Commodity Price Exposures of Chinese Steel Producers

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List of Abbreviations

BF/BOF	blast furnace/basic oxygen converter (method)
CCPI	China Coal Price Index
CFR	cost and freight
CNCA	China National Coal Association
CNY	Chinese yuan
CSI	China Securities Index
CSRC	China Securities Regulatory Commission
EAF	electric arc furnace (method)
Fe	iron
IODEX	Platts Iron Ore Index
ICE	Intercontinental Exchange
LCH	London Clearing House
LTC	long-term contract
MBIO	Metal Bulletin Iron Ore (Index)
MBIO-62	Metal Bulletin's iron ore (62% Fe fines)
NAFTA	North American Free Trade Agreement
OTC	over-the-counter
S&P	Standard and Poor's
SSE	Shanghai Stock Exchange
ST	special treatment
SZSE	Shenzhen Stock Exchange
TSI	The Steel Index
US/USA	United States of America
USD/US$	United States (US) dollar/s

Abstract

Important financial risks facing Chinese steel producers include steel, iron ore and coking coal price risks. This thesis estimates the exposures to these financial risks for 31 publicly listed Chinese steel producers between 2008 and 2015. Furthermore, this thesis investigates the impact of a regime shift from long-term to short-term pricing contracts on iron ore exposures. Iron ore prices have become increasingly volatile since this regime shift. Steel producers are expected to be exposed to iron ore prices, one of the key inputs for steelmaking. As the world's largest group of steel producers, Chinese steel producers rely heavily on iron ore imports, due to the undersupply of high quality iron ore from the Chinese domestic region. This study examines the commodity price exposures facing Chinese steel producers. In particular, it investigates their exposures to iron ore prices and how these exposures have changed since the iron ore pricing regime shift in 2010. The study finds that Chinese steel producers are in general positively exposed to steel price and negatively exposed to iron ore price, but natural hedge exists between iron ore and steel. In addition, the impact of regime shift on iron exposures only becomes significant when longer horizon data are analysed.

Declaration

I certify that the work in this thesis entitled "Commodity price exposures of Chinese steel producers" has not previously been submitted for a degree nor has it been submitted as part of the requirements for a degree to any other university or institution other than Macquarie University. I also certify that the thesis is an original piece of research and it has been written by me. Any help and assistance that I have received in my research work and the preparation of the thesis itself have been appropriately acknowledged. In addition, I certify that all information sources and the literature used are indicated in the thesis.

Hui Yu

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Chapter 1. Introduction

The steel industry is generally facing bulk commodity price risk exposures[1] to steel, iron ore and coking coal, due to the fact that iron ore and coking coal are the two major inputs for steel production, and steel is the product of the industry. Since the second quarter of 2010 when the long-term contract pricing mechanism[2] came to an end, iron ore prices have become extremely volatile. Specifically, the iron ore price reached its historical high of US$190.15 per metric tonne in February 2011, and has dropped more than four times during the last five years to US$41 per metric tonne at the end of 2015. As the world's largest group of steel producers and iron ore consumers, Chinese steel producers are expected to face significant exposure to iron ore prices.

The pricing mechanism shift for iron ore and the increasing price volatility that has followed have led to several questions. Firstly, are the Chinese steel producers exposed to iron ore prices at a significant level? Secondly, since the structural change in the iron ore pricing mechanism, has the iron ore price exposure of the Chinese steel producers changed? Finally, as the steel producers are facing both steel price exposure (the revenue side of risks) and iron ore price exposure (the cost side of the risks), is the cost side of the risk, to some extent, offset by the revenue side of the risks?

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[1] In this study, the term 'exposure' is defined as the sensitivity of stock returns to the price changes of an underlying asset. This definition is consistent with the major existing literature on financial risk exposures including studies by Jorion (1990), Tufano (1998), Jin and Jorion (2007), Carter et al. (2006), Treanor et al. (2014) and Berghöfer and Lucey (2014).

[2] The global iron ore pricing mechanism was largely based on long-term contract prices that were adjusted annually. This pricing mechanism has changed from the first half of 2010 when annual pricing contracts were adjusted to quarterly pricing contracts. Since 2011, the pricing period has been shortened to monthly and towards spot prices (Caputo et al., 2013; Dalian Commodity Exchange, 2013).

On the topic of the risk exposures of non-financial firms, many studies[3] investigate exposures to changes in exchange rate, interest rate and commodity prices. When analysing the commodity price exposures that non-financial firms are facing, many researchers focus on the prices of resource commodities such as gold (Jin and Jorion, 2007); oil and gas (Jin and Jorion, 2006); jet fuel (e.g. Loudon, 2004; Carter et al., 2006; Treanor et al., 2014; Berghöfer and Lucey, 2014; Mohanty et al., 2014); or commodity price risks across different industries (Bartram, 2005). However, few studies have examined the commodity price exposures facing steel producers and even fewer have specifically analysed the iron ore price exposure.

Although Jorion (1990) suggests that the exchange rates present higher volatility than other financial prices, such as the interest rate and inflation, and thus becomes a more important source of risk, Bartram (2005) shows that commodity prices present even higher volatility than most foreign exchange rates and interest rates. This is also true of the iron ore and steel price volatility. Figure 1.1 presents the weekly returns of the risk variables applied in this study. Panel (A) graphs the weekly returns of China Securities Index (CSI)'s 300 Index. Panels (B), (C) and (D) graph the weekly price changes of the three commodities: iron ore, steel and coking coal. Panel (E) graphs the weekly changes in the foreign exchange rate. When these are compared, the price changes of iron ore are shown to have the highest volatility among the three commodities. Moreover, the foreign exchange rate presents the lowest volatility among these price changes. This is due to the fact that, until the end of 2015, the exchange rate of the Chinese yuan (CNY) to the US dollar (USD) was still not freely traded globally, and was controlled by the Chinese

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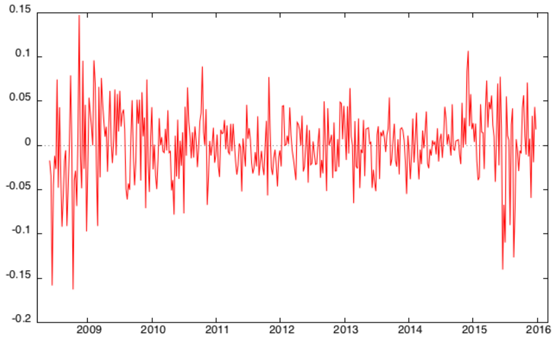
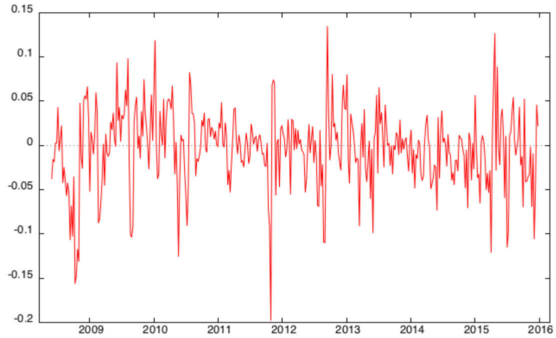
[3] Smithson and Simkins (2005) review a list of the current literature on exposures and risk management.

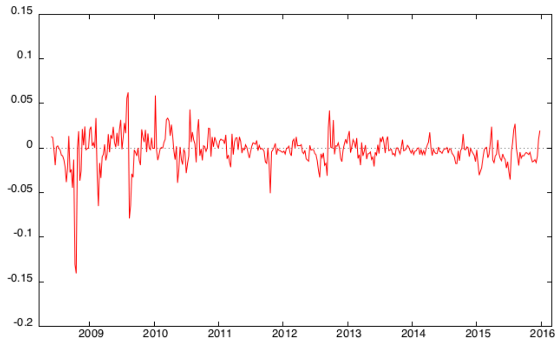
government. According to Figure 1.1, the Chinese steel producers are expected to be more exposed to commodity price risks, especially to iron ore price risks, than to exchange rate risks.



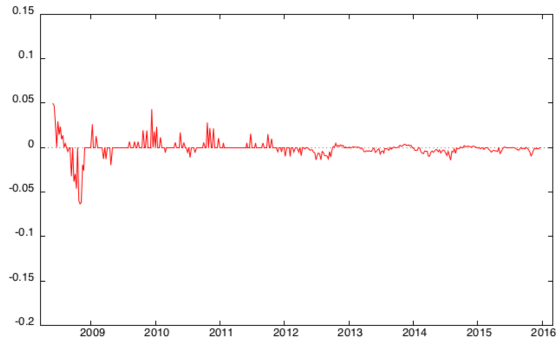
(A) CSI 300 index weekly returns



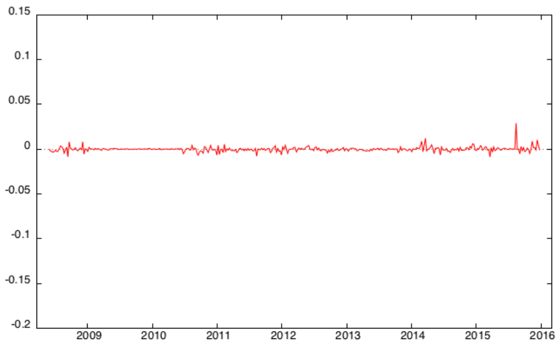
(B) Iron ore spot price index weekly returns



(C) Steel spot price index weekly returns



(D) Coking coal spot price index weekly returns



(D) USD/CNY index weekly returns

Figure 1.1 Risk Variables

The purpose of this study is to examine the commodity price exposures facing the steel producers in China. An investigation of the Chinese steel industry and the commodity price exposures faced by Chinese steel producers is of considerable significance. This study seeks to contribute in the following aspects.

Firstly, iron ore prices have become increasingly volatile since the late 2000s. This has become a serious issue for Chinese steel producers as they rely heavily on importing iron ore (Dalian Commodity Exchange, 2013). Therefore, it is essential that an examination is undertaken of whether the iron ore price exposure of steel producers has changed as a result of the iron ore pricing regime shift in 2010. Not only is this study expected to fill the gaps in previous research by examining commodity price risks facing a different industry—the steel industry—at the same time, it focuses on a type of commodity price risk that has not been studied extensively, namely, the iron ore price risk.

Furthermore, by comparing iron ore price exposures facing the steel industry before and after the iron ore pricing mechanism regime shift, this study contributes to both the steel industry and the iron ore mining industry by providing information on how the volatility of iron ore prices has changed due to the regime shift, and how it has affected the exposures of steel producers. In this study, the data sample period is set between May 2008 and December 2015, thus including the structural change for iron ore prices in the second quarter of 2010. This structural change provides a natural experiment for testing this research topic.

The earlier literature on exposures to commodity price risks mainly uses a single risk horizon (Tufano, 1998; Bartram, 2005; Jin and Jorion, 2006; Mohanty, 2014; Berghöfer and Lucey, 2014; Treanor et al., 2014). Following the approach adopted by Nguyen and Faff (2003) and Loudon (2004), this study applies multi-week horizon analysis by measuring the multi-week returns under different lengths of risk horizon on an over-lapping basis. Similar to the findings of Chow et al. (1997) and Loudon (2003), this study's results show that the longer horizon returns tend to be more informative, as the number of cases with significant exposures to these commodity risks increases with the horizon length. By comparing the results under different risk horizons, the study provides evidence to explain why commodity price risks are not found to be of greater significance than other financial risks, even though commodity prices show higher volatility, as Bartram (2005) also finds.

