% of significance. This means that the original series containing no unit root is stationary.

6.3 Data and profit formula

This study has extracted the daily trading data of dominant contracts for hot-rolled coil futures, iron ore futures, and coke futures since March 2014. The thesis takes into account that the dominant contracts for hot-rolled coil futures switch in January, May, and October and those for other goods in January, May, and September. There are also inconsistencies in the switching time of dominant contracts. To avoid the variations in objects caused by different switching months of dominant contracts, this study takes the dominant contract switching time of January, May, and September for iron ore as a reference and converts the dominant contract switching time of January, May, and October for hot-rolled coils and coke to the months consistent with the dominant contract switching time for iron ore. Additionally, as hot-rolled coil futures would be launched in March 2014, to circumvent the issue of low trading volumes and irrational factors at the commencement of trading of a new variety, we discard the trading data for the year 2014 and select the daily trading data for hot-rolled coil futures, iron ore futures, and coke futures from January 2015 to March 2022.

According to the production process of hot-rolled coil products, the production of one ton of hot-rolled coil products requires 0.65 tons of coke and 1.70 tons of iron ore, plus a fixed cost of RMB 600 to RMB 900. Therefore, the profit formula for the hot-rolled coil industry chain in the futures market is:

$$\text{Profit} = \text{HC} - 0.65 * \text{J} - 1.70 * \text{I} - \text{c}$$

In the formula, Profit represents the hot-rolled coil profit curve, HC represents the hot-rolled coil futures market price; J represents the coke futures market price; I represents the iron ore futures market price; 0.65 and 1.7 are the respective price coefficients.

To further prove that the profit curve formula of the hot-rolled coil industry chain conforms to the general laws of statistics, this study uses the hot-rolled coil market price as the dependent variable and the iron ore futures price and coking coal futures price as independent variables to conduct multiple linear regression analysis.

6.4 Empirical result

The dominant contracts for futures of various goods generally feature good liquidity. The thesis uses the continuous futures contract data integrating the data from dominant contracts in different periods to conduct regression analysis and unit root tests. It should be noted that the dominant contracts in each period for futures of various goods do not always expire in the same month. For example, the hot-rolled dominant contract at the end of May expires in October, namely contract 10, and the dominant contract for coke futures expires in September, namely contract 09. This difference may affect the conclusions of this study. Therefore, this study conducted two sets of research on each regression and test analysis: 1) Continuous futures price data integrating the data from dominant contracts in different periods; 2) Continuous futures price data after smoothing the futures contracts to ensure a consistent expiration month of futures contracts for each trading day.

Table 6.1 presents the results of the multiple linear regression analysis. From the table, it can be seen that the multiple regression analysis results of the hot-rolled coil industry chain exhibit a high R-squared and adjusted R-squared, indicating a strong correlation among products in this industry chain. Furthermore, the R-squared value for the smooth regression results of the hot-rolled coil industry chain is higher than the unoptimized result (0.902 vs. 0.905), which implies that optimization can more accurately represent the relationships between the industry chains.

From the perspective of coefficients, under the full sample regression results, there is a certain similarity between the two coefficients. In terms of price, 1 ton of hot-rolled coil products requires 0.95 tons of coke and 1.42 tons of iron ore (unsmooth regression results); 1 ton of hot-rolled coil products requires 0.97 ton of coke and 1.39 tons of iron ore (smooth regression results). Although the regression results differ from the actual hot-rolled coil production coefficients of physical enterprises, the difference is controllable. Moreover, transactions in the futures market are influenced by fundamental factors as well as speculative and irrational factors, which to a certain extent will distort the correlation relationship.

Table 6.1 Multiple regression results for the hot-rolled coil industry chain

	hc	hc_smooth
const	923.9305***	920.3801***
	-39.9916	-40.3731
I	1.4246***	
	-30.1867	
J	0.9484***	
	-70.8821	

I_smooth		1.3925***
		-29.8654
J_smooth		0.9675***
		-72.6238
Adj. R-squared	0.902	0.905
R-squared	0.902	0.906

The thesis verifies the rationality of the coefficients in the profit formula for the hot-rolled coil industry chain. Following this analysis, it will address the academic question of whether the profit formula for the hot-rolled coil industry chain can be used for hedging, starting from whether the profit curve exhibits the characteristic of mean reversion. This study uses the ADF stationarity test method to verify whether the profit formula for the hot-rolled coil industry chain can be used for hedging. Table 6.2 presents the results of the stationarity test for hot-rolled coil profits and multiple regression residuals.

Table 6.2 The stationarity test results for hot-rolled coil profits and regression residuals

	hc	hc_ols	hc_smooth	hc_smooth_ols
t-value	-3.0346**	-3.4936***	-2.892**	-3.1262**
p-value	0.0318	0.0082	0.0463	0.0247

As indicated in Table 6.2, the t-value for all items is statistically significant at the 0.05 level, indicating that each profit curve satisfies the characteristics of mean reversion. Hence, it is viable to carry out hedging based on this characteristic.

Figure 6.1 presents the smooth and unsmooth hot-rolled coil futures profit curves, factoring in a fixed cost of RMB 900. From the figure, it can be seen that the hot-rolled coil profit curve is generally distributed above the zero axis, indicating that hot-rolled coil enterprises are profitable most of the time. There are also a few occurrences where the hot-rolled coil profit curve is below the zero axis, indicating that hot-rolled coil enterprises were losing money at those times. However, the profit curve quickly recovers to be above the zero axis. It is worth mentioning that the hot-rolled coil profit curve showed significant fluctuations in 2021, as reflected in Figure 6.1. The increase in profit fluctuations places higher requirements for physical enterprises' price and production management. This also implies that the research in the thesis will help physical enterprises enhance their abilities for price management to better cope with market fluctuations.

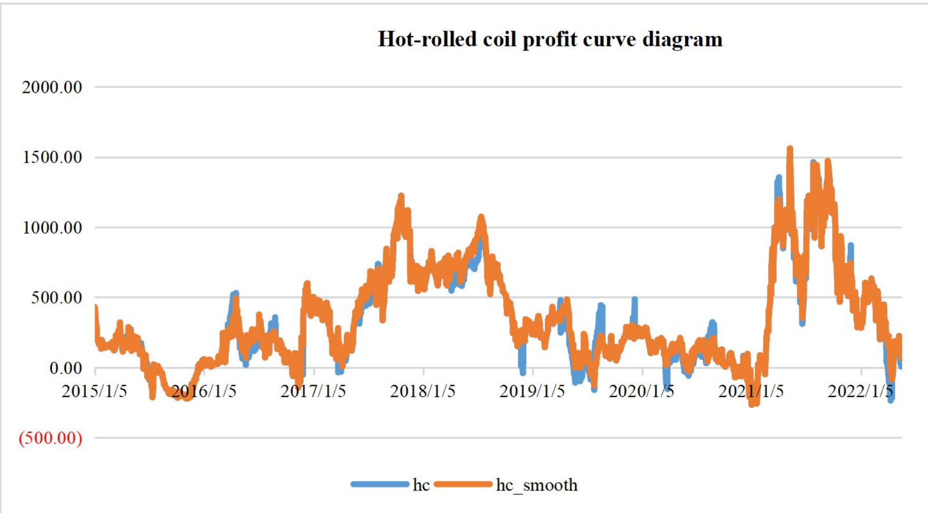

Figure 6.1 Hot-rolled coil profit curve diagram

In conclusion, according to the above discussion, the profit curve for the hot-rolled coil futures industry chain is consistent with the mean reversion model, both in terms of statistical regression results and the actual operation results of the industry. In the following empirical research, this study will explore whether profit curve-based hedging is superior to traditional single-commodity hedging. Additionally, it will also investigate effective hedging strategies based on the mean reversion model of the profit curve.

7 Hedging strategies based on the equilibrium relationship of the futures supply chain in the hot-rolled coil industry chain

In the previous studies, the thesis has already demonstrated that the hot-rolled coil profit curve conforms to the mean reversion characteristic, whether the hot-rolled coil profit curve is based on the actually produced relationship or the statistical regression analysis. This chapter will establish multiple investment strategies to verify whether the hedging strategy based on hot-rolled coil profits is superior to the traditional single-commodity hedging strategy.

7.1 Strategy formulation

From the perspective of producers, enterprises purchase raw materials in the market, produce products, and then sell them in the market. Therefore, there is a natural short position for raw materials and a natural long position for products. When the product prices in the market are high, enterprises can sell their products in the market to make a profit, which motivates them to hedge when the prices are at a high level to secure some profits. However, if the product prices in the market are low, it is not good for enterprises to take either the strategy of short-selling or the strategy of going-long: 1) If enterprises take the strategy of going-long, they increase their exposure to risks while increasing production volume. If they take the right direction, they can make a profit without any operation; if not, their losses will exacerbate; 2) If enterprises take the strategy of short-selling, they face a fixed product price. Given the low product price, they still operate at or below the breakeven point, incurring potential losses. Therefore, enterprises are only motivated to engage in hedging operations when product prices are high. Enterprises taking the profit hedging strategy have the same behavior.

Based on the above analysis, enterprises are only motivated to engage in hot-rolled coil hedging operations when prices (profits) are high. When prices are low, they are only motivated to take the going-long strategy for iron ore and coke for hedging and will not engage in hedging operations for finished products. Therefore, the two strategies involved in this study are only used in the situation when the hot-rolled coil prices (profits) are high.

Strategic condition settings: Assume that enterprises use a total principal of RMB 100,000,000 for hedging, the margin ratios for hot-rolled coil, iron ore, and coke are 21%, 21%, and 30% respectively; transaction fees are 0.01%, 0.01%, and 0.14% of the nominal transaction amount respectively.