This study is differentiated from most research on this topic in that it investigates data samples under China's economic environment and in the Chinese capital markets. Chinese steel producers, the world's largest group of steel producers, provide a representative sample of the entire industry in terms of raw materials' price exposures. Therefore, by studying Chinese steel producers' exposures, this study provides related parties with valuable information in financial risk management from a different angle in order to explore 'cost-side' risk management.

As the capital markets in China have not completely opened up to international investors, to date, only limited research is available in regard to the level of risks that Chinese listed firms are facing, not to mention the levels of specific commodity price risks to those firms. Even less investigation has been undertaken on the current status of how Chinese firms manage their financial risk exposures. The fact is that until recent years, Chinese steel producers have very limited access to financial derivatives, an important type of tools of financial hedging used extensively by global firms. For instance, only one out of the 31 listed Chinese steel producers included in this study used derivatives to hedge commodity price exposure as to the end of Financial Year 2015. The good news, however, is that financial regulations in China have been relaxing step by step towards free markets and, as a result, Chinese firms have more alternatives for managing risks through both domestic markets and international markets. By investigating the risk exposures that Chinese steel producers are facing, this study is expected to provide empirical results that are useful for steel producers in making optimal risk management decisions; for regulators in scrutinising current regulations or introducing new regulations; and for researchers in expanding findings in this area to a different industry under a different economic environment.

This study investigates the commodity price exposures of 31 Chinese steel producers from May 2008 to December 2015 to examine whether these firms are exposed to the price changes of the above-mentioned commodities, especially to the price changes of iron ore. The methods applied in this study are extended from earlier research that has examined stock return exposures of firms in relation to major risk factors such as exchange rates (e.g. Allayannis and Ofek, 2001; Bodnar and Wong, 2003) and commodity prices (e.g. Tufano, 1998; Jin and Jorion, 2007; Treanor et al., 2014). The results show that, throughout the whole sample period, the sample firms in general are negatively exposed to iron ore price risk and positively exposed to steel price risk. In addition, further evidence is offered in this study that exposures to these risks increase as the length of the risk horizon increases, with this evidence consistent with the findings of Loudon (2003). Moreover, the increase in the horizon length, to a large extent, increases the number of significant cases in the regression results.

Secondly, this study tests whether the regime shift—the iron ore pricing mechanism changing from annual pricing to shorter-term pricing—has had any impact on the steel producers' exposures to iron ore prices. The finding is that under shorter risk horizons, the changes in iron ore price risks are not significant, but when the annual horizon is applied, significant differences appear, accompanied by more significant cases. A possible explanation for this finding is that longer-term exposures to iron ore prices are more significant to steel producers.

In addition, when the risk variable of the return spread between steel and iron ore is examined, the results show that the sensitivity of the stock returns reduces when compared separately to the sensitivity to the iron ore prices and that of steel prices. This evidence implies the existence of a possible natural hedge between steel and iron ore.

The remainder of this study proceeds as follows. Chapter 2 introduces the background of the Chinese steel industry and the history of iron ore pricing mechanism changes. Chapter 3 summarises the prior literature on the risk exposures of non-financial firms, which is followed by the development of the hypotheses for this study. Chapter 4 describes the selection of the sample data and the methods employed. Chapter 5 reports the empirical results and Chapter 6 presents the conclusion.

Chapter 2. Background

2.1 Background of this Study

The steel industry is one of the fundamental industries that are closely related to global economic development, with China being the world's largest steel-producing country representing around 44.8% of the global market for steel and over 49.6% of global crude steel production in 2015 (World Steel Association, 2016). Figure 2.1 plots the annual tonnage of crude steel produced by the top seven major steel-producing countries between 1990 and 2015. As this figure shows, not only has China been the world's largest steel-producing country for the last two decades, but the country's share of total crude steel production worldwide is also rapidly increasing. Furthermore, Table 2.1 shows the world's top 10 steel-producing firms in 2015, five of which are Chinese firms. In fact, 28 of the world's top 50 steel producers in 2015 are based in China (World Steel Association, 2016). Indeed, the rapid expansion of urbanisation in China has led to a large demand for steel and steel products, and the consequential increase in steel production has driven a high demand for raw materials such as iron ore and coking coal for the past few decades.

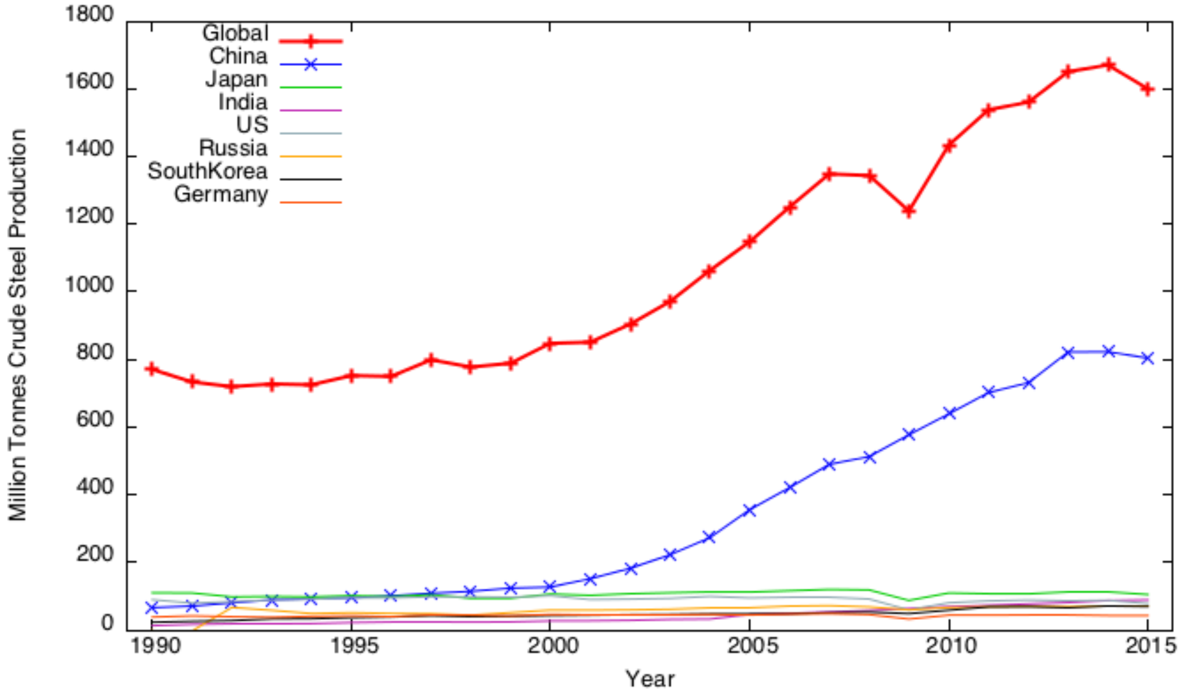


Figure 2.1 Tonnage of Crude Steel Produced by Major Steel-Producing Countries 1990–2015

Notes: Figure 2.1 graphs the annual tonnage of crude steel produced by the top seven major steel-producing countries between 1990 and 2015. In 2015, these seven countries in total contributed over 75% of the world's crude steel production. Tonnage is expressed in million metric tonnes. Data are sourced from the World Steel Association.

Table 2.1 Top 10 Steel Producers 2015

Companies	Headquarters	2015 Tonnage	2015 Ranking
ARCELORMITTAL	Luxembourg	97.14	1
HESTEEL GROUP	China	47.75	2
NIPPON STEEL & SUMITOMO METAL	Japan	46.37	3
POSCO	South Korea	41.98	4
BAOSTEEL GROUP	China	34.94	5
SHAGANG GROUP	China	34.21	6
ANSTEEL GROUP	China	32.50	7
JFE STEEL CORPORATION	Japan	29.83	8
SHOUGANG GROUP	China	28.55	9
TATA STEEL GROUP	India	26.31	10

Notes: Table 2.1 presents the top 10 steel producers in the world and the tonnage of steel produced in 2015. Tonnage is expressed in million metric tonnes. Data are extracted from the World Steel Association (2016).

Nevertheless, according to a steel industry report issued by the Ministry of Commerce of the People's Republic of China's Department of Foreign Trade (2015), the Chinese steel industry has experienced broad financial losses since the beginning of 2015. In addition, this report lists several facts that may have affected the profitability of Chinese steel producers. Apart from the fact that steel demand has decreased and the level of steel production is at overcapacity, Chinese steel producers are also facing higher risk exposures to commodity prices, including raw material prices and steel prices, owing to the increasing price volatility of these commodities in recent years.

Over 90% of the steel producers in China use iron ore and coking coal as raw materials to produce steel (Holloway et al., 2010; World Steel Association, 2015b). However, although China has largely been self-sufficient in coking coal, the majority of iron ore used by Chinese steel producers is imported from other countries, mainly Australia and Brazil, as shown in Table 2.2. The reason is that China has very limited domestic reserves of high quality iron ore[4], and those domestic reserves with high quality iron ore are even more expensive to explore, with the iron ore being more expensive to transport, than the cost of directly importing iron ore from overseas (Holloway et al., 2010). Due to their heavy reliance on imported iron ore, Chinese steel producers are expected to be facing substantially higher risk exposures to iron ore prices.

[4] According to industry norms, an iron (Fe) content at 62% or above is considered to constitute high quality reserves, while the reserves in China have a relatively low average iron content at around 33% (Holloway et al., 2010; Jorgenson, 2010).