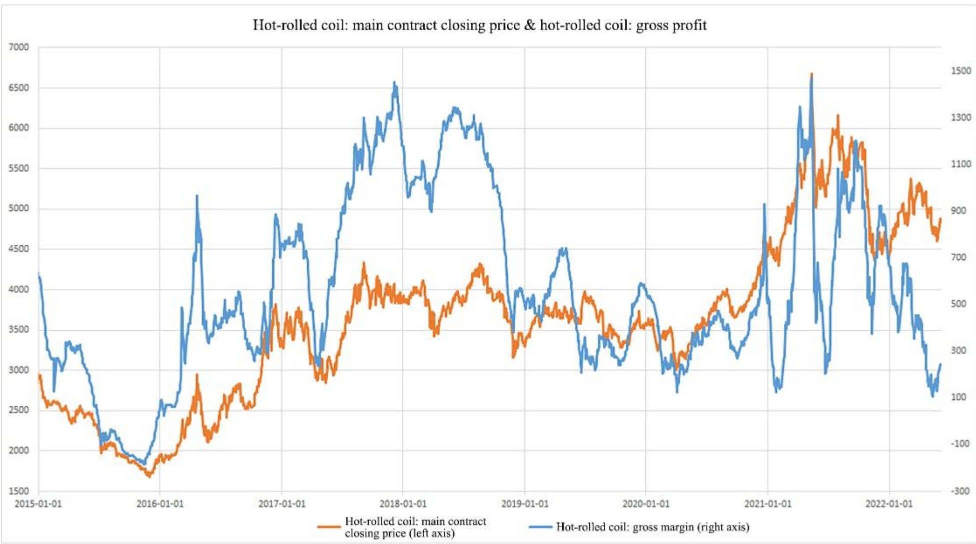

Figure 7.1 Hot-rolled coil prices and gross profits

Strategy 1: Hot-rolled coil single-commodity hedging strategy

Under this strategy, enterprises' hedging ratio is only related to the prices of hot-rolled coil varieties. Based on my years of experience in market engagement, it can be seen from Figure 7.1 that in both 2017 and 2018, the price remained below the level of RMB 4,500. From the end of 2020 to March 2021, the price gradually grew to RMB 4,500. From November 2021 to February 2022, the price exceeded RMB 4,500. Moreover, based on my experience, the lowest price level is RMB 3,000 and the highest price level is about RMB 6,000. This indicates that RMB 4,500 is an important node for hot-rolled coil products, and when the price remains relatively high above RMB 4,500, the probability of hedging and making a profit is high. Additionally, the interval distance is set based on the author's years of industry experience. Therefore, the hot-rolled coil price ranges have been determined as per the following strategies:

When the price of hot-rolled coil futures is below RMB 4,500/ton, no action is taken;

When the price of hot-rolled coil futures is greater than or equal to RMB 4,500/ton and less than RMB 5,000/ton, take a short-selling strategy for hot-rolled coil products with a 15% position;

When the price of hot-rolled coil futures is greater than or equal to RMB 5,000/ton and less than RMB 5,250/ton, take a short-selling strategy for hot-rolled coil products with a 35% position;

When the price of hot-rolled coil futures is greater than or equal to RMB 5,250/ton and less than RMB 5,500/ton, take a short-selling strategy for hot-rolled coil products with a 50% position;

When the price of hot-rolled coil futures is greater than or equal to RMB 5,500/ton and less than RMB 5,750/ton, take a short-selling strategy for hot-rolled coil products with a 60% position;

When the price of hot-rolled coil futures is greater than or equal to RMB 5,750/ton and less than RMB 6,000/ton, take a short-selling strategy for hot-rolled coil products with a 70% position;

When the price of hot-rolled coil futures is greater than or equal to RMB 6,000/ton, take a short-selling strategy for hot-rolled coil products with an 80% position.

Strategy 2: Hot-rolled profit hedging strategy

The hot-rolled coil futures market profit is calculated based on the hot-rolled coil profit formula. The formula is as follows:

$$\text{Profit} = \text{HC} - 0.65 * \text{J} - 1.7 * \text{I}$$

The hedging ratio of enterprises is only related to the profit of the hot-rolled coil futures industry chain. From Figure 7.1, it can be seen that RMB 600 is an important node for the profit per ton of hot-rolled coil products, and the relative profit is high at this point. When the profit remains above RMB 600, the probability of hedging and making a profit is high, but this will not be lasting. The interval distance is also set based on the author's years of industry experience. Therefore, the hot-rolled coil profit ranges have been determined as follows:

When the profit of hot-rolled coil futures is below RMB 600/ton, no action is taken;

When the profit of hot-rolled coil futures is greater than or equal to RMB 600/ton and less than RMB 700/ton, take a short-selling strategy for hot-rolled coil products with a 15% position;

When the profit of hot-rolled coil futures is greater than or equal to RMB 700/ton and less than RMB 1,000/ton, take a short-selling strategy for hot-rolled coil products with a 35% position;

When the profit of hot-rolled coil futures is greater than or equal to RMB 1,000/ton and less than RMB 1,200/ton, take a short-selling strategy for hot-rolled coil products with a 50% position;

When the profit of hot-rolled coil futures is greater than or equal to RMB 1,200/ton and less than RMB 1,500/ton, take a short-selling strategy for hot-rolled coil products with a 60% position;

When the profit of hot-rolled coil futures is greater than or equal to RMB 1,500/ton, take a short-selling strategy for hot-rolled coil products with an 80% position.

7.2 Comparative analysis of investment strategies

The previous section presented two specific hedging investment strategies: 1) single-commodity hedging strategy; and 2) futures market profit hedging strategy. Before comparing the backtesting results, the thesis first conducts a comparative analysis of the two strategies.

The two strategies are optional hedging strategies for hot-rolled coil manufacturers and are used by these manufacturers for hedging operations when product prices (profits) are high to secure their profits.

From the perspective of application, the single-commodity hedging strategy boasts a wider range of applications. In theory, any enterprise requiring hot-rolled coil products in their production process can employ the single-commodity hedging strategy; while the profit hedging strategy is only applicable to hot-rolled coil manufacturers.

From the perspective of influencing factors, market entry and exit under the single-commodity hedging strategy solely depends on the changes in absolute price levels. However, the presence of factors such as inflation may cause a long-term slow rise in the price of a single commodity, leading to the ineffectiveness of absolute price levels. Furthermore, the futures market profit hedging strategy requires that the production process of products remains stable over a considerable length of time and that the demand for raw materials used for producing these products holds a dominant position in the total social demand for raw materials.

The thesis will compare and analyze the backtesting results of the two strategies later.

Figure 7.2 presents the backtesting results of the investment strategy based on single-commodity hedging. From Figure 7.2, it is not difficult to find that the price of hot-rolled coil products was below RMB 4,500 from 2014 to December 2020, which did not trigger the conditions for opening positions. Consequently, the earnings of the strategy were all zero, which only started to rise after December 2020. This is obviously not in line with the actual situation because enterprises would not wait until December 2020 to start hedging operations. Figure 7.1 shows that taking the price above RMB 4,500 as a starting point for hedging reflects the rearview mirror syndrome and does not have practical significance over a longer time scale. Therefore, the thesis will propose a single-commodity hedging improvement strategy based on the single-commodity hedging strategy in the next section. From the perspective of cumulative profits, the strategy generated a net profit of RMB 15 million, which was mainly achieved at the end of 2020, with an annualized yield rate of about 1.875% over the past eight years. In terms of fund occupation, the maximum fund occupation of the strategy was around RMB 17 million. However, there were significant fluctuations in fund occupation.

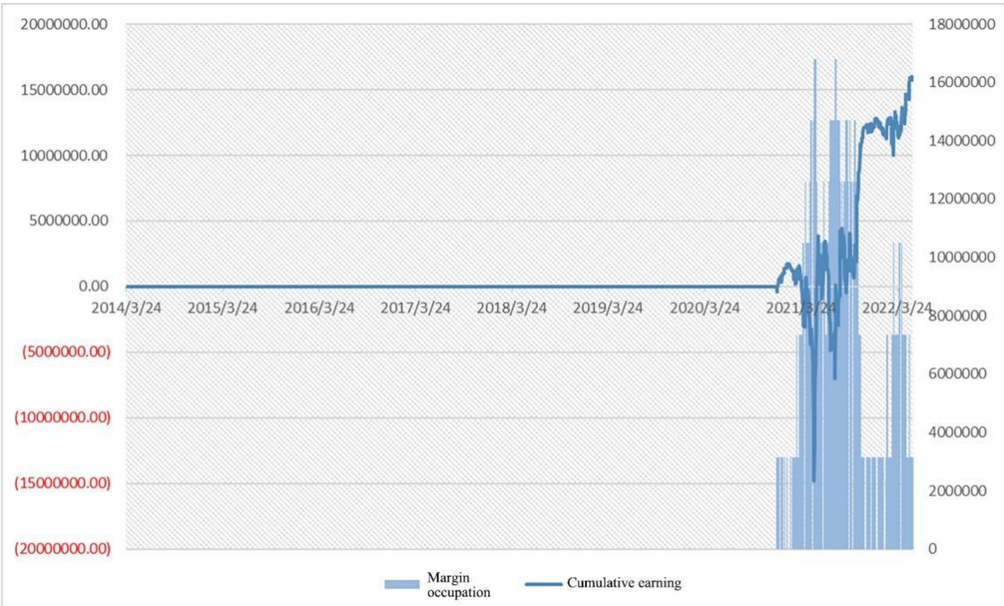

Figure 7.2 Investment results for the single-commodity hedging strategy

Figure 7.3 presents the backtesting results of the investment strategy based on hot-rolled coil profit hedging. From the perspective of the strategy's performance, the strategy resulted in net losses from March 2014 to March 2016, with a total loss of around RMB 15 million, accounting for 15% of the actual reserve funds. Subsequently, the profits of the strategy continued to rise.

As of the strategy backtesting cutoff date of March 24, 2022, the strategy yielded a profit of RMB 50 million, with a yield rate of over 50% and an annualized yield rate of about 6.25%, underlining consistent stability in the strategy's performance. In terms of fund occupation, the cumulative fund occupation of the strategy is around RMB 22 million.

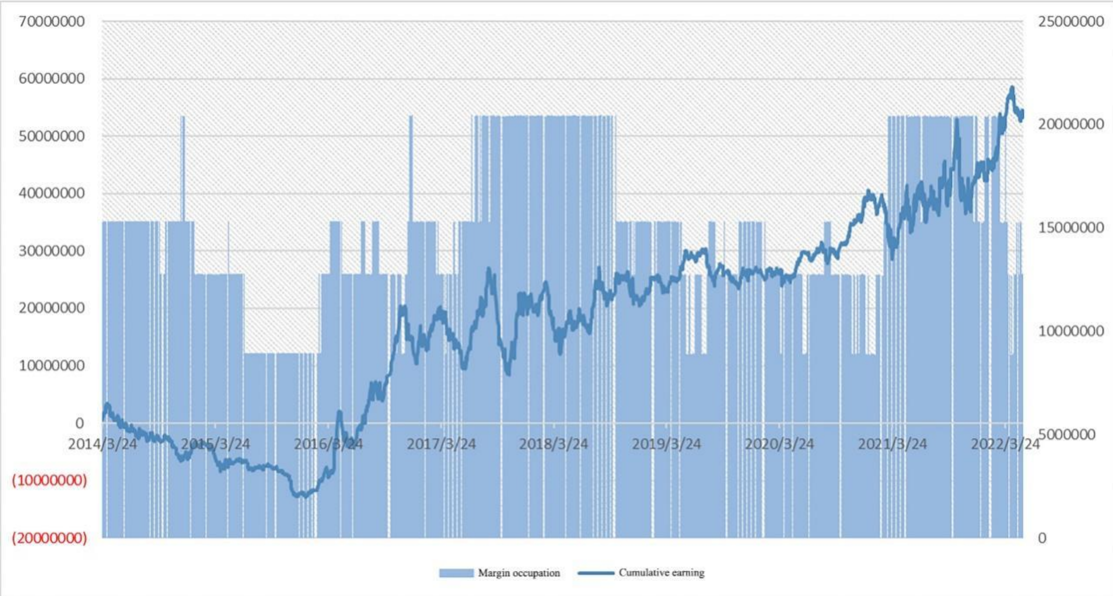

Figure 7.3 Investment results for the profit hedging strategy

Based on the comparison of the investment backtesting results for the two strategies, the following conclusions can be drawn.

From the perspective of profits, the two strategies yield similar results, but the single-commodity hedging strategy has weaker stability. The single-commodity hedging strategy exhibits a relatively long static period. The strategy indicates that investors taking this strategy started to open positions at the end of 2020, which was not in line with the actual investment situation. This shortcoming will be improved subsequently.

From the drawdown perspective, the futures market profit hedging strategy demonstrates higher stability in drawdown, but the two strategies exhibit a similar absolute drawdown value. The single-commodity hedging strategy experienced an aggregate drawdown of about 15% within three months, with a drastic drawdown in the short term; while the futures market profit hedging strategy incurred an aggregate drawdown of about 15% in two years, with an overall smooth drawdown rate.

From the perspective of fund occupation, the single-commodity hedging strategy requires fewer funds but is subject to severe fluctuations; while the futures market profit hedging strategy requires more funds but offers more stable earnings. In fact, communication can be conducted with relevant futures companies to use the portfolio margin calculation method to determine the holding positions of such combined investments, which can effectively reduce the fund occupation of the strategies. The portfolio margin is calculated as the maximum of either the cumulative margin of the long positions or the cumulative margin of the short positions.

Based on the above analysis, the futures market profit hedging strategy has some advantages, which are derived from the bias caused by the rearview mirror syndrome inherent in the single-commodity hedging strategy. Consequently, to draw a more general conclusion, the thesis will propose improved hedging strategies in the next section and conduct a comparative analysis of the improved strategies.

7.3 Improved hot-rolled coil hedging investment strategies

In the previous section, the opening, adding, reduction, and closing of positions for the two strategies depended on given absolute prices. However, in practical application, investors can only obtain historical information for current investment decisions to obtain future ROI. Therefore, the absolute price levels may, to some extent, be derived from a "future function", resulting in strategy distortion. The improved hot-rolled coil hedging strategies proposed in this section will solve the problem. Specifically, the new strategies will use historical prices to determine the criteria for each position in the investment strategies.

Strategy 1-1: Hot-rolled coil single-commodity hedging strategy

In the improved strategies, we still assume that the hedging ratio of enterprises is only related to the price of hot-rolled coil varieties, but the specific market entry points are determined by the historical prices of hot-rolled coil varieties.

The opening price of hot-rolled coil products is obtained by weighting the quantile of the total historical price set from position opening to the present with the quantile of the three-year historical price set, namely:

$$\mathrm{p(x)} = \frac{N_{3year}}{N_{3year} + N_{total}} Q(\{Hist\ Price\}_{total}, x) + \frac{N_{total}}{N_{3year} + N_{total}} Q\big(\{Hist\ Price\}_{3year}, x\big)$$

Where x represents the quantile and Q is the quantile function, with the first element in the function representing the set of price elements. Q({y},x) represents the x quantile of the set {y}. $\{Hist\ Price\}_{total}$ represents the set of all closing prices since the launch of varieties. $\{Hist\ Price\}_{3year}$represents the set of all closing prices of varieties over the past three years. $N_{(\cdot)}$ represents the number of elements in the set. Under the control of the weighting coefficients in the above formula, as historical data increases, the weight of all samples will gradually decrease. This will prevent historical extreme market conditions from interfering with the model's opening conditions, thereby increasing the frequency of opening positions.

Moreover, the thesis also sets up scenarios where the limit quantile is exceeded in the strategy to prevent the continuous rise of hot-rolled coil prices, surpassing the historical price ceiling and thereby causing short positions to reach their limit prematurely. The specific strategies are as follows:

When the price of hot-rolled coil futures is below RMB $\mathrm{p}(85)$ /ton, no action is taken;

When the price of hot-rolled coil futures is greater than or equal to RMB $\mathrm{p}(85)$ /ton and less than RMB $\mathrm{p}(90)$ /ton, take a short-selling strategy for hot-rolled coil products with a 15% position;

When the price of hot-rolled coil futures is greater than or equal to RMB $\mathrm{p}(90)$ /ton and less than RMB $\mathrm{p}(95)$ /ton, take a short-selling strategy for hot-rolled coil products with a 30% position;

When the price of hot-rolled coil futures is greater than or equal to RMB $\mathrm{p}(95)$ /ton and less than RMB $\mathrm{p}(100)$ /ton, take a short-selling strategy for hot-rolled coil products with a 40% position;

When the price of hot-rolled coil futures is greater than or equal to RMB $p(100)$ /ton and less than RMB $p(100) * 1.05$ /ton, take a short-selling strategy for hot-rolled coil products with a 50% position;

When the price of hot-rolled coil futures is greater than or equal to RMB $p(100) * 1.05$/ton and less than RMB $p(100) * 1.1$/ton, take a short-selling strategy for hot-rolled coil products with a 60% position;

When the price of hot-rolled coil futures is greater than or equal to RMB $p(100) * 1.1$/ton and less than RMB $p(100) * 1.15$/ton, take a short-selling strategy for hot-rolled coil products with a 70% position;

When the price of hot-rolled coil futures is greater than or equal to RMB $p(100) * 1.15$/ton and less than RMB $p(100) * 1.2$/ton, take a short-selling strategy for hot-rolled coil products with an 80% position;

When the price of hot-rolled coil futures is greater than or equal to RMB $p(100) * 1.2$/ton, take a short-selling strategy for hot-rolled coil products with an 80% position.

7.4 Comparative analysis of the improved hot-rolled coil hedging strategies

The hot-rolled coil hedging strategies based on historical price quantiles avoid the future function problem caused by the use of absolute prices. This section will analyze and compare the improved hot-rolled coil hedging strategies.

Similar to the previous strategies, these two strategies are used by manufacturers for hedging operations when product prices (profits) are high to secure their profits.

From the perspective of applications, the improved hedging strategies remove reliance on the "future function" and conform to the actual investment environment, applicable to a wider range of manufacturers. Profit hedging will not be determined through historical market data because the calculation of profits involves the addition and subtraction of multi-commodity prices, which to some extent counterbalances the impact of factors such as macroeconomic inflation, ensuring that manufacturers' profits usually fluctuate within a reasonable range.

From the perspective of influencing factors, the market entry and exit of the single-commodity hedging strategy depend on short-term and long-term historical price changes. However, the entry point will be affected by the historical price extreme value. Additionally, the drastic price changes in the sample will cause corresponding fluctuations in the opening position, resulting in the problem of repeated opening and closing of positions. The futures market profit hedging strategy requires that the production process of products should remain stable over a considerable length of time and that the demand for raw materials used for producing these products should hold a dominant position in the total social demand for raw materials.

The improved hedging strategies need to take a certain period of historical data as statistical samples to calculate the quantile of hot-rolled coil prices. Consequently, the thesis adjusts the backtesting period. The thesis selects the data from March 24, 2014, to April 16, 2017, as the historical reference range for hot-rolled coil prices and the period from April 18, 2017, to May 20, 2022, as the backtesting range for the strategies. To facilitate the comparison of the differences between the two strategies, the thesis conducts backtesting on the profit hedging strategy over the same backtesting period.