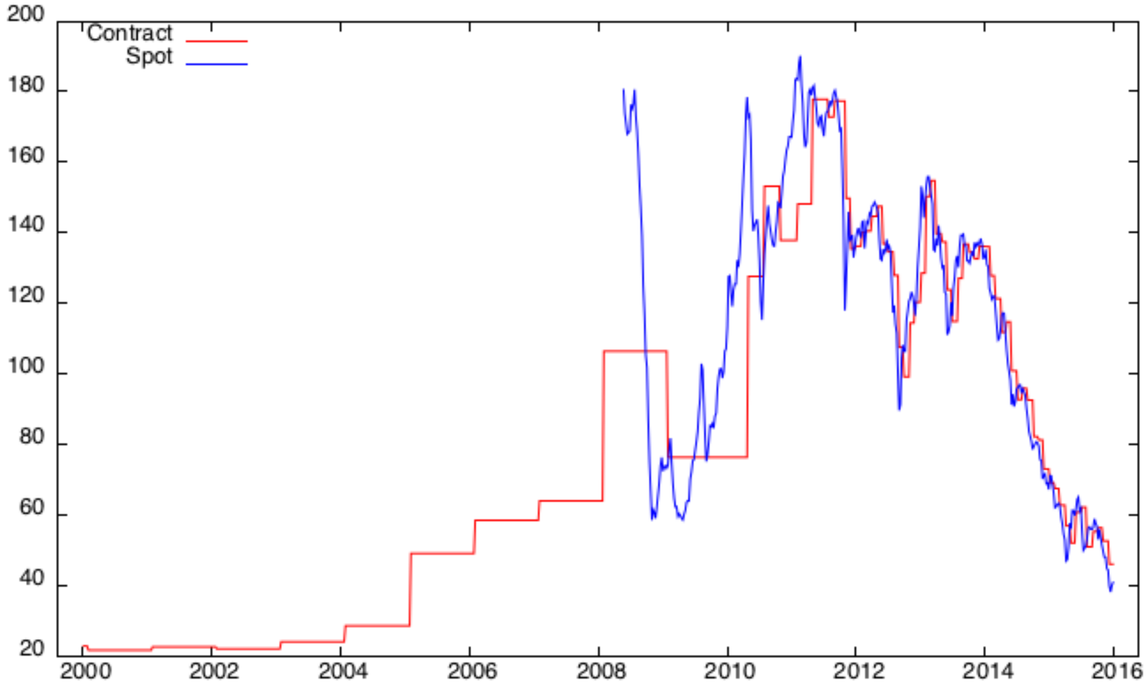
Table 2.2 Top Regions from which China Imported Iron Ore in 2015

Exporting region	Exports to China
Oceania	607.6 (74.86%)
Other America	207.6 (52.24%)
Total iron ore imports to China	953.4

Source: World Steel Association (2016)

Notes: Data are expressed in million tonnes. The numbers in parentheses represent the percentage of total exports from that region to China. The region of 'Other America' represents the region in the Americas that is not in the North American Free Trade Agreement (NAFTA) region (i.e. the region that is not the United States [USA], Canada and Mexico). The numbers in Table 2.2 indicate that the top two regions that exported iron ore to China in 2015, namely, Oceania and Other America exported a volume of iron ore that constituted over 85% (or 815.2 million tonnes) of the total iron ore imported by China. In the Oceania region, Australia was the main country exporting iron ore, accounting, in 2014, for over 99.5% of the iron ore export volume (754.3 of 756.5 million tonnes) from the Oceania region or 50.65% of the world's total exports (754.3 of 1,489.1 million tonnes). In 2015, the Oceania region accounted for 53.8% (811.6 of 1,508.2 million tonnes) of the world's total iron ore exports. All data in this table are extracted from the World Steel Association (2016).

Iron ore import prices to China had been guided by long-term contract (LTC) negotiations since the 1960s. The LTCs defined the price and quantities of iron ore to be traded between partners, generally over a period of 10–16 years (Hurst, 2015a). Before April 2010, iron ore was purchased through LTC prices fixed for each year. Until then, iron ore prices had been fairly stable and predictable. However, as seen in Figure 2.1, in recent years, the iron ore pricing mechanism has shifted towards shorter-term pricing, including the spot market, which has resulted in increasing price volatility. As a result, steel producers face the primary task of managing the iron ore price risk to maintain profitability.



Source: Datastream and Bloomberg

Figure 2.2 USD per metric tonne of China's imports of iron ore (62% Fe fines), with cost and freight (CFR) delivered to China

Notes: The red line represents USD per metric tonne of China's imports of iron ore (62% Fe fines) with cost and freight (CFR) delivered to Tianjin port (contract price), while the blue line is the USD per metric tonne of China's imports of iron ore (62% Fe fines) with CFR delivered to Qingdao port (spot price). From Figure 2.2, a significant difference is noticeable between the spot and contract prices before 2010. However, since the long-term contract (LTC) pricing mechanism was abandoned in mid-2010, the iron ore prices have become increasingly volatile, initially and briefly surging to a record high but, since then, decreasing dramatically.

2.2 Overview of the Steel Industry

2.2.1 Steelmaking Process

The two main types of process used to produce crude steel are the blast furnace/basic oxygen converter (BF/BOF) method and the electric arc furnace (EAF) method.

According to the World Steel Association's (2014) "Fact Sheet – Steel and Raw Materials", the integrated steelmaking process based on the BF/BOF method, on average, uses 1.4 tonnes of iron ore and 0.8 tonnes of coking coal to produce one tonne of steel, while the recycled steel-EAF process, on average, uses 0.88 tonnes of recycled steel (or ferrous scrap) and only 16 kg of coking coal to produce one tonne of crude steel. Therefore, the type of production method adopted is critical in determining what raw materials are needed to produce steel.

In contrast to the USA where only one-third of the crude steel is produced using recycled steel through the EAF process, in 2014, over 93% of China's crude steel was produced using iron ore and coking coal through the BF/BOF process (World Steel Association, 2015b). This is a strong indication that China needs a large and sustainable supply of both iron ore and coking coal to maintain and increase its steel production in order to meet its huge and continuously expanding demand for steel.

2.2.2 Raw Materials

Iron ore, coking coal and recycled steel are regarded as the key raw materials in steel production.

1) Iron ore

Iron ore is undoubtedly essential for the production of steel. As 98% of mined iron ore is used to make steel (World Steel Association, 2014), steel producers are virtually the terminal users of the world's iron ore.

The type and content of iron ore are crucial for steelmaking. Although China itself owns relatively extensive reserves of iron ore, the iron content is normally at around a mere 33%, which is much lower than most types of imported iron ore which have an iron content of 62% or above (Holloway et al., 2010). Chinese steel producers have long realised that the overall costs to import iron ore from overseas are usually less than if purchasing domestically, even if the cost of freight for imported iron ore is higher. The reason is that by using higher quality iron ore as the raw material, steel producers can save more on production costs and achieve higher production efficiency.

The types of iron ore imported from Australia and Brazil normally have iron content of 62% or higher and thus are preferred by Chinese steel producers. Since 2007, the total volume and dollar amount of iron ore imported by China from these two countries alone has been above 60% of all iron ore imported for every single year (Dalian Commodity Exchange, 2013).

2) Coking coal

In contrast to iron ore, coking coal is not normally classified by type or content for steelmaking as it acts only as the primary reducing agent of the iron ore.

China is one of the countries with the largest coal reserves and has been largely self-sufficient in supplying and meeting the demand from the steel industry (Holloway et al., 2010). When designing the model for discovering the relationship between the prices of bulk commodities and Chinese steel, Caputo et al. (2013) assumed that coking coal prices accordingly did not respond to Chinese steel prices, and effectively set the coefficient on Chinese steel prices in the coking coal price equation to zero in the coefficient matrix. The motivation behind this idea is the fact that a low proportion of coking coal is traded on the spot market in China. The model qualitatively yielded similar results, with the authors concluding that the price of coking coal responds more gradually to an unanticipated increase in the Chinese steel price (Caputo et al., 2013).

3) Recycled steel or ferrous scrap

Recycled steel is an important alternative to iron ore in steel production. With the use of recycled steel as the raw material to produce steel being better for the environment and for resource utilisation efficiency, steel producers are being encouraged to gradually switch from the BF/BOF process to the EAF process in the long run.

However, to date, the ferrous scrap resources in China have been nowhere near enough to meet the needs of its domestic steel production. According to the research report by Dalian Commodity Exchange (2013), it is not easy to solve the conflict between the low level of ferrous scrap supply and the strong growth of steel production. Another critical factor is that, to date, less than 10% of Chinese steel producers are using the EAF process to produce steel; thus, very few are using ferrous scrap as the raw material to produce steel. As the switching costs for production facilities are extremely high, industrial associations in China believe that there is a low probability that ferrous scrap will replace iron ore as the raw material for steelmaking in the foreseeable future (Dalian Commodity Exchange, 2013). In 2015, China imported 2.3 million tonnes of ferrous scrap, accounting for only 2.77% of the world's total imports of ferrous scrap (2.3 of 82.9 million tonnes). In 2014, the figure was 2.6 of 95.3 million tonnes (World Steel Association, 2016).

2.2.3 Steel Prices

The steel industry in China is widely acknowledged as a quasi-oligopoly, with its pricing mechanism being that the largest steel producers set the price and smaller firms follow with a certain degree of adjustment (Tian et al., 2005). Normally, the large steel producers quote prices that are higher than those of smaller steel producers due to the effects of reputation and branding, but Tian et al. (2005) note that this pricing mechanism was violated at some specific time periods. Between late 2003 and early 2004, a serious supply shortfall of steel products in China occurred with a contemporaneous price increase for raw materials (iron ore, coking coal, energy, etc.). Smaller steel producers rapidly increased the quotes for their steel products; however, surprisingly, large steel producers did not increase their prices to the same extent, thus creating the abnormal situation in which steel products made by smaller steel producers were more expensive than those made by large steel producers. This scenario implies that steel prices do not only depend on raw material prices, but also on the level of competition within the industry.

2.2.4 History of the Iron Ore Import Pricing Mechanism

Some researchers discuss the changes in the iron ore price and their effect on China's import demand from the perspectives of macroeconomics and steel manufacturing. Tcha and Wright (1999) utilise annual time series data from 1973–1996 and analyse China's iron ore imports from Australia. Their study indicates that the volume of steel production in China is positively correlated to China's imports of Australia's iron ore, while increases in the relative price of Australia's iron ore and in labour disputes, measured by working days lost in Australia, appear to reduce China's import demand.

However, even though iron ore prices have been gradually increasing for the last decade, China's import demand for iron ore does not appear to have reduced but, instead, has increased dramatically. In 2008, Baosteel Group, one of China's leading steel producers, signed an agreement with BHP Billiton for an additional 94 million tonnes of iron ore supply. This contract entitles Baosteel Group to be supplied with 10 million tonnes of iron ore every year for the next decade at a price to be mutually agreed each year (BHP Billiton, 2008). A further indication of China's increasing demand for iron ore is illustrated in Table 2.3 which shows that China has long been the world's largest consumer and importer of iron ore, with this expected to steadily increase (World Steel Association, 2015a).

Table 2.3 Imports of Iron Ore

	2008	2009	2010	2011	2012	2013	2014
China	444,028	628,175	618,915	686,747	745,434	820,175	933,108
	47.57%	*64.22%*	*57.75%*	*60.22%*	*61.79%*	*64.27%*	*65.01%*
Asia	661,105	796,219	839,084	911,030	989,138	1,053,825	1,192,491
	70.83%	*81.40%*	*78.29%*	*79.89%*	*82.00%*	*82.58%*	*83.08%*
European	181,219	105,979	155,124	155,378	147,830	157,129	157,800
Union	*19.41%*	*10.83%*	*14.47%*	*13.63%*	*12.25%*	*12.31%*	*10.99%*
North	26,435	6,001	20,316	18,494	17,696	15,086	21,049
America	*2.83%*	*0.61%*	*1.90%*	*1.62%*	*1.47%*	*1.18%*	*1.47%*
World	933,401	978,139	1,071,802	1,140,385	1,206,334	1,276,195	1,435,340

Source: World Steel Association (2015a)

Notes: Table 2.3 reports the total imports of iron ore by China, Asia, the European Union (28 countries), North America and the World from 2008–2014. Data are expressed in thousand metric tonnes and, for each region, as a percentage of the World's total imports.