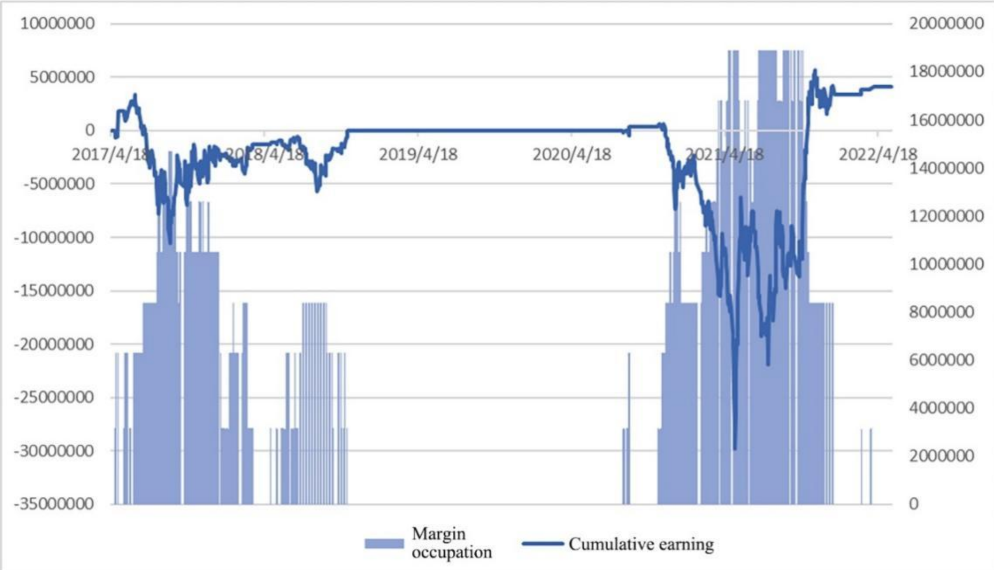

Figure 7.4 Investment results for the single-commodity hedging strategy (1-1)

Figure 7.4 presents the backtesting results for the hedging investment strategy based on the historical price quantile of a single hot-rolled coil variety. From Figure 7.4, it is not difficult to find that the hot-rolled coil hedging strategy using historical price quantile demonstrates a higher frequency of opening positions than the hot-rolled coil hedging strategy using absolute price levels. However, the final profits of the former strategy are considerably lower than those of the latter. This is partially due to the drastic fluctuations in the historical prices of hot-rolled coil products, with prices ranging from about RMB 2,800 at the beginning of 2017 to approximately RMB 6,700. The excessive historical price fluctuations have led to a large interval between the opening quantile of hot-rolled coil products, resulting in a prolonged holding period and diminishing the sensitivity of opening and closing positions. This also led to a rapid drawdown of the total profits of the strategy in 2020, with a backtesting period lasting as long as two years. In practical strategy operations, few investors can persist through such a long strategy drawdown period.

Figure 7.5 Investment results for the profit hedging strategy (20170418-20220520)

Figure 7.5 shows the backtesting results of the investment strategy based on the hot-rolled coil futures market profit hedging from April 18, 2017, to May 20, 2022. From the perspective of profits, the profit growth curve for the hot-rolled coil market profit hedging is very steady and is fundamentally characterized by continuous growth. The cumulative ROI over the past five years has reached about 40%, with a compound annualized yield rate of 6.9%. From the perspective of drawdown, the hot-rolled coil futures market profit hedging strategy experienced a profit drawdown to below zero three times during the strategy execution cycle in April 2017, October 2017, and March 2018. In the following two months, the profits rapidly recovered to above zero, ensuring a good strategy experience. From the perspective of fund occupation, the strategy incurs a relatively low fund occupation of around RMB 20 million.

Through comparison, the differences between the two strategies become obvious. Firstly, in terms of the frequency of opening positions, the hot-rolled coil futures market profit hedging strategy has a higher frequency of opening positions, with positions opening throughout the entire backtesting period. Secondly, in terms of final profits, with the same initial capital of RMB 100 million, the final profit from the profit hedging strategy is about RMB 40 million, with a cumulative yield rate of 40%; while the final profit from the hot-rolled coil single-commodity hedging strategy based on historical price quantile is only about RMB 5 million, with a cumulative yield rate of merely 5%, far behind that of the profit hedging strategy. Finally, in terms of holding experience, the hedging strategy based on the historical price quantile of hot-rolled coil products has a drawdown period of up to two years, while the profit hedging strategy generates significant positive profits after about a year and a half, with the time of negative profit spanning only about six months. Therefore, the latter is significantly superior to the former hedging strategy in this regard.

Additionally, the hot-rolled coil single-commodity hedging strategy based on the historical price quantile corrects the rearview mirror syndrome bias of the single-commodity hedging strategy based on absolute price levels, but it does not show significant improvement in terms of opening frequency (with no position opening from the beginning of 2019 to mid-2020). Moreover, its final profits are less than those of the absolute price-based strategy (it achieved a final profit of RMB 5 million, while the absolute price-based strategy achieved a final profit of RMB 15 million). This shows that in the actual operation of single-commodity hedging, there is no long-term effective hedging strategy. It is necessary to manually determine the prices for opening/adding positions of the strategy and the position size corresponding to each price based on the industry development status, futures market prices, and macroeconomic trends. This poses a strong requirement for the ability of hedging participants, but relevant personnel from most small and medium-sized enterprises lack the required ability.

In summary, the hot-rolled coil futures market profit hedging strategy is superior to the hot-rolled coil single-commodity hedging strategy in terms of opening frequency, capital management, final profits, and holding experience. Moreover, the former is easy to operate. It is just necessary to understand the proportion of various raw materials in the hot-rolled coil production process and fixed costs to derive the calculation formula for the hot-rolled coil futures market profit, which is more in line with the actual situation of physical enterprises participating in the financial market. Consequently, the profit hedging strategy proposed in this study has substantial practical significance.

8 Risk management of industry chain futures market profit hedging

In the previous chapters, the thesis has fully demonstrated the superiority of the futures market profit hedging strategy. Subsequently, the thesis will explain the risks that participating enterprises in the futures industry and supply chains need to pay attention to in implementing hedging strategies, as well as the measures and management methods they adopt to deal with these risks.

The preparation process of steel mainly includes: 1) Iron ore is processed through sintering and smelting into crude iron products; 2) Crude iron products are processed through rolling and heat treatment into steel products; 3) Steel products undergo mechanical processing and other specialized processes to be processed into various required types of steel. Overall, the main production processes of steel include ironmaking, steelmaking, steel casting, and steel rolling, as shown in Figure 8.1.

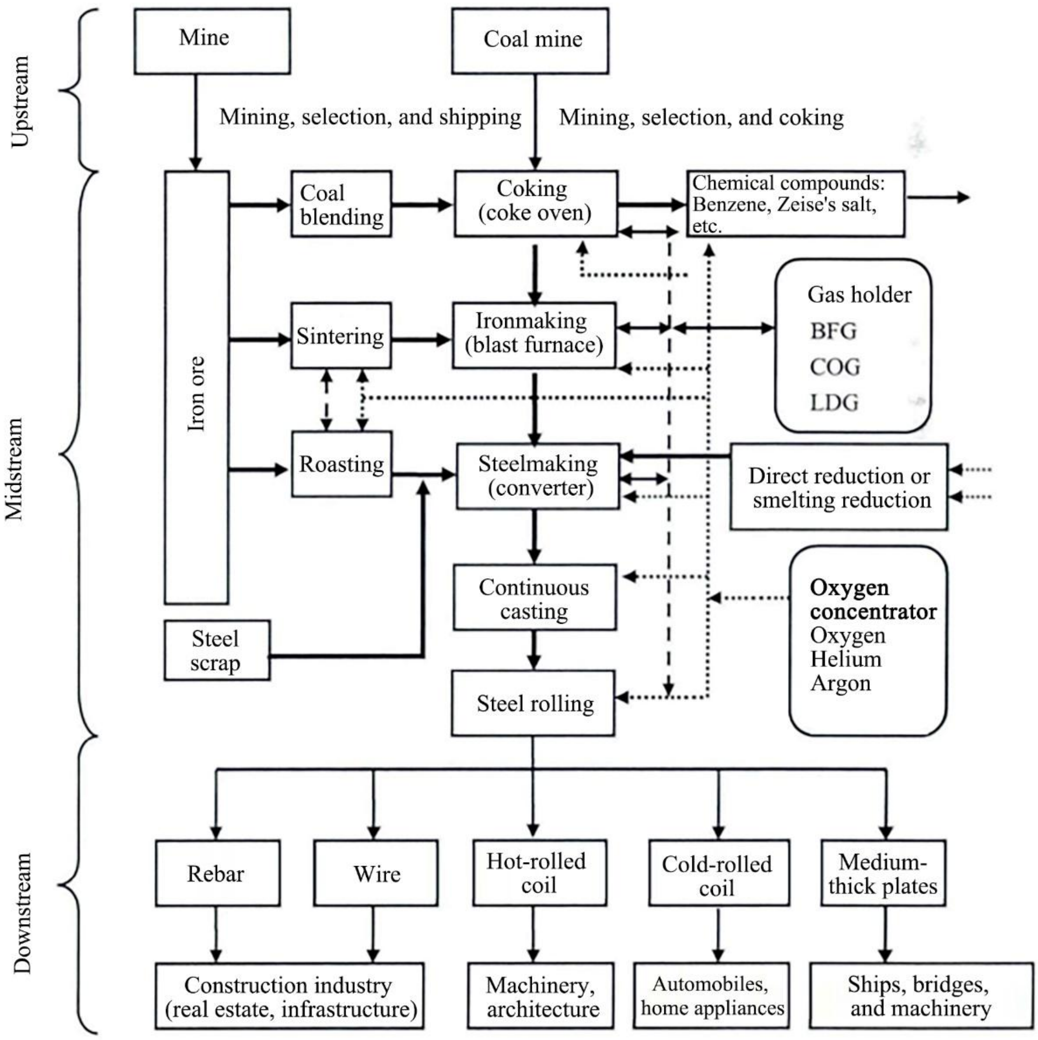

Figure 8.1 Schematic diagram of upstream and downstream industry chains of steel

The main smelting costs of steel include the costs of core raw materials such as iron ore, the costs of auxiliary materials such as limestone and refractories, the costs of fuels such as coal and gas, manufacturing costs, labor costs, and other costs regarding the recycling of waste gas and slag. Based on the principles of steel smelting, combined with the actual production of mainstream domestic steel plants, it is calculated that the production of each ton of pig iron requires 1.5-2 tons of iron ore, 0.4-0.5 tons of coke, and 0.2-0.3 tons of flux.

Based on the above analysis, it is known that the core factors influencing the costs of blast furnace ironmaking are the prices of iron ore and coke. Excluding the costs of iron ore and coke, other costs and expenses can be offset by the revenue from recycling various by-products generated during the ironmaking process. After being offset, these costs and expenses account for only about 10% of the total costs. The current mainstream steel smelting equipment in China consists of converters and electric furnaces. In steel smelting, the pig iron and scrap steel used by these two types of equipment exhibit a certain proportion. Specifically, with converters, the use proportion of scrap steel is only about 10%, while for electric furnaces, the use proportion rises to about 80%. According to the current macro policies, using electric furnaces for steelmaking is a high energy consumption method. Therefore, domestic mainstream steel smelting enterprises are all equipped with converters for steelmaking. In addition to the costs of main raw materials, other costs of steelmaking account for about 18%. The costs involved in the steel rolling process mainly include the expenses for gas and electricity, as well as costs regarding the wear of rolling equipment. Additionally, due to process differences among various types of steel, the rolling costs also differ slightly. On the whole, the steel rolling cost is RMB 150 to RMB 300 per ton.

Process	Blast furnace-converter	Short process-Electric arc furnace (EBT+LF+CC)	Short process-Medium frequency furnace (IF+CC)
Steps	Blast furnace smelting → Hot metal pretreatment → Converter smelting → Secondary refining → Continuous casting → Rolling	Electric arc furnace smelting → Secondary refining → Continuous casting → Rolling	Medium frequency furnace smelting → Rolling
Pig iron manufacturing cost per ton	RMB 1.6*iron ore + RMB 0.45*coke + RMB 0.13*pulverized coal injection + RMB 150 other expenses		
Crude steel manufacturing cost per ton	(RMB 0.96*pig iron + RMB 0.1*scrap steel) + (RMB 0.004* ferrosilicon + RMB 0.009*silicomanganese) + RMB 200 other expenses	RMB 1.13* (scrap steel%*scrap steel + molten iron%*molten iron) + (RMB 0.003*ferrosilicon + RMB 0.0065*silicomanganese) + (RMB 622*industrial electricity) + (RMB 0.0035*graphite electrode A + RMB 0.0006*graphite electrode B) + (RMB 54 refractory materials + RMB 75 auxiliary materials + RMB 37 gas + RMB 8 spare parts)	RMB 1.13*scrap steel price + (RMB 690*industrial electricity) + (RMB 22 refractory materials)
Rebar manufacturing cost per ton	RMB 1.02*crude steel + RMB 150 rolling + labor costs	RMB 1.02*crude steel + RMB 150 rolling + labor costs	RMB 1.02*crude steel + RMB 150 rolling + labor costs

Figure 8.2 Schematic diagram of steel production costs

Currently, for all relevant products in upstream and downstream links of the steel futures industry chain, there are corresponding futures contracts in the futures market. Based on the production relations of steel products, the futures industry chain profit hedging model has fully taken into account the futures market prices of various futures instruments in the industry chain. To facilitate research, the thesis takes the price of hot-rolled coil futures contracts as that of steel products, the price of iron ore and coke futures contracts of the same month as that of smelting raw materials, and the price difference among the three as the core indicator for monitoring the profits of steel mills. If the price difference deviates, it indicates a "malfunction" in the futures market. At this time, steel mills have excessively high profits, which creates an opportunity for profit hedging.

8.1 Strategic risks

Due to factors such as national policies and changes in macroeconomics, the strategy may face certain risks under specific circumstances, and in such cases, the hedging strategy may fail. Strategic risks are categorized into two types: 1. The risk of overall failure of the strategy; 2. The risk of an effective strategy with exposed vulnerabilities.

The risk of overall failure of the strategy mainly comes from major changes such as national policy adjustments and industrial structure transformation. For example, at the end of 2020, China proposed to reduce crude steel output in 2021. The steel industry plays a significant role in the national economy. Introducing policies regulating crude steel output can help control overcapacity and drive technological innovation, transformation, and upgrading in the steel industry. Under the influence of the policy, the annual crude steel output in 2021 decreased by about 30 million tons. Against the backdrop of policies regulating crude steel output, during the peak seasons of March, April, September, and October in 2021, the production profit of hot-rolled coils rapidly increased to over RMB 1,000 per ton of steel, reaching a record high. When there are national policy adjustments or industrial structure transformations, there may be a risk of overall failure of the strategy.

The risk of an effective strategy with exposed vulnerabilities arises from the difficulty in ensuring complete consistency between hedging instruments and underlying assets, which could lead to forced liquidation risks. In the actual production process of steel mills, steel is often processed into various finished products for sale, such as hot-rolled, cold-rolled, galvanized, and coated products commonly found in the sheet steel industry chain. Hot-rolled coil futures only track hot-rolled coils. Therefore, the risk arises when hot-rolled coil prices increase significantly. At the same time, the prices of other finished products do not rise as much, leading to a substantial widening of the price gap between hot-rolled coils and other finished products. For instance, the forced liquidation of nickel futures by companies such as Glencore in 2022 is an extreme example of this risk. The delivery material for LME Nickel futures is refined nickel, including nickel plates, nickel pellets, and nickel powder. The delivery requires compliance with the ASTM B39-79(2018) standard set by ASTM International, which specifies a nickel content of no less than 99.8%, or the National Standard GB/T 6516-2010 for Ni9990 grade, which requires a total content of nickel and cobalt of no less than 99.9%. The nickel products of Tsingshan Holding Group mainly include nickel matte, nickel alloy, ferronickel, and nickel sulfate, which are not consistent with the deliverable products of LME Nickel. Although Tsingshan Holding Group has achieved an annual production capacity of 1.8 million tons of nickel alloy, equivalent to about 180,000 tons of nickel metal, its products do not fully match the hedging instruments. Therefore, when many companies conduct forced liquidation on futures contracts, enterprises participating in hedging may still face exposed vulnerabilities.

8.2 Operational risks

The operational risk mainly originates from strategy implementation, referring to the risk of inadequate strategy implementation due to factors such as changes in the objective of strategy implementation, deviations in operation, and operational errors.

Changes in the objective of strategy implementation mainly refer to the transition in the hedging strategy's objective from hedging to speculation during the implementation process. Due to the hedging strategy's long implementation period, which sometimes may exceed one year, and the fact that production-oriented enterprises often possess a certain speculative mindset, the objective of strategy implementation may be affected by changes in managers' ways of thinking or subjective interference by the implementers, resulting in changes in the hedging strategy's objective. For example, some steel companies may consider raw material prices undervalued during the hot-rolled coil profit hedging process. They may choose to engage in hedging for raw materials instead of hot-rolled coils. In such cases, if there is a sharp drop in raw materials or steel material prices, steel companies may incur considerable unrealized losses. Conversely, if a company subjectively believes that hot-rolled coil prices are relatively overvalued and only engages in hedging for steel materials instead of raw materials, it may suffer substantial losses in the event of sharp increases in raw material or steel material prices.

Operational deviation in strategy implementation primarily refers to changes in the proportion of profit hedging during the process. For example, if a supply chain enterprise does not hedge following the proportion of $\text{Profit} = \text{HC} - 0.65 * \text{J} - 1.7 * \text{I}$ during implementation, but rather subjectively adjusts some parameters (for instance, J adopts 0.8 or I adopts 1.8), or there is excessive hedging of raw material or finished product inventories, operational deviation in strategy implementation will occur and bring significant risks to the hedging strategy.

Strategy implementation may also be affected by various other factors. For instance, errors in placing orders that will lead to failure in transactions at the market price, or “slippage” caused by unreasonable and excessive hedging and insufficient liquidity can cause additional risks or losses. Therefore, during strategy implementation, it is necessary to adhere to the fundamental objective of hedging, maintain the proportion of hedging even with short-term market fluctuations, and pay attention to significant changes in the futures market in real time to make profits or stop losses in time.

Other operational risks include:

(1) Errors in order placement. The operational risk that a trader mistakenly places orders is often reported in the news. Details are the key to success. Enterprises involved in hedging need to pay attention to operational

risks. First, it is recommended to employ skilled traders with professional knowledge who are familiar with trading rules such as contract codes, trading direction, and contract multipliers. Second, it is advised to establish dedicated trading channels for issuing trading instructions, and instructions issued by individuals other than the designated issuer should not be accepted. Futures trading instructions should involve stages of “order receiving”, “entrustment”, “reporting”, and “confirmation”, which coordinate with each other to reduce operational risks.

(2) Insufficient liquidity. Liquidity risk mainly refers to the risk posed by contract holders not hedging contracts promptly at reasonable prices or closing contracts. Enterprises participating in hedging should choose contracts with higher or sufficient liquidity. In the event of substantial hedging volumes, it is crucial to exit in time or transition to an active contract before losing liquidity.

(3) Changes in exchange rules. Enterprises participating in hedging need to monitor exchange trading rules closely. For instance, when margining for position maintenance, it is essential to reserve funds in advance to ensure that the hedging quantity meets the futures exchange’s position limit rules. They should promptly apply for hedging positions according to exchange rules to avoid forced liquidation due to unfamiliarity with the rules. Additionally, it is important to pay attention to changes in delivery brands and warehouses announced by the exchange.