1) Long-term contract

Since the 1960s, the iron ore import price in China has been guided by long-term contract (LTC) negotiations. The trading price was initially negotiated annually between the world's largest three iron ore suppliers (BHP Billiton, Rio Tinto and Vale) and the world's largest iron ore consumers (including Nippon Steel & Sumitomo Metal and POSCO). Once both parties had agreed on a certain price for that year, the negotiation was acknowledged as finished and the price became globally accepted. This mode of negotiation is known as "initial move and follow".

Table 2.4 presents the history of changes in the iron ore pricing mechanism. In 2004, China's Baosteel Group joined LTC negotiations and became a representative of another section of the world's major iron ore consumers—the Chinese steelmaking community. However, since 2010, the largest three iron ore suppliers have rejected the continuation of the annual basis of pricing iron ore. Instead, they changed the pricing period to quarterly and then to monthly, which is very close to the spot price. Under this pricing mechanism, Chinese steel producers have to take on the increasing exposure to iron ore price risk.

Table 2.4 History of Iron Ore Pricing Mechanism Changes

Time	Iron Ore Pricing Mechanism
Before 1950	Mainly based on spot pricing.
Early 1960s	Short-term supply contracts appeared.
1980	Annual-based long-term contract negotiation mechanism was formed.
2003 and 2004	As a representative of Chinese steel producers, Baosteel Group participated in the long-term contract negotiation process.
2008	The 'initial move and follow' mode was broken in 2008: Rio Tinto set its own annual price for iron ore.
2009	The 'initial move and follow' mode was again broken in 2009: China did not accept a 33% price drop.
2010	The largest three iron ore mining firms changed the pricing period from annual to quarterly.
2011	The monthly pricing period started to form.

Source: Dalian Commodity Exchange (2013)

2) Spot Market – Iron Ore Index

Since the long-term contract (LTC) negotiation pricing mechanism started to transform to a short-term negotiation period, steel producers have paid more attention to iron ore price indices. Several institutions to date have created indices for global iron ore prices. The Steel Index (TSI), S&P Global Platts and the Metal Bulletin Iron Ore (MBIO) Index are the most widely quoted. Even though they use slightly different data sources and the methods employed are also slightly different, it is generally acknowledged that the prices in these three major benchmark indices tend to move either together or very closely to each other (Dalian Commodity Exchange, 2013; Caputo et al., 2013).

3) Derivatives Markets

Derivative contracts on iron ore have been trading over-the-counter (OTC) since 2008. Deutsche Bank was the first to start trading iron ore OTC swaps, followed by Singapore Exchange which brought OTC iron ore swaps into its clearing house. The London Clearing House (LCH), Intercontinental Exchange (ICE) and CME Group started to trade iron ore derivatives contracts in the following years. Iron ore futures contracts were established in both India and Singapore in 2011. In China, iron ore futures contracts have been trading in the Dalian Commodity Exchange since 2013. Therefore, an abundant range of choices of iron ore derivatives is available worldwide.

Chapter 3. Prior Research and Hypotheses Development

3.1 Prior Research on Financial Risk Exposures

A large body of literature has been developed from past investigations on how firms are exposed to certain types of risks. Previous studies analysing the influence of financial risk exposures on non-financial firms have mainly focused on financial risks such as exchange rates.[5] In the studies that have examined commodity price exposures, samples from the airline industry and resources or mining firms are most commonly selected by researchers.[6] Nevertheless, little research has explored the exposures of steel producers to commodity prices, and even less research has investigated iron ore prices.

Jorion (1990) finds that the percentage of foreign operations of US-based multinationals is positively related to the co-movement between stock returns and the value of the US dollar. To be specific, Jorion finds a significant positive association between currency exposure and the foreign sales measure (Jorion, 1990). Bartov and Bodnar (1994), on the other hand, do not find a significant association between contemporaneous change in the US dollar and abnormal returns of the sample firms. When studying the Australian market, Nguyen and Faff (2003) find that Australian firms, in general, are extensively exposed to currency fluctuations in the long run. Muller and Verschoor (2006) extensively review the literature on currency exposure. As one of their conclusions, they state that researchers should emphasise the importance of the cost and revenue structure of firms and other external environments. In addition, they notice that recent models are shown to

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[5] See, for example, Jorion (1990), Bartov and Bodnar (1994), Allayannis and Ofek (2001), Bodnar and Wong (2003) and Muller and Verschoor (2005).

[6] See, for example, Loudon (2004), Jin and Jorion (2006), Jin and Jorion (2007), Treanor et al. (2014) and Berghöfer & Lucey (2014).

demonstrate the impact of pricing strategies and pass-through effects on the mechanism linking stock returns and exchange rate changes (Muller and Verschoor, 2006). These findings raise the question of whether such results would also be found when linking stock returns to commodity price changes.

Noticing that commodity prices are more volatile than exchange rates and interest rates, Bartram (2005) presents a comprehensive analysis of the commodity price exposure of a large sample of non-financial firms. However, the finding of the study is that, despite the higher volatility of commodity prices, firms are not found to be more exposed to commodity price risks than they are to the risks of exchange rates or interest rates.

When analysing commodity price exposures, researchers tend to focus on resource industries such as oil and gas producers (Jin and Jorion, 2006), the gold mining industry (Tufano, 1998; Jin and Jorion, 2007) and the airline industry (Loudon, 2004; Carter et al., 2006; Treanor et al., 2014; Berghöfer and Lucey, 2014). In studying the gold mining industry, Tufano (1998) finds that the average mining stock moved 2% for each 1% change in gold prices; however, these exposures vary considerably over time and across firms. With regard to the airline industry, most researchers recognise through their studies that jet fuel prices constitute an economically large operation cost for airline firms (Treanor et al., 2014), and that airline stock returns and cash flows are negatively correlated to fuel price changes (Carter et al., 2006). Moreover, Loudon (2004) finds similar results for both Qantas and Air New Zealand in that they are both negatively exposed to fuel price risks in the short term, with the significance of the exposure becoming more prevalent as the length of the horizon extended. The author finds that exposure to fuel price risk is sensitive to the events of September 2001. Mohanty et al. (2014) extend previous studies and investigated the oil price exposures of the US travel and leisure industry. Similar to previous results, they find that several subsectors, including airlines, recreational services, and restaurants and bars, are significantly exposed to oil price risk, but such exposures vary considerably over time, especially during certain changes in the economic environment such as the 2007–2009 recession.

In addition, studies find evidence that, when exposed to commodity price risks, some firms manage these exposures by involvement in hedging activities. Nevertheless, no conclusive answers have been found as to whether hedging activities truly have positive effects on reducing firm risks. For example, Treanor et al. (2014), while analysing the US airline industry, find that both financial and operational hedging are important tools in reducing airline exposures to jet fuel price risk. However, Berghöfer and Lucey (2014), while investigating the global airline industry, do not find evidence that either financial hedging or operational hedging significantly reduces oil price exposures. Furthermore, by analysing a sample of 234 large non-financial firms, Guay and Kothari (2003) argue that the effect of hedging with derivatives is not economically significant, even though previous empirical research findings suggest that it has a significant economic effect.

In comparison, the literature on the steel industry and its exposures to commodity price risks is limited. Caputo et al. (2013) build a model to test the relationship between raw materials (iron ore and coking coal) and Chinese steel prices. Their underlying assumption is that the steel price can be taken as a mark-up on the prices of iron ore and coking coal. In their analysis, they find that, with a US$1 increase in the price of Chinese steel, the spot price for iron ore tends to react quickly, overshooting its long-run equilibrium value. The same does not apply to coking coal, the price of which responds more gradually, aligning with the authors' hypothesis that coking coal prices do not respond to the Chinese steel price synchronously (Caputo et al., 2013).

3.2 Hypotheses Development

Firms are generally believed to be exposed to financial risks such as interest rates, exchange rates and commodity prices. For the past few decades, we have witnessed not only that financial prices have become more volatile, but also that such increased volatility has caused an unfavourable impact on many firms (Smithson, 1998). Many empirical studies also show that firms in different industries are exposed to financial risks in various forms.[7] As financial risks create uncertainty about firms' future cash flows, managing financial risks has become a critical part of the overall risk management and corporate finance strategies of firms (Loudon, 2004).

The current research topic has extended beyond those studies that have investigated the impact of jet fuel price changes on airline firms. Similar to those studies, this thesis analyses the 'cost-side' of risk management. A major difference, however, is that while the airline industry constitutes only a part of the total consumption of crude oil, almost all iron ore mined is for steel production. This is an indication that iron ore prices reflect information that is mostly from the steel industry, thus further mitigating the problem of heterogeneity that may exist in other commodities.

Figure 3.1 illustrates that, historically, iron ore has had unique price changing patterns, with very slight price changes for over two decades until the early 2000s. It was only after the regime shift from long-term contract (LTC) pricing towards shorter-term pricing between the world's major iron ore miners and steel producers that iron ore prices became increasingly volatile. Unlike jet fuel or other commodities that do not involve industry-

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[7] See, for example, Treanor et al. (2014), Berghöfer and Lucey (2014), Jin and Jorion (2007) and Bartram (2005).

wide long-term contract (LTC) pricing, iron ore did not experience substantial price changes during financial downturns before the 2000s.

Two hypotheses can be tested based on the relationship between iron ore and coking coal prices and steel producers, as well as the history of changes in the iron ore pricing mechanism:

Hypothesis 1: Steel producers are negatively exposed to iron ore and coking coal price changes, and are positively exposed to steel prices throughout the sample period.

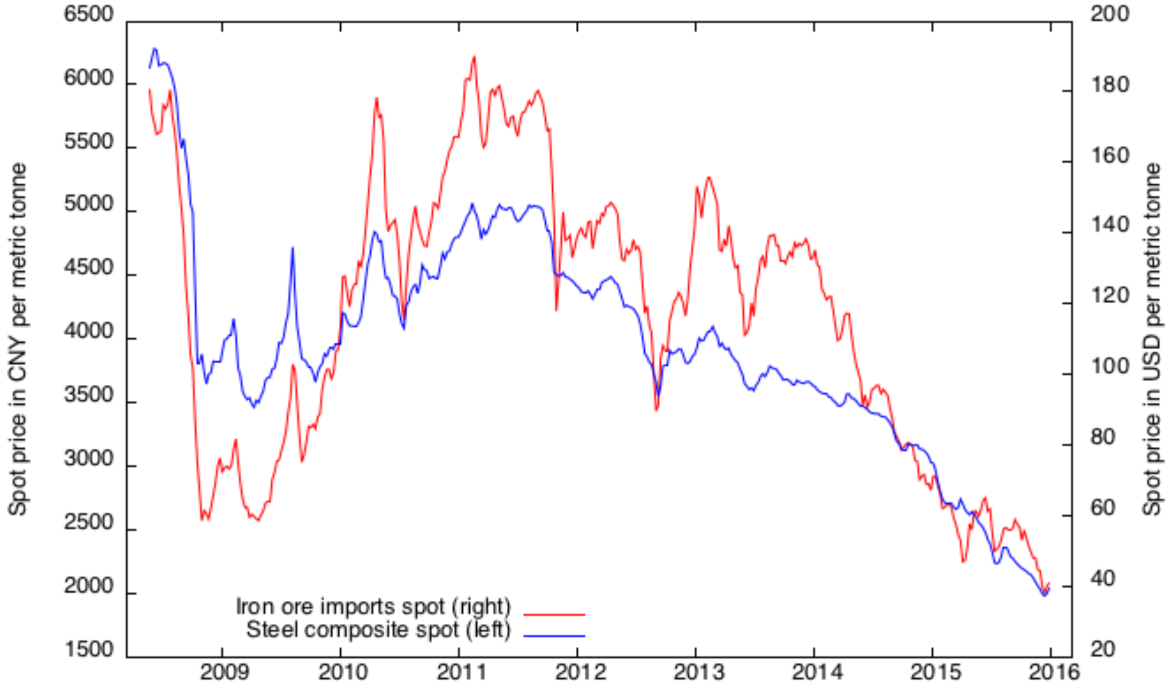
Hypothesis 2: Steel producers are more sensitive to iron ore price changes after April 2010 when the iron ore contract pricing changed from annual to shorter terms.