(4) Delivery risks. If enterprises participating in hedging decide to go through delivery, they should be aware of delivery risks and ensure sufficient funds or physical goods for delivery. Before the delivery month, buyers and

sellers should adjust their positions to a deliverable multiple according to delivery rules. As a delivery seller, it is important to fully consider the transport time of physical goods, the work efficiency of delivery warehouses, and the limited number of delivery warehouses. It is necessary to confirm the storage capacity in advance. During delivery, the storage and inspection stages will be influenced to some extent by natural conditions and human factors, resulting in delivery risks. Hence, enterprises participating in hedging should start from easier to more challenging tasks and from smaller to larger quantities to control the delivery risks and avoid falling into the dilemma of forced liquidation.

8.3 Fundamental risks

8.3.1 Risks of industry chain process improvement

Process improvements may lead to changes in the consumption of raw materials and fuel. The coefficient in the profit formula of steel mills considers only the current production process of the steel mill. If there are future process improvements, such as reducing coke consumption or increasing scrap steel consumption, it is necessary to further optimize the formula by adjusting weights to prevent ineffective hedging caused by inconsistency between theoretical profit and actual production profit. Different steel mills should adjust coefficients suitable for their production based on their actual production consumption.

From the perspective of coke, the difference between spot profit and market profit results from steel mills using a variety different from the benchmark one on the market that has better quality. There is also a difference between iron ore and its benchmark variety, with the price gap between Super

Special and PB grades widening. Coke price premium/discount cycle: If the coke spot price increases before the coke price premium cycle, the rebar profit on the futures market may fall. Conversely, expectations of coke spot price decreases can boost profits of steel mills on the futures market, although actual inventory consumption at the plant may cause spot profits to fall behind market profits. For example, in 2021, there was an event in the alloy industry where production and electricity were restricted. This led to a surge in electricity costs, a decrease in alloy output, and a rapid increase in costs, driving up spot prices quickly in response to rising production expenses.

8.3.2 Risk of non-convergence due to macro factors

The factors influencing steel mill profits are complex. From a macro perspective, policy intervention has profound impacts on market profit dynamics.

The impact of policies on steel mill profits can be divided into three stages:

In the first stage, before 2015, the steel industry was in a relatively laissez-faire phase in terms of policy, which led to severe overcapacity, excessive medium frequency furnaces, and substandard steel products on the market. The phenomenon of “bad money driving out good” put large steel enterprises at an obvious disadvantage in price competition. At the same time, some steel enterprises lacked industrial self-discipline. In pursuit of maximizing profits, they recklessly expanded their production capacity, resulting in a severe oversupply and long-term unprofitability of steel materials.

In the second stage, in November 2015, China proposed the policy of supply-side structural reform. China's steel industry, focusing on "reducing overcapacity, reducing excess inventory, deleveraging, lowering costs, and strengthening areas of weakness", comprehensively carried out supply-side structural reform. Since 2016, major steel-producing regions have successively completed their annual capacity reduction tasks, with a cumulative reduction of 45 million tons of crude steel capacity in 2016, 50 million tons in 2017, and 30 million tons in 2018. By the end of 2018, the steel capacity reduction upper limit of 140-150 million tons set in the 13th Five-Year Plan was completed ahead of schedule. Meanwhile, the frequent environmental protection production restrictions had a huge impact on reducing steel output in major steel-producing regions, thus making steel profits remain at a relatively high level for a long time during this period.

In the third stage, since 2019, policy measures have focused on consolidating the results of capacity reduction, preventing the resurgence of substandard steel products, and strictly managing capacity replacement. However, in the past two years, steel capacity replacement has allowed some backward and "zombie" capacities to re-enter the stage. Short-term oversupply has not been fundamentally resolved, resulting in a year-by-year decline in steel prices and steel material profits.

Data on the capacity replacement schemes issued by major steel mills from 2017 to 2019 show that through capacity replacement, steel mills nationwide have reduced ironmaking capacity by 230 million tons and steelmaking capacity by 270 million tons, while adding 210 million tons of ironmaking capacity and 230 million tons of steelmaking capacity, with an average replacement ratio of 1.13:1. From this perspective, the problem of overcapacity in the industry will continue to exist as new capacity is gradually put into production.

The policy has a moderate degree of predictability. In the socialist market economy system, there is usually minimal excessive intervention in policies, with the market's invisible hand allowed to self-regulate. However, policy intervention will occur when the contradictions become so prominent that they affect the normal functioning of the market. The concept of supply-side reform in the steel industry was first proposed in November 2015, when the industry was experiencing its most severe losses.

To avoid the risk of non-convergence due to macro factors, under different policy backgrounds, it is necessary to adjust the hedging entry points and position proportions according to macro policies.

8.4 Countermeasures

8.4.1 Daily/regular risk exposure management

Exposure refers to the portion of financial risks that exist in financial activities and the extent to which these activities are affected by financial risks. Risk exposure refers to exposed vulnerabilities. To reduce and effectively control risks, banks or creditors will take measures to offset risks, a process known as hedging. The risks that remain unmitigated after hedging are referred to as "risk exposure". In a broad sense, risk exposure means the total balance of various risk assets held by a bank. In the thesis the exposure of industry chain hedging usually refers to trading exposure.

Daily risk exposure calculation

In the thesis, the strategy of industry chain futures market profit hedging has been adopted to help enterprises earn profits and gain revenue from futures investments. Taking hot-rolled coil futures as an example. A portfolio consists of futures varieties of iron ore, coke, and hot-rolled coils, forming a long-short investment portfolio. Due to differences in product unit price and profit replication ratios, the long-short portfolio is not one with zero nominal principal, which can lead to risk exposure. Based on the strategy's features, the risk exposure can be calculated as follows:

Daily risk exposure = Hot-rolled coil nominal principal - Iron ore nominal principal - Coke nominal principal.

Regular risk exposure calculation

The daily risk exposure calculation is used to monitor the level of risk exposure each day instead of predicting the potential changes in exposure trends. The regular risk exposure calculation considers the potential losses caused by adverse market conditions. The regular risk exposure calculation usually employs the Value at Risk (VaR) method.

VaR is the maximum potential loss a financial asset or securities portfolio may incur over a certain period at a specified confidence level.

Based on this definition, to build a VaR model for a financial asset or securities portfolio or calculate its value, three coefficients need to be determined: holding period $\triangle t$, confidence level α, and observation period.

1. Holding period $\triangle t$ refers to the period over which the maximum loss of the assets held needs to be calculated, showing the risks of assets managed by risk managers during this period. The choice of holding period needs should

be based on the characteristics of assets held or managed. For highly liquid positions, daily intervals are often chosen to calculate daily risk returns and daily VaR values. Similarly, for over-the-counter derivatives, daily intervals are selected to calculate daily VaR values. However, for long-term positions (such as pension funds), monthly intervals are typically chosen to calculate monthly VaR values.

2. Confidence level α. Typically, the choice of confidence interval or confidence level reflects, to some extent, the risk preference of financial institutions or managers. A larger confidence interval signifies a smaller acceptable range of risk, a greater aversion to risk, and a desire to determine forecast results with higher certainty and accuracy. In other words, it is hoped that the chosen model can accurately predict regular outcomes and forecast extreme events with high accuracy. The choice of confidence intervals varies with the risk preferences of financial managers. For example, Bankers Trust, being more risk-averse, sets its confidence level at 99%, while JPMorgan Chase Bank, Citibank, JPMorgan Chase & Co., and Bank of America respectively choose 97.5%, 95.4%, and 95% as their confidence level.

3. The observation period refers to the range of data with volatility and correlation that needs to be studied under a given confidence level and holding period, and it is therefore called the data window. For example, choose the observation period of a certain asset's data for the next 6-12 months, examine the volatility risk of its weekly holding return rate, and make sure that the choice of observation period balances the likelihood of historical trading data predicting future trends with the risks brought by market structure changes. To overcome the impact of business cycles, it is generally preferable to have a

longer historical data period. However, if the period is too long, there is a higher likelihood of market structural changes, making it difficult for historical trading data to accurately reflect the correlation between the present and the future.

Based on the above analysis, the regular risk exposure is calculated as follows:

Regular risk exposure = Position direction * (Historical hot-rolled coil α% N-day maximum loss * Hot-rolled coil nominal transaction amount - Historical coke α% N-day maximum loss * Coke nominal transaction amount - Historical iron ore α% N-day maximum loss * Iron ore nominal transaction amount)

Setting of enterprise architecture and other monitoring indicators

In terms of organizational structure, it is recommended that enterprises involved in hedging establish risk control positions or departments independent of research and trading decisions to monitor and manage risks.

Primary monitoring indicators include strategy profitability and risk exposure. Other monitoring indicators can be set by enterprises based on specific strategy requirements (such as maximum position size, the proportion of maximum position size in total production capacity, warning lines, and stop-loss lines).

In terms of monitoring methods, risk control personnel monitor strategy profits/losses, risk exposure, and the difference between the dynamics of other risk indicators and pre-set indicators. During business operations, they report alerts promptly when risk exposure reaches the upper limit and reduce risk exposure exceeding the limit.

Monitoring periods can be divided into real-time monitoring and regular reporting. The latter can be determined based on the management needs and staffing of enterprises.

8.4.2 Monitoring of strategic risk indicators

The previous section focused on the calculation and monitoring measures of portfolio risk exposure from the perspective of a company's risk control department. This section mainly discusses risk management methods of the strategy in implementation.

Regularly test the mean reversion characteristics and parameter stability among futures varieties

This strategy is an industry chain investment strategy derived from the assumption that the residuals among futures varieties satisfy mean reversion characteristics. Therefore, the loss of correlation among futures varieties is one of the important risks faced by the strategy. Based on the issue, it is necessary to regularly test the strategy from two aspects: 1) Whether the long-term equilibrium relationship among futures varieties still exists. 2) Whether the regression coefficient among futures varieties has changed significantly. The verification methods for the two aspects can be found in Chapter 6 of the thesis.

The strategic setting of single-entry stop-loss and continuous stop-loss suspension

The profit model of this strategy is to earn returns from the mean reversion of the price difference among futures varieties. Hence, there is a possibility of loss when the price gap among varieties continues to widen. If the price gap widens significantly, there may be a risk of substantial losses or even liquidation. Given this, the strategy should set single-entry stop-loss and continuous stop-loss suspension.

Single-entry stop-loss: Set a maximum loss value for each trade when entering the market using a strategy based on the position and investment amount. Generally, the maximum loss value varies from 2% to 10% of the total investment amount. If the cumulative losses during the holding period reach the maximum loss value, it is advisable to close out the position and wait for the next trade.

Continuous stop-loss suspension: Set a continuous stop-loss tolerance value (generally 5-10 times) in advance before strategy implementation. When the strategy triggers a single-entry stop-loss repeatedly and continuously, it is possible that the fundamentals of the variety have changed, or the widening of the price gap among varieties has not ended. Therefore, the investor should suspend the strategy for some time until he/she believes that the fundamentals have returned to normal or the widening of the price gap is approaching its end.

9 Conclusions and Suggestions

This chapter sorts out all the research content of the thesis and presents the research conclusions. Based on this study, this chapter puts forward corresponding policy suggestions. Finally, this chapter summarizes the study's shortcomings and shows prospects for possible future research directions.

9.1 Conclusions

This thesis proposes a futures market profit hedging model based on the bulk commodity industry chain. Traditional hedging strategies usually center around a single product, commonly involving companies hedging against the price of their end products or essential production materials. Traditional hedging strategies can only help enterprises fix the cost of one variety, but they cannot hedge against the price fluctuations among varieties. Therefore, traditional hedging strategies no longer meet the production management needs of enterprises, and it is necessary to establish hedging strategies that match the volatile domestic and international markets. With a diverse range of products, China's futures market covers the production processes of multiple varieties, enabling enterprises to replicate the upstream and downstream industry chain products involved in the production of end products in the futures market.

At the theoretical level, the thesis employs the Cournot model and proposes an improved Cournot model based on futures profit expectations. By innovatively integrating futures prices as future price information into the model's mechanism, the thesis derives the optimal production arrangement for enterprises under the classic Cournot model. By comparing the optimal production equations of enterprises using two types of models (the classical model and the improved model considering futures), the thesis finds that: 1) When current futures market profit is high, enterprises focusing on futures will raise their expectations for future price ceilings and produce more products; 2) If other manufacturers do not consider futures market profits and adopt static price ceilings, manufacturers monitoring futures market prices can earn more production profits through futures hedging in the bull market (when futures market profits are high) and produce fewer products in the bear market (when futures prices are low) to avoid losses and gain a competitive advantage; 3) If all manufacturers focus on futures market profits and ignore the equilibrium price ceiling, then when market profit is high, the total output Q will be too high, resulting in an increase of D_{T+1} in spot inventory for the next period. This will affect the spot price for the T+1 period and even cause losses of manufacturers. The results of the theoretical model show that enterprises referring to futures market profit can better arrange their production plans, thus smoothing out price fluctuations brought by the cycles. Enterprises that can correctly apply the profit information of the futures industry chain will also gain better competitive advantages in the competition, which also explains why the number of enterprises engaged in hedging has been increasing in recent years.

At the empirical level, the thesis takes hot-rolled coil varieties as examples and builds a hedging model based on the market profit of hot-rolled coil futures. The empirical analysis of the thesis unfolds in two aspects: 1) The thesis verifies that the price residuals of hot-rolled coil futures, coke futures, and iron ore futures satisfy the mean reversion relationship from statistical significance and actual production significance, confirming the possibility of industry chain hedging; 2) The thesis establishes several hedging investment strategies, including traditional single-commodity hedging strategies and those based on market profits. Through comparison of the two types, it is found that hedging strategies based on market profits have higher ROI, higher opening rates, and lower volatility, indicating certain advantages of these hedging strategies.

Additionally, regarding the hedging strategies discussed in the thesis, the thesis also studies the risk management of industry chain futures market profit hedging. By summarizing, the thesis identifies three major risks associated with industry chain futures profit hedging: Strategic risk, operational risk, and fundamental risk. Strategic risk refers to the overall failure of the strategy or the risk of an effective strategy with exposed vulnerabilities. Operational risk refers to the risk of inadequate strategy implementation due to factors such as changes in the objective of strategy implementation, deviations in operation, and operational errors. Fundamental risk refers to the changes in profit coefficients and macro risks brought about by improvements in enterprise production processes. Subsequently, the thesis proposes various risk management methods to address the identified risks, including daily/regular risk exposure management, monitoring of strategic risk indicators, and the establishment of internal risk control systems of enterprises.

In future expansions, the empirical process and strategy formulation of the thesis can be easily applied to other varieties. Corn, soybean meal, and live pig futures can form a futures industry chain for live pig breeding. Rebar, iron ore, and coke futures can form an industry chain for rebar production. Similar industry chains are widely present in the chemical industry and the black futures sector. Therefore, live pig farmers can use the method proposed in the thesis to hedge profits for live pig farming, and steel manufacturers can also use a similar method to hedge profits for steel production. The specific implementation methods are: 1) Determine the futures profit hedging formula based on econometric statistics or production relations of products; 2) Backtest the historical data of the determined futures profit hedging formula, calculate residuals of the profit hedging formula, and test the residuals' stationarity; 3) If residuals pass the stationarity test, it indicates that the profit hedging formula is effective in the futures market, and one can set the profit quantile for the futures market and use different positions to enter the market for profit hedging based on different quantiles.

9.2 Suggestions on industry chain hedging for enterprises

When enterprises conduct hedging, it is crucial to prioritize the hedging strategy's effectiveness. Enterprises should make adequate preparations for hedging, attach great importance to all aspects of hedging, and supervise the hedging process. This process involves market analysis, the formulation of hedging strategies, implementation, and delivery, as well as supervision and management.

(I) Market analysis

The hedging strategies proposed in the thesis only take information from the futures market as the basis for hedging. However, in actual operation, the fundamental information of various varieties and industry chains should be taken into account in decision-making. Careful analysis and judgment of market trends are the basis of correct decision-making. Enterprises should establish fast information channels to study and predict future market trends. The information involved in market analysis includes but is not limited to:

1. The global economy's development: The development of the global economy aims to help enterprises analyze the stage of the current global economic cycle to judge changes in demand on a global level and supply-side production arrangements for their production plans.

2. Research reports of foreign institutions: A large number of institutions at home and abroad have released various research reports on the trends of all kinds of commodities. These include domestic and overseas investment banks and global leading bulk commodity enterprises. Research reports from such institutions are of significant reference value for enterprises.

3. Inventory of important domestic and foreign warehouses: The production, logistics, and application of bulk commodities require warehouses to store spot products. The inventory of bulk commodities can also help enterprises analyze changes in the supply-demand dynamics of bulk commodities.

4. Domestic spot market trends: The bulk commodity market is where domestic bulk commodity enterprises are mostly actively involved. Enterprises engage in purchasing bulk commodities and selling their finished products in this market. Spot market trends directly affect the revenue changes and ultimate profits of bulk commodity enterprises. Enterprises should react promptly and quickly to changes in the spot market.

5. Domestic and international import and export policies on bulk commodities: China is a major importer of bulk commodities and a major exporter of finished products. Therefore, international trade has a significant

impact on bulk commodity enterprises. International exchange rates and the import and export policies on bulk commodities can also affect the production arrangements of enterprises. For example, Southeast Asian countries such as India, Malaysia, and Thailand have imposed export quota restrictions on rubber several times, causing impacts on the production of related enterprises in China.

6. Feedback from the futures market: The futures market is a derivative market of the spot market, but it can also reflect the spot market's expectation of subsequent changes in a variety to a certain extent. This thesis has improved hedging strategies for enterprises by analyzing the profit relationship of industry chains in the futures market and has achieved some results.

(II) Formulation of hedging strategies

After analyzing international and domestic macroeconomic conditions, industry trends, and expectations for varieties, the futures department of a bulk commodity enterprise should formulate interim or annual hedging strategies based on the enterprise's business development goals and production capacity constraints. On this basis, the hedging strategies should be submitted to the enterprise's business leadership team for review. After the leadership team's approval, workable hedging strategies are formed.

The formulation of hedging strategies must clarify the following points:

(1) Hedging target: During the planning period, it is necessary to clarify whether the hedging is for a single commodity or multiple commodities and whether it is hedging at the cost end or the product end.

(2) Hedging direction: The direction of hedging should be determined based on the production situation of the product. For example, if the hedging

target is the raw material on the production side, the buying price should be locked; conversely, the selling price should be locked.

(3) Hedging quantity: The hedging quantity should match an enterprise's production arrangements and should not exceed the enterprise's production capacity limit. Otherwise, there is a risk that hedging may turn into speculation.

(4) Hedging price: The hedging price will directly affect the outcome of current hedging. It is recommended that enterprises adopt the method of batch-based position establishment and gradual accumulation used in the thesis for market hedging accumulation to avoid excessive risk exposure in a short period.

(5) Hedging duration: The hedging duration should match the enterprise's production-sales cycle. If hedging is only for products at the production end, the position should be closed after the annual production procurement is completed. Similarly, hedging at the product end should match the sales cycle of products.

(III) Implementation of hedging strategies

After hedging strategies are approved, first, the futures department of the enterprise should formulate a specific hedging operation plan. Second, the hedging operation plan must receive approval from relevant leaders before implementation commences. Finally, the results of the operation need to be reported daily or at regular intervals to the leader in charge of futures. The leader responsible for the enterprise's futures business should conduct timely and effective supervision and inspection of hedging strategy implementation.