Moreover, although iron ore contributes to a large portion of the raw material costs in steelmaking, there is a possibility that changes in iron ore prices can, in some way, be offset by changes of steel prices. The steel industry is different from most other industries in that it is exposed to both input price risks (raw materials including iron ore and coking coal) and output price risks (steel).

Iron ore prices are acknowledged as closely following steel prices, as 98% of mined iron ore is used to make steel (World Steel Association, 2014). In addition, the Dalian Commodity Exchange (2013) states that the prices of imported iron ore, steel and domestic iron ore are highly correlated and affect each other interchangeably.

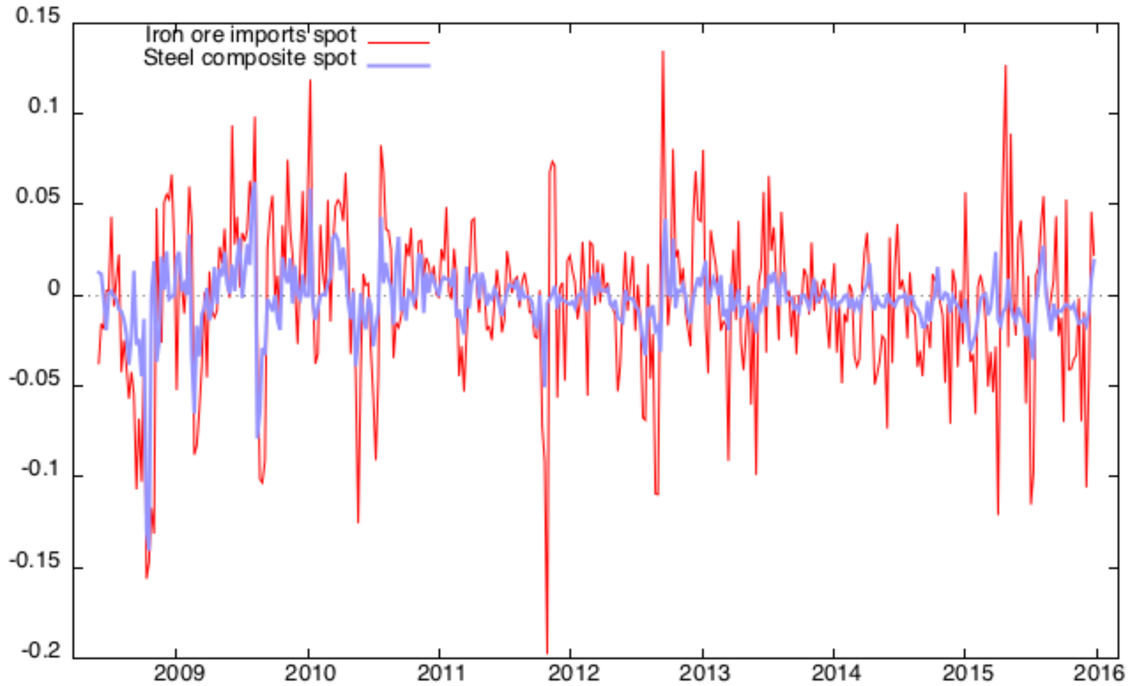
In a sense, it is intuitive to say that steel producers are negatively exposed to iron ore price changes due to the fact that iron ore is an input commodity to steel production. However, if the prices of iron ore are truly highly correlated with steel prices, there may be a possibility that iron ore price exposures (the cost side of risk) are naturally hedged to steel price exposures (the revenue side of risk), provided that the spreads between iron ore and steel price changes stay consistent. Bartram (2005) suggests that one of the explanations of why some firms may not show a significant commodity price exposure is that they are able to pass the effect of commodity price changes on to firms linked in the value chain. However, the author further argues that whether pass-through can be feasible would depend on the elasticity of the demand. In other words, in a perfectly competitive market where the demand is highly elastic, it is unlikely that firms could manipulate prices without significantly affecting the demand (Bartram, 2005).

Figure 3.2 illustrates the weekly log returns of steel and iron ore prices. Together with the price movements shown in Figure 3.1, the implication is that although the two prices have similar trends, they are not perfectly correlated, nor do they have a constant stable spread. At certain periods of time, the two prices even tend to move adversely. In addition, Figure 3.2 indicates the difference between the log returns of iron ore and steel prices. The figure shows that the volatility of iron ore returns has exceeded that of steel returns to a large extent since 2010. These facts imply that there is a necessity to investigate whether a natural hedge exists between iron ore and steel prices in the steel industry and, if so, to what extent.



Data source: Datastream

Figure 3.1 Comparison of Steel and Iron Ore Prices



Data source: Datastream

Figure 3.2 Comparison of Steel and Iron Ore Weekly Log Returns

As an expansion from several conventional risk pricing models (e.g. Jorion, 1990; Loudon, 2004; Berghöfer and Lucey, 2014), in this study, one of the models introduces a variable of spread between steel and iron ore returns to explore whether firms are exposed to this spread. In other words, this spread variable is set to examine whether the risk of iron ore price changes is at least partially offset by the risk of steel price changes. If this hypothesis is true, steel producers are expected to be less sensitive to the spread risks between iron ore and steel price changes than to the risks of iron ore and steel price changes, respectively. This is novel to the risk management research field as the current literature on the financial exposure of firms either does not test the effect of natural hedging at all or tests it as a part of operational hedging strategies (e.g. Berghöfer and Lucey, 2014). Thus, in this study, a third hypothesis is tested:

Hypothesis 3: Steel producers' sensitivity to the spread between iron ore returns and steel returns is expected to be lower than their sensitivity to iron ore price changes and steel price changes, respectively.

Chapter 4. Data and Methods

4.1 Data Description

4.1.1 Selection of Proxies for Bulk Commodity Prices

In this study, the Metal Bulletin's Iron Ore (62% Fe fines)[8] (MBIO-62) Index is selected to represent iron ore price changes in USD; the Steel Composite Price Index published by MySteel, one of the Chinese steel industry's major research institutions, is selected to represent steel price changes in CNY; and the China Coal Price Index (CCPI) published by the China National Coal Association (CNCA) is selected to represent coking coal price changes in Chinese yuan (CNY).

Although each type of commodity usually has more than one price index, these indices tend to move closely with each other (Caputo et al., 2013). What needs to be considered when selecting the right proxies for the prices of the commodities is in which currency the prices are quoted.

For instance, with iron ore, while China has its own sets of price indices quoted in Chinese yuan (CNY), global indices for iron ore are most commonly quoted in US dollars (USD). The three global iron ore price benchmarks in USD are: Platts Iron Ore Index (IODEX), The Steel Index (TSI)[9] and the Metal Bulletin Iron Ore (MBIO) Index. The assessments of all three of these price indices are published on a CFR[10] Qingdao, North China basis, which are also used by steel producers, traders and mining firms to price long-term and

[8] This type of iron ore (62% Fe fines) is used as the underlying asset benchmark for the most frequently traded iron ore-related financial instruments, such as iron ore futures contracts traded at the CME Group and the Dalian Commodity Exchange.
[9] Platts acquired TSI in July 2011 (thesteelindex.com).
[10] Cost and freight price quote.

spot contracts.[11] Due to the fact that the majority of iron ore purchased by the sample steel producers in this study is from imports, the prices for importing iron ore are quoted in USD, as is the convention. Hence, a USD price index for iron ore is considered to be an appropriate proxy.

On the other hand, as most coking coal purchased by the sample steel producers is from the Chinese domestic market, it is thus reasonable to expect that a CNY price index for coking coal is more suitable. In accordance with this selection criterion, this study selects the China Coal Price Index (CCPI) published by the China National Coal Association (CNCA) as the proxy for coking coal price risk.

A similar logic can be applied to the selection of a proxy for steel prices. China is not only known as the world's largest steel producing country, but also as the world's largest steel consuming country. In 2015, less than 14% (111.6 of 803.8 million tonnes) of steel produced in China was exported (World Steel Association, 2016) which indicates that, for most steel traded by Chinese steel producers, CNY is used for pricing. Therefore, an index of steel prices based on CNY is the closest proxy to reflect the financial situation of the sample firms.

4.1.2 Selection of Sample Steel Producers

The focus of the analyses reported in this thesis is on the Chinese publicly listed firms in the steel industry. The data came from a sample comprising 31 steel producing firms listed on either of the two Chinese stock markets: the Shanghai Stock Exchange or the Shenzhen Stock Exchange. Table 4.1 presents the list of the sample firms. These firms are classified as "Code 31: Industry of ferrous metal smelting and rolling processing" under China

[11] Please refer to Platts' official website (platts.com) for further information.

Securities Regulatory Commission (CSRC) Industry Classification (2015).[12] As the entire population of the publicly listed Chinese steel producers is relatively small, it is thus both feasible and reasonable to include all firms in the analysis as comprising the sample.

4.1.3 Selection of Sample Period and Control Variables

The sample period of this study is between May 2008 and December 2015. Due to the fact that the iron ore price index (MBIO-62) used in this study only started from May 2008, this is therefore the longest sample period available. This sample period includes both the period when the long-term contract (LTC) pricing mechanism for iron ore was still in existence (i.e. before April 2010), and the period when the iron ore pricing mechanism had started to shift towards spot prices.

In addition to the analysis based on the entire sample period, this study further examines two sub-periods. Sub-period 1 is from May 2008 to April 2010, when long-term contracts (LTCs) were still the pricing guidance or benchmark for iron ore prices, with the prices still set once a year. Sub-period 2 is from April 2010, the year when the three largest iron ore mining firms decided to start the quarterly-pricing basis for iron ore, through to the end of 2015 which is in accordance with the latest annual financial data available for the sample firms.

In this study, two risk factors are introduced as control variables: foreign exchange returns, and market returns. Foreign exchange rates of USD to CNY released by US Federal Reserve are selected as the proxy for foreign exchange rate changes. With regard to stock market data, the proxy selected to represent market returns is the Shanghai Shenzhen CSI

[12] As at the end of 2015, in total, 32 firms are classified under Code 31 of CSRC's industry classification. However, in this study, one firm is eliminated from the sample as its listing time is less than one year.

300 Index. There are two stock markets in mainland China: the Shanghai Stock Exchange (SSE) and the Shenzhen Stock Exchange (SZSE). The CSI 300 Index is a capitalisation-weighted stock market index designed to replicate the performance of 300 common stocks traded on the Shanghai Stock Exchange and the Shenzhen stock exchange. The selected 300 stocks are the most heavily traded stocks in the Chinese A-share markets[13], and represent about 70% of the total market capitalisation of both Shanghai and Shenzhen stock exchanges (Hou and Li, 2014). The CSI 300 Index has been widely accepted as the benchmark for the Chinese A-share markets[14] (Hou and Li, 2014; Yang et al., 2012). All data are obtained from Datastream.

[13] In the Chinese stock markets, stocks are classified as A-shares and B-shares to differentiate groups of investors: A-shares are available only for Chinese domestic investors, denominated in Chinese yuan (CNY); and B-shares are available for both domestic and foreign investors, denominated in USD.

[14] A-shares and B-shares can be listed on both Shanghai and Shenzhen stock exchanges. However, in this study, the stocks of the sample firms selected and analysed are all A-shares.

Table 4.1 Sample Firms and Financial Data as at the end of 2015

CSRC Code	Name of the Sample Firms	Years Listed	Total Assets (CNY Million)	Total Assets (USD Million)	Debt to Asset %	ROA %	ROE %
000708.SZ	DAYE SPECIAL STEEL	18	5,137.56	793.35	31.91	6.17	7.93
000709.SZ	HESTEEL GROUP	18	178,811.55	27,612.27	74.50	1.67	1.32
000717.SZ	SGIS SONGSHAN(*ST)	18	16,560.31	2,557.26	97.86	-11.66	-157.70
000761.SZ	BENGANG STEEL PLATES	17	44,461.64	6,865.81	72.02	-6.45	-24.11
000825.SZ	TAIGANG STAINLESS STEEL	17	72,447.82	11,187.47	69.51	-3.40	-16.05
000898.SZ	ANSTEEL GROUP	18	88,596.00	13,681.09	50.70	-2.85	-10.09
000932.SZ	VALIN STEEL TUBE & WIRE	16	76,498.89	11,813.04	86.05	-3.05	-33.82
000959.SZ	BEIJING SHOUGANG GROUP	16	66,538.46	10,274.94	65.45	-1.83	-4.85
002075.SZ	JIANGSU SHAGANG GROUP	9	6,550.06	1,011.47	38.11	-2.75	-3.43
002110.SZ	SANSTEEL MINGUANG	8	7,124.12	1,100.11	76.85	-14.08	-43.78
Total no. of sample firms listed on the Shenzhen Stock Exchange: 10							
600005.SH	WUHAN IRON & STEEL	16	94,455.84	14,585.97	69.73	-6.67	-23.28
600010.SH	BAOTOU STEEL	14	144,932.16	22,380.58	67.36	-2.93	-10.01
600019.SH	SHANGHAI BAOSTEEL GROUP	15	234,123.15	36,153.55	47.83	1.08	0.89
600022.SH	SHANDONG IRON & STEEL	11	53,275.91	8,226.92	56.62	2.19	0.54
600117.SH	XINING SPECIAL STEEL	18	25,380.16	3,919.23	92.84	-5.09	-85.94
600126.SH	HANGZHOU IRON & STEEL	17	3,865.72	596.95	34.30	-18.21	-39.44
600231.SH	LINGYUAN IRON & STEEL	15	15,299.09	2,362.50	66.64	2.87	1.16
600282.SH	NANJING IRON & STEEL	15	36,343.42	5,612.19	82.61	-3.76	-32.73
600295.SH	EERDUOSI RESOURCES	14	44,482.18	6,868.99	69.79	4.18	3.44
600307.SH	JIU STEEL GP HONGXING	15	38,781.65	5,988.70	76.39	-13.93	-57.81
600390.SH	KINGRAY SCIENCE & TECH (*ST)	14	2,282.61	352.48	45.27	-15.78	-35.93
600399.SH	FUSHUN SPECIAL STEEL	15	12,995.09	2,006.72	85.23	4.64	10.73
600408.SH	SHANXI ANTAI GROUP	12	6,617.13	1,021.82	75.80	0.02	2.49

600507.SH	FANGDA SPECIAL STEEL	12	9,305.73	1,437.00	75.63	2.73	4.24
600569.SH	ANYANG IRON & STEEL	14	32,226.59	4,976.46	83.20	-5.15	-42.77
600581.SH	BA YI IRON & STEEL (*ST)	13	18,268.58	2,821.05	104.96	-10.22	-722.03
600608.SH	SHANGHAI BROADBAND TECH (ST)	23	267.68	41.34	91.18	25.98	0.00
600782.SH	XINYU IRON & STEEL	19	28,226.24	4,358.73	69.65	1.38	0.75
600808.SH	MAANSHAN IRON & STEEL	21	62,454.47	9,644.29	66.79	-5.82	-23.01
601003.SH	LIUZHOU IRON & STEEL	8	22,626.29	3,493.98	80.38	-3.71	-23.46
601005.SH	CHONGQING IRON & STEEL	8	39,228.08	6,057.64	89.78	-11.02	-85.76
Total no. of sample firms listed on the Shanghai Stock Exchange: 21							

Notes: Table 4.1 presents the sample firms included in this study. There are, in total, 31 sample firms, with 10 firms listed on the Shenzhen Stock Exchange (codes ending with SZ) and 21 firms listed on the Shanghai Stock Exchange (codes ending with SH). These firms are classified as “Code 31: Industry of ferrous metal smelting and rolling processing” under China Securities Regulatory Commission (CSRC) Industry Classification (2015). ST and *ST denote stocks under special treatment, indicating that the daily price change is limited to +/- 5% of the last trading day’s closing price. More details are presented in the Appendix 2. All data are as at the end of 2015. Total assets (USD million) are converted from total assets (CNY million) based on the USD/CNY exchange rate (US Federal Quote). Data are extracted from Datastream.

4.2 Methods

4.2.1 Models

The models applied in this study are based on the capital asset pricing model, first introduced by Sharpe (1964) and Lintner (1965). One way of understanding risk exposures is from the sensitivity of a firm's stock returns to the randomness of risks as representatives. This sensitivity is measured by the regression coefficient of the stock price changes on the change in risk factors (Jorion, 1990). Jorion (1990) introduces a risk-factor model to estimate exchange rate exposure. Differing from previous models (e.g. Adler and Dumas, 1984), Jorion's model specifically controls for market movements by introducing a market risk factor. This market-adjusted model is then widely used by researchers examining exchange rate exposures and, in general, as a theoretical foundation in other studies that investigated financial risk exposures.[15] Specifically, for studies focusing on certain commodity price exposures, researchers apply this fundamental framework by introducing additional risk factors representing commodity price changes. Recent models testing risk factors are mostly based on this concept (see, e.g. Tufano, 1998; Allayannis and Ofek, 2001; Loudon, 2004; Jin and Jorion, 2007; Treanor et al., 2014).

Weekly data are used in the analysis. The data frequency used to estimate the risk exposures facing sample firms vary in the current literature. Most of the earlier studies tend to use monthly data (e.g. Jorion, 1990; Allayannis and Ofek, 2001; Guay and Kothari, 2003; Carter et al., 2006; Jin and Jorion, 2006), while more recent studies prefer to use a shorter data frequency, including weekly (e.g. Caputo, 2013; Berghöfer and Lucey, 2014)

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[15] For exchange rate exposures, studies include Allayannis and Ofek (2001), Bodnar and Wong (2003) and Nguyen and Faff (2003); for other financial price exposures, studies include Tufano (1998), Jin and Jorion (2007), Carter et al. (2006), Treanor et al. (2014) and Berghöfer and Lucey (2014).

or even daily (e.g. Treanor et al., 2014). The reason why weekly data are used in this study is that weekly data are not as noisy as daily data, but are expected to provide more precise estimation than monthly data. However, different risk horizons of weekly, monthly, quarterly and annual returns are used, respectively, to test whether there is any variation for results and whether the significance of results is affected. The relevant literature and previous evidence is further discussed in the next section.

In the current study, the risk exposure estimation method is based on Jorion's (1990) model except that, instead of foreign exchange or interest rate, commodity price changes are introduced as risk factors. According to the models most widely used by researchers[16] to estimate risk exposures facing non-financial firms, exposure is generally represented by the sensitivity of a firm's stock returns to the changes of underlying financial risk. Therefore, the log returns of the prices for iron ore, steel and coking coal are introduced as commodity price risk factors.

Model 1: risk exposures to commodity prices facing steel producers

$$R_{i,t} = a_i + \beta_{m,i} \times R_{mkt,t} + \beta_{iron\ ore,i} \times R_{iron\ ore,t} + \beta_{steel,i} \times R_{steel,t} + \beta_{coking\ coal,i} \times R_{coking\ coal,t} + \beta_{FX,i} \times R_{FX,t} + \varepsilon_{i,t} \quad \text{Equation (1)}$$

where

$R_{i,t}$ is the log return on the *i*th firm's common stock in period *t*;

$R_{mkt,t}$ is the log return on the corresponding market index in period *t*;

[16] Studies include Jorion (1990), Tufano (1998), Loudon (2004), Jin and Jorion (2007) and Berghöfer and Lucey (2014).

$R_{iron\ ore,t}$, $R_{steel,t}$, and $R_{coking\ coal,t}$ are the log returns on the prices for iron ore, steel and coking coal in period t, respectively, and

$R_{FX,t}$ is the log return on the foreign exchange rate of USD to CNY.

In Equation (1), $\beta_{iron\ ore,i}$, $\beta_{steel,i}$, and $\beta_{coking\ coal,i}$ are the commodity price risk factors for firm *i* at time *t*. Risk factors for the market index ($\beta_{m,i}$) as well as USD ($\beta_{FX,i}$) are used as control factors.

Model 2: risk exposures – exposure to the spread between steel and iron ore returns

Model 1 of this study tests the direct impact of commodity price changes on firm risks. Model 2, on the other hand, estimates the sensitivity of stock returns to the spread between iron ore and steel returns. Instead of separately estimating iron ore and steel price exposures, Model 2 substitutes a single risk factor for these two risk factors, with the single risk factor representing the spread between iron ore and steel returns.

The return of the spread between iron ore and steel prices can be explained in two ways. One way is to express the spread as the difference between log returns of iron ore and steel to indicate the risk that price changes of iron ore cannot be naturally hedged by price changes of steel.

$$Return\ spread = R_{steel} - R_{iron\ ore} \qquad \text{Expression (1)}$$

Under this approach, the spread on returns can be used directly as a risk factor as it also represents returns.

The second way is to firstly express the iron ore price as a percentage of a weighted average steel price per metric tonne, as is implicated by Hurst (2015b). While analysing the disparity in the price elasticities of iron ore and steel supply, Hurst (2015b) incorporates a multiplier of 1.4 to indicate that every 1.4 metric tonnes of iron ore is used to produce each tonne of steel in a modern BOF. This is in line with the information provided by the World Steel Association (2014). A similar multiplier adjustment is used by Caputo et al. (2013). Under this logic, the spread risk can also be expressed by the price ratios between iron ore and steel:

$$Price\ ratio\ between\ iron\ ore\ and\ steel \ = \frac{1.4 \times P_{iron\ ore} \times FX}{P_{steel}} \qquad \text{Expression (2)}$$

Log returns of the price ratios are then calculated and used as the variable representing spread risk.

In fact, these two approaches for calculating spreads between iron ore and steel are effectively the same. This can be justified via arithmetic calculation.[17] In this study, expression (1) is used to keep the regression processes neat.

Therefore, Model 2 can be expressed as shown in the following equation:

$$R_{i,t} = a_i + \beta_{m,i} \times R_{mkt,t} + \beta_{spread,i} \times R_{spread,t} + \beta_{coking\ coal,i} \times R_{coking\ coal,t} + \beta_{FX,i} \times R_{FX,t} + \varepsilon_{i,t} \qquad \text{Equation (2)}$$

where $R_{spread,t}$ is the difference of returns between steel and iron ore, calculated using expression (1).

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[17] After rearrangement of the formula, the log returns of price ratios between iron ore and steel can be rewritten as:

$$R_{iron\ ore} - R_{steel} + R_{FX}$$

Under regression analysis, the coefficient results for the spread risk factor under both spread formulae are the same in absolute value.

4.2.2 Risk Horizons

Earlier empirical findings show that non-financial firms face less exchange rate exposure than expected but, according to Bartram and Bodnar (2007), the "exchange rate exposure puzzle" is simply an issue resulting from firms' hedging activities at company level; that is, we only see what the final risk is, but not what the risk is before hedging. More specifically, based on results from empirical tests, the researchers suggest that the reason why the expected number of firms is much less than expected in terms of those firms found to be exposed to the exchange rate exposure net of hedging is that firms with high gross exchange exposures but which have implemented hedging to reduce these exposures may exhibit no higher exposures than those with low exposures initially. In other words, both show low exposures to the exchange rate. Nevertheless, some researchers notice from their empirical results that when the return horizon is longer, evidence of exposures is stronger (Jorion, 1990; Chow et al., 1997; Loudon, 2004). Griffin and Stulz (2001) notice in their study that the importance of industry common shocks increases when measurement intervals are increased from weekly industry excess returns to yearly returns. The authors imply that a possible explanation is that weekly data have too low a signal: noise ratio—the proportion of variation in stock returns that represents the exchange rate and industry effects (Griffin and Stulz, 2001). Nguyen and Faff (2003) obtain similar results from their study of exchange rate exposures for Australian non-financial firms, in which the number of firms with significant exposures increases with the time horizon. Furthermore, in a study of the airline industry in Australia and New Zealand, Loudon (2004) argues that the effect of "the exposure puzzle" applies not only to currency risk, but also to interest rate and fuel price risks.

Therefore, in this study, different lengths of risk horizon are implemented in each model. Specifically, exposures are estimated with risk horizons of one (1) week, four (4) weeks (one month), 12 weeks (one quarter) and 52 weeks (one year) on an overlapping basis. By comparing exposure coefficients under various horizons, this study seeks to test whether longer measurement intervals for returns are indeed more informative on the true degree of exposure due to a stronger signal: noise ratio, as has been tested by other researchers (Chow et al., 1997; Griffin and Stulz, 2001; Loudon, 2004).

4.2.3 Structural Change in Exposures after Pricing Regime Shift

Since April 2010, when the iron ore pricing mechanism shifted from long-term contract (LTC) annual pricing to a shorter-term pricing schedule, one plausible expectation is that the iron ore price exposure of steel producers would experience structural changes due to the pricing regime shift. To test whether the exposure coefficients had structural change due to the event of the long-term contract (LTC) pricing regime shift, in the third part of the analysis, this study separates the above two regression models into two sub-periods: May 2008 to April 2010 as the long-term contract period or Sub-period 1, and April 2010 to December 2015 as the post-long-term contract period or Sub-period 2. The date to divide the sample period into two sub-periods is determined according to the contract prices index extracted from Datastream. The index shows that the import contract prices for iron ore to China were set annually until 23 April 2010 but, since then, the annual pricing mechanism for iron ore contract prices has been broken.

Chapter 5. Results

5.1 Exposure of Steel Producers

To test Hypothesis 1, this study firstly estimates the exposure coefficients for iron ore, steel and coking coal using Model 1. In addition, market returns and exchange rate changes are set as control variables in this model. In this section, data from the whole sample period are included in the regression in order to test exposures throughout the entire period, thus introducing a benchmark for the following tests. Standard errors of the coefficients are corrected to be heteroscedasticity and autocorrelation-consistent.

Table 5.1 presents the summary statistics of the exposure coefficients with weekly data under Model 1. The three exposure coefficients reported are for iron ore, steel and coking coal price risks. As iron ore and coking coal are input materials, the coefficients for these two commodities are expected to be negatively related to the stock returns of steel producers. That is, price appreciation in iron ore or coking coal is expected to have a negative impact on steel producers' profitability which, in turn, will affect stock returns in the opposite direction. In contrast, as steel is the product of steel producers and is on the revenue side, the steel producers are expected to be positively exposed to steel prices. Table 5.1, Panel A to Panel C illustrate the exposure coefficients of iron ore, steel and coking coal under different risk horizons of weekly, monthly, quarterly and annual. In addition, for each risk horizon, the numbers of cases at 5% and 10% significance level are counted. A total number of 31 firms are included in the regression analysis.

Previous empirical findings show that commodity price risks are not found to be more statistically significant than other financial risks such as interest rates and foreign exchange rates, even though commodity prices are generally more volatile. In Bartram's study (2005), the percentage of firms with significant exposures at 5% level ranges from 5.9% to 15.9% for commodity price exposures with monthly data. This range is similar to results in other studies[18] that investigate monthly foreign exchange rate exposures and interest rate exposures of non-financial firms. However, in the current study, the percentages of firms with exposures at 5% significance level under the monthly horizon for all three commodity price risks are above this range. To be specific, 5 of the 31 sample firms (16.13%) present as having iron ore price exposure at 5% significance level. This percentage is even higher for steel price exposure (15 of 31 firms, 48.39%) and coking coal price exposure (6 of 31 firms, 19.35%).

When using weekly data to estimate foreign exchange rate exposures of resource firms, Nguyen and Faff (2003) find a higher percentage of significant cases (25.93%) but, when a monthly horizon is used, the percentage drops to zero. In this study, similar evidence is found when the commodity price exposures of steel producers are analysed; however, in this study, the quarterly horizon is the risk horizon that the exposure coefficients drop for both iron ore and steel price risks. To be specific, for the exposure coefficients to iron ore price risk under Model 1, the quarterly horizon has fewer negative cases (2 of 31) at 5% significance level than the monthly horizon (5 of 31). On the other hand, for the exposure coefficients to steel price risk, the quarterly horizon has fewer positive cases (7 of 31) at 5% significance level than the monthly horizon (15 of 31). The means of the exposure coefficients for both commodity risks are also lower under the quarterly horizon than under the monthly horizon. One possible explanation is that in the steel industry, the

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[18] For studies analysing foreign exchange rate exposure, researchers typically find a range of 5% to 20% of significant cases. Studies include Bartram (2005), Bartov and Bodnar (1994), Loudon (1993) and Jorion (1990).

quarterly exposures may be hedged either through natural hedging or through operational and financial hedging activities adopted by these firms.

In general, the annual horizon has the strongest explanatory power, with the highest percentage of significant cases for all three commodity exposure coefficients, especially for iron ore exposures (70.97% negative cases at 5% significance level) and steel exposures (61.29% positive cases at 5% significance level).

In regard to the signs of the coefficients, the predictions for iron ore and steel prices under Hypothesis 1 are confirmed, in general, with the exposures to iron ore prices being negative, and the exposures to steel prices being positive. The regression results for these two exposures are both statistically and economically significant at the annual risk horizon. For the median firm, a 1% increase in iron ore (steel) prices leads to a 0.35% decrease (0.67% increase) in the stock price. However, there are two positive cases for iron ore price exposure that are significant at 5% level under the annual horizon. One possible explanation for this finding is that the firm holds a long position in iron ore which creates positive exposures to iron ore prices. According to the annual report information, one[19] of the two firms that presented a positive exposure to iron ore prices directly holds 100% shares in an iron ore mining company and indirectly holds 51% shares in another iron ore mining company. These investments possibly make the firm less reliant on iron ore imports, the prices of which are more difficult to control or negotiate.

Another possible explanation that may lead to these counterintuitive results is the "daily price limit" rule imposed by both the Shanghai Stock Exchange and the Shenzhen Stock Exchange. Specifically, the exchanges have imposed a daily price up/down limit of 5% for

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[19] Fangda Special Steel (CSRC code: 600507SH)

stocks under special treatment (ST shares or *ST shares) to stabilise the Chinese stock market.[20] This rule directly sets a range of +/-5% for the price volatility of these stocks. As a result, the movements in stock prices may not fully reflect the risk exposures faced by the firms. Among the 31 firms included in this study, four firms have stocks that are under special treatment during the sample period, one of which[21] presents signs for exposure coefficients that are opposite to expectations for both iron ore and steel.

The results for coking coal price exposures contain even more counterintuitive cases. Differing from the results for other risk horizons, the results from the annual horizon suggest that more firms are facing positive exposures to coking coal price risks at 5% significance level than are facing negative exposures. This is contrary to the prediction that steel producers are negatively exposed to coking coal prices, as appreciation in coking coal prices will negatively affect steel producers' profitability. Following these findings, further investigation is undertaken of the annual reports and structure of these Chinese steel producers. Interestingly, most firms with significant positive exposures to coking coal price risks either have a business line of coking coal mining or, under the same group, control some coking coal mining firms.[22] With easier access to coking coal and probably at better prices, these firms appear, to some extent, to be hedged against coking coal exposures.

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[20] Please refer to the Appendix 2 for more details regarding the "daily price limit" rule and the definition of "special treatment (ST)".
[21] Shanghai Broadband Technology (CSRC code: 600608SH)
[22] Please refer to Table A.1 in the Appendix 1 for the list of sample firms that have significant business relationships or transactions for coking coal trades.

Table 5.1
Summary statistics of exposures to commodity price risks: whole sample period

Panel A: $\beta_{iron\ ore,i}$				
Horizon	1 week	4 weeks	12 weeks	52 weeks
No. of observations	396	393	385	345
Mean	0.0205	-0.0640	-0.0109	-0.3839
Median	0.0246	-0.0714	-0.0566	-0.3457
Standard deviation	0.0586	0.0985	0.1856	0.3821
Minimum	-0.0852	-0.2135	-0.2856	-1.3487
Maximum	0.1448	0.1430	0.4332	0.5416
No. of negative cases significant at 5% level	0	5	2	22
No. of negative cases significant at 10% level	0	5	5	24

Panel B: $\beta_{steel,i}$				
Horizon	1 week	4 weeks	12 weeks	52 weeks
No. of observations	396	393	385	345
Mean	0.2118	0.4159	0.3040	0.8103
Median	0.2179	0.4211	0.2849	0.6724
Standard deviation	0.1102	0.2073	0.3354	0.9988
Minimum	0.0015	0.0134	-0.4898	-1.5311
Maximum	0.6325	0.7142	0.9693	3.9251
No. of positive cases significant at 5% level	4	15	7	19
No. of positive cases significant at 10% level	7	19	10	20

Panel C: $\beta_{coking\ coal,i}$				
Horizon	1 week	4 weeks	12 weeks	52 weeks
No. of observations	396	393	385	345
Mean	-0.0476	-0.2478	-0.3503	0.1794
Median	-0.0438	-0.2743	-0.3436	0.2505
Standard deviation	0.2349	0.2606	0.3354	0.8631
Minimum	-0.6585	-0.7788	-1.1524	-1.6043
Maximum	0.4535	0.4796	0.3557	2.5617
No. of negative cases significant at 5% level	2	6	12	6
No. of negative cases significant at 10% level	4	11	17	6

Notes: This table reports the summary statistics of the exposure coefficients from Model 1:

$$R_{i,t} = a_i + \beta_{m,i} \times R_{mkt,t} + \beta_{iron\ ore,i} \times R_{iron\ ore,t} + \beta_{steel,i} \times R_{steel,t} + \beta_{coking\ coal,i} \times R_{coking\ coal,t} + \beta_{FX,i} \times R_{FX,t} + \varepsilon_{i,t}$$

where $R_{mkt,t}$, $R_{iron\ ore,t}$, $R_{steel,t}$, $R_{coking\ coal,t}$ and $R_{FX,t}$ are the market return, the change in iron ore import spot price, the change in steel price, the change in coking coal price and the change in exchange rate, respectively. Cross-sectional distributions of the exposure coefficients are reported. Results are for the sample period from May 2008 to the end of December 2015, and consist of data from 31 steel producers with complete weekly stock returns during the sample period. Coefficient standard errors are corrected to be heteroscedasticity and autocorrelation-consistent. Panel A to Panel C present results for the three risk factors, applying different risk horizons using overlapping data: weekly (1 week), monthly (4 weeks), quarterly (12 weeks) and annual (52 weeks).

5.2 Structural Change in Exposures

In the second section of the analysis, Hypotheses 2 and 3 are tested. The study investigates in detail the exposures to iron ore and steel prices, as well as to the return spreads between steel and iron ore. Due especially to the fact that iron ore prices were set to match the long-term contract (LTC) prices on an annual basis until the first quarter of 2010, the iron ore price exposures of steel producers are expected to experience structural change when the long-term contract (LTC) pricing mechanism started to shift towards shorter-term pricing schedules after that date.

In this section, the regression of Model 1 is separated into two sub-periods to reflect the event of the pricing regime shift: Sub-period 1 (May 2008 to April 2010) and Sub-period 2 (April 2010 to December 2015).

5.2.1 Structural Change in Iron Ore Exposures

Table 5.2 reports the comparison of the iron ore price risk coefficients for these two sub-periods. Similar to the results in the first section of the analysis, weekly data still do not generate significant results. Moreover, as illustrated on Table 5.2, although over 20% of the negative cases are statistically significant for Sub-period 1 under the monthly horizon and the quarterly horizon (both horizons had 7 of 31 or 22.58% of cases at 5% significance level), the expected exposure coefficients of iron ore price risks (-0.0900 under the monthly horizon and -0.0238 under the quarterly horizon) are not as economically significant as the commodity price exposures generated in previous studies.

[23] The results only become both statistically and economically significant for both Sub-period 1 and Sub-period 2 with the annual horizon.

Furthermore, when comparing the coefficients under the annual horizon between the two sub-periods, the results suggest that steel producers' exposures to iron ore prices greatly increase from an average of -0.16 to an average of -0.41. In other words, steel producers have become more sensitive to iron ore price movements in the opposite direction in Sub-period 2. This finding provides support to Hypothesis 2 that the regime shift of the iron ore pricing mechanism has led the steel producers to greater exposures to iron ore prices.

5.2.2 Structural Change in Spread Exposures

The second model of this study is to examine Hypothesis 3, that is, whether any possible natural hedges between steel and iron ore prices exist among Chinese steel producers during both Sub-period 1 and Sub-period 2. As mentioned previously, iron ore prices are commonly believed to be highly correlated to steel prices (World Steel Association, 2015b; Dalian Commodity Exchange, 2013). If that is the case, steel producers should expect at least part of the iron ore price exposures to be naturally hedged by steel prices. As shown in Table 5.4, Panel A, the correlation between iron ore and steel spot prices is as high as expected, but the correlation between the returns of these two commodities is not as high. In the common practice of risk management, it is the volatility of returns that the firms

[23] Jin and Jorion (2006) find that the mean exposure coefficients for both oil and gas price risks under the monthly horizon are over 0.30 when using a two-factor model. The mean of the quarterly jet fuel exposure coefficients is found by Treanor et al. (2014) to be -0.1179. The mean of the monthly oil price exposure coefficients for the airline industry is found by Mohanty et al. (2014) to be -0.214. The mean of the weekly jet fuel exposure coefficients is found by Berghöfer and Lucey (2014) to be -0.131 for the world's airline industry and -0.247 for the airline industry in North America.

should manage; therefore, the steel producers should focus on the correlation between the returns of iron ore and steel prices when managing commodity price risks.

To the steel producers, iron ore price changes are cost-side risks, while steel price changes are revenue-side risks. Intuitively, at least part of the cost-side risks will be offset by the revenue-side risks, indicating the existence of a natural hedge. If this is the case, the standard deviation of the spreads between iron ore and steel price returns (or the 'return spreads' quoted in the following context for simplicity) is expected to be lower than the sum of the standard deviations of iron ore and steel price changes, as the standard deviations of the price changes are commonly used as risk metrics. Table 5.4, Panel B presents the standard deviations of the iron ore price changes and steel price changes, as well as the standard deviation of the return spread for the entire sample period. As shown on the table, the standard deviation of the return spread of 0.0364 is less than the standard deviation of iron ore price changes of 0.0437, suggesting that the iron ore price risk is partially offset by the steel price risk. Following this logic, in this part of the analysis, the exposure coefficients of return spread are expected to be lower in absolute value than the exposure coefficients of iron ore and steel prices. Moreover, a coefficient of return spread closer to zero would imply that steel producers are not very sensitive to the return spread, implying the existence of natural hedging.

A straightforward way to examine whether any natural hedging is in existence is to investigate whether the expected exposure coefficient of the spread risk is lower than both the exposure coefficient of iron ore price risk and that of steel price risk in absolute value. Therefore, Model 2 is introduced. Different from Model 1, Model 2 combines the risk variables for iron ore and steel prices into a single risk variable, the spread between the iron ore and steel returns, or the 'return spread'. Hypothesis 3 is then tested by comparing the expected exposure coefficient of the return spread risk to the combination of the exposure coefficients of steel and iron ore price risks.

Table 5.5 reports the regression results for Model 2. In general, the results of the coefficient estimations support the prediction that the exposures to return spread are not as economically significant as the exposures to iron ore prices estimated in previous sections. Most coefficient estimations are lower than 0.10 (except for Sub-period 1 under the quarterly horizon and Sub-period 2 under the annual horizon). Indeed, even with an annual horizon, the exposure to return spreads is still economically significant. For the median firm, a positive exposure coefficient of 0.3571 (under the annual horizon) of the return spread indicates that every 1% increase in return spread between iron ore and steel contributes to 0.357% of the stock price increase. However, the coefficient estimate is already reduced in terms of sensitivity compared to that of iron ore exposure (-0.4109) under the same risk horizon and same sub-period.

Similar to the results in the previous two sections, the weekly horizon results in this section are still not significant enough to draw any conclusions, but starting from the monthly horizon, the exposures to the return spreads show more negative cases that are statistically significant under Sub-period 1, and more positive cases that are statistically significant under Sub-period 2. The percentage of significant positive cases increases with the increasing length of the risk horizon, reaching over 64.5% (20 of 31) with an annual horizon (at 5% significance level). One possible explanation for the coefficient sign change from Sub-period 1 to Sub-period 2 is that, during the period when iron ore was still purchased using long-term contract (LTC) prices, the narrowing down of the return spreads between steel and iron ore was beneficial to the stock returns of the steel producers. By then, the iron ore price risks were still hedged by the long-term contracts (LTCs) and, to a large extent, the spot price changes of iron ore did not affect them. On the other hand, the positive correlation between the return spreads and stock returns, which appears in Sub-period 2 under the annual risk horizon, implies that an increase in the spreads of returns affects the stock returns of the steel producers in positive ways. This evidence further indicates the necessity for steel producers to manage their risk exposures to return spreads between steel and iron ore.

Table 5.2, Table 5.3 and Table 5.5 each report the expected exposure coefficients of iron ore price risk, steel price risk and return spread risk, respectively, for both sub-periods. By comparison, the coefficients of the spread risk during both sub-periods and under all risk horizons are less than the combined exposure coefficients of the two individual commodities, thereby confirming Hypothesis 3.

Table 5.2 Structural Change in Iron Ore Price Exposures

Risk horizon	1 Week		4 Weeks		12 Weeks		52 Weeks	
Sub-period	1	2	1	2	1	2	1	2
Observations	100	295	97	292	89	284	49	244
Mean	-0.0070	0.0137	-0.0900	-0.0601	-0.0238	-0.0271	-0.1611	-0.4109
Median	-0.0187	0.0158	-0.0885	-0.0543	0.0046	-0.0104	-0.2503	-0.4208
Standard deviation	0.1311	0.0901	0.1958	0.1304	0.2244	0.2118	0.3343	0.4168
Minimum	-0.2077	-0.2268	-0.4688	-0.3012	-0.4413	-0.4051	-0.7132	-1.4990
Maximum	0.2083	0.1695	0.4073	0.2023	0.4228	0.4905	0.7206	0.5455
No. of negative cases:	16	14	21	21	15	17	21	26
No. of significant cases:								
positive cases at 5% level	0	0	0	0	3	2	1	2
positive cases at 10% level	0	0	1	0	4	2	3	2
negative cases at 5% level	0	1	7	2	7	3	15	22
negative cases at 10% level	0	2	8	5	8	6	16	24

Notes: Table 5.2 presents the exposure coefficients of iron ore price risks as estimated from Model 1 using weekly data. Specifically, the regression results of two sub-periods are reported separately to investigate structural change for the event of pricing regime shift. Sub-period 1 (i.e. 23 May 2008 to 23 April 2010 in this study) represents the sample period when long-term contracts (LTCs) were still leading iron ore prices, while Sub-period 2 (i.e. 30 April 2010 to the end of December 2015 in this study) represents the sample period when the long-term contract (LTC) pricing mechanism started to shift towards shorter-term pricing schedules. In addition, this table reports the regression results under different risk horizons using overlapping data: weekly (1 week), monthly