(IV) Delivery of hedging positions

The spot department should timely inform the futures department of the information on commodities that need to be physically delivered within one month before the delivery month. After the delivery is completed, the futures department should promptly submit the warehouse receipts to the financial management department. If the spot department is unable to deliver on schedule due to various reasons such as shortages of commodities, tight funds, or transportation obstructions, the spot department needs to promptly report specific situations to the enterprise leaders in charge. The responsible leaders will discuss and coordinate the handling of such situations. If the delivery of commodities still cannot be completed after coordination, the spot department must inform the futures department to close out the position before the delivery month.

(V) Fund management and allocation

The funds used for futures hedging should be authorized within a reasonable range to the futures department for allocation. First, the futures department should develop a plan for the capital requirements of hedging and a utilization scheme. Second, after the plan and scheme are confirmed, the necessary margin must be provided punctually according to the timeline and capital demand of the scheme. If there is an urgent need for additional margin due to special circumstances during implementation, the futures department should submit a written application and increase the margin after obtaining consent from responsible leaders. Finally, it is particularly important to ensure that any balance of margin funds is promptly withdrawn during the use of the margin.

(VI) Supervision and management

Enterprises engage in futures hedging with the primary objective of avoiding market risks. Therefore, during futures hedging, enterprises should not only enhance their business capabilities and management skills but also strengthen compliance in various aspects such as decision-making and authorization. Meanwhile, they should establish a risk supervision system to effectively monitor operational risks and handle the balance between decentralization and centralization. By creating a supervision system that has effective constraint mechanisms while maximizing the initiative of operators at all levels, enterprises can improve their risk management capabilities and ensure the smooth implementation of futures hedging.

Based on the process of enterprise hedging transactions, effective supervision should include the following dimensions:

1. Effective supervision during the formulation of hedging plans and implementation schemes.

2. Supervision during the hedging transaction process.

3. Post-event supervision and audit system.

9.3 Research limitations and prospects

The limitations of this study mainly include:

Based on futures market profits and the classic Cournot model, the thesis proposes an improved Cournot model that takes into account the futures market. However, besides price, many factors in the futures market are worthy of being included in investment decision-making. Neglecting many such factors and solely considering the price factor is one of the limitations of the thesis.

When formulating investment hedging strategies, the thesis adopts a simple method based on historical price percentiles to determine entry points. At the practical operation level, this method is somewhat simplistic and may cause early entries in extreme historical market conditions, resulting in longer holding periods and a worse holding experience. The method needs to be further optimized.

When formulating hot-rolled coil industry chain hedging strategies, the thesis fails to take into account the actual production situations of enterprises, making hedging strategies somewhat deviate from the production conditions of enterprises. However, enterprises have different production processes and capacities. This thesis overlooks these factors and adopts a certain amount of investment as the investment capital.

Limited by the length of the thesis and research abilities, this study still has many shortcomings. Many research contents need to be continuously advanced in future studies, which is hereby pointed out.

This thesis only considers the hot-rolled coil industry chain as the research subject. As more futures varieties are continuously listed in China, there will be more and more industry chains whose products in upstream and downstream links are listed on the futures market. Research methods proposed in the thesis can also verify the feasibility of profit hedging for such industry chains. Moreover, not only China has futures markets. Whether the related varieties in international mainstream futures markets also exhibit similar mean reversion characteristics is also a topic worth studying.

The hedging strategies in the thesis do not take into account the actual production cycle and production capacity constraints of enterprises. In actual production, the cycle of procurement-production-sales also exists, while the calculation of futures market profits is completed in real time. Will the mismatch between the cycle and calculation affect the ultimate effectiveness of hedging? Furthermore, different enterprises have slightly different production processes and production capacity limits. How to take such factors into account in hedging strategies to make them more closely aligned with enterprises' actual situations is the direction of subsequent research.

References

[1] 高辉，赵进文. 沪深300股指套期保值及投资组合实证研究[J]. 管理科学，2007（02）：80-90.

[2] 井天祥，杨金正. 沪深300指数期货套期保值比率动态调整的套期保值策略分析[J]. 投资与合作，2022（03）：19-21.

[3] 李献刚. 企业套期保值面临的困境及对策[J]. 特区经济，2021（12）：119-122.

[4] 梁斌，陈敏和缪柏其等. 我国股指期货的套期保值比率研究[J]. 数理统计与管理，2009，28（01）：143-151.

[5] 林孝贵. 基于收益与风险比率的期货套期保值策略[J].系统工程.2004(1):74-77.

[6] 刘晓宇，潘军昌和王雨桐等. 期货市场价格对农业投资者行为的影响研究——基于中国豆粕产业投资者套期保值和产能扩张行为[J]. 南方农机，2022，53（10）：194-198.

[7] 潘长风赵华. 在协整分析中如何处理截距和趋势[J]. Shu liang jing ji, ji shu jing ji yan jiu，2004，21（1）：106-109.

[8] 彭红枫，叶永刚. 基于修正的ECM-GARCH模型的动态最优套期保值比率估计及比较研究[J]. 中国管理科学，2007（05）：29-35.

[9]齐明亮. 套期保值比率与套期保值的效绩——上海期铜合约的套期保值实证分析[J]. 华中科技大学学报(社会科学版)，2004（02）：51-54.

[10]史晋川，陈向明和汪炜. 基于协整关系的中国铜期货合约套期保值策略[J]. 财贸经济，2006（11）：37-40.

[11]佟孟华. 沪深300股指期货动态套期保值比率模型估计及比较——基于修正的ECM-BGARCH(1,1)模型的实证研究[J]. 数量经济技术经济研究，2011，28（04)：137-149.

[12]王辉，谢幽篁. 中国商品期货动态套期保值研究:基于修正ADCC和DADCC-GARCH模型的分析[J]. 世界经济，2011（12)：120-139.

[13]王骏张宗成赵昌旭. 中国硬麦和大豆期货市场套期保值绩效的实证研究[J]. 中国农业大学学报，2005（04)：131-137.

[14]吴冲锋钱宏伟吴文锋. 期货套期保值理论与实证研究(I)[J]. 系统工程理论方法应用，1998（04)：20-26.

[15]袁象王方华曹范愚. 协整关系对期货套期保值策略的影响[J]. 数理统计与管理，2003（02)：44-47.

[16]张屹山，方毅和黄琨. 中国期货市场功能及国际影响的实证研究[J]. 管理世界，2006（04)：28-34.

[17]曹望. 热轧卷板期货价格影响因素的实证分析[D].浙江大学, 2019. DOI: 10.27461/d.cnki.gzjdx.2019.000277.

[18]崔超.我国热轧卷板期货价格与现货价格动态关系研究[J].中国管理信息化, 2015,18(15):147-149.

[19]王梦丽. 我国钢材期货价格波动及影响因素的研究[D].山东大学,2018.

[20]吴坡特. 便利收益分析与期现套利[D].厦门大学,2018.

[21]张一丁. 中缅管线热轧卷板的原料套期保值项目风险管理研究[D].东北大学,2014.

[22]李岩. 中国钢材期货市场非线性特征及套期保值策略研究[D].东北大学,2017.

[23]闫希辉,张好治,张保华.食用油套期保值品种可替代性研究[J].粮食与油脂, 2009(07):33-34.

[24]郭炜,刘宜忠.利用铜期货代替铅从事套期保值业务的探讨[J].财政监督,2009(10):13-14.

[25] 首创期货.废钢市场如何利用钢铁期货实现套期保值[J].资源再生,2009(04):48-49.

[26]徐长宁.品种替代的套期保值方法浅析[J].中国金属通报,2014(13):24-26.

[27]王瑞庆. 考虑期权交易的电力市场纳什均衡及发电商竞争策略研究[D].上海大学,2009.

[28]邢伟,马珊珊,宋雅婷等.基于现货市场的双寡头制造商风险管理策略研究[J].系统科学与数学,2016,36(06):822-834.

[29]张瀚元,殷晓鹏.贸易壁垒对产业链下游寡头市场均衡的影响——以大豆产业链为例[J].宏观经济研究,2020(10):42-57+125.

[30]燕嘉敏.基于消费者剩余的异质企业古诺双寡头博弈的动态竞争[J].兰州文理学院学报(自然科学版),2022,36(06):21-28+58.

[31]周晓阳,陈可欣,温浩宇等.政府补贴下考虑零售商不同竞争行为的闭环供应链决策及合同选择[J].中国管理科学,2022,30(03):176-188.

[32] ENGLE, R. F., GRANGER, C. W. J. Co-Integration and Error Correction: Representation, Estimation, and Testing[J]. Econometrica, 1987, 55 （2): 251-276.

[33]Chen, T., Li, W. and Yu, S., 2021. On the price volatility of steel futures and its influencing factors in China. Accounting, pp.771-780.

[34] Qiao, Han & Mao, Yingming & Liu, Xiang & Zhao, Yingxue. (2012). An Exploration on Cross Hedging Method of Chinese Steel Enterprises for Spot Iron Ore and Enlightenments. Proceedings of the 2012 5th International Conference on Business Intelligence and Financial Engineering, BIFE 2012. 172-176. 10.1109/BIFE.2012.44.

[35] Lim, Siew & Turner, Peter. (2016). Airline Fuel Hedging: Do Hedge Horizon and Contract Maturity Matter?. Journal of the Transportation Research Forum. 10.5399/osu/jtrf.55.1.4325.

[36] Castle, Kevin. (2015). Case Study: NuSkin Future Pricing Strategy.

[37] Zhao, Jieyuan & Goodwin, Barry. (2012). Dynamic Cross-Hedge Ratios: An Application of Copula Models.

[38] Hayenga, M.L., and D.D. DiPietre. "Cross-Hedging Wholesale Pork Products Using Live Hog Futures." American Journal of Agricultural Economics 64 (1982):747-751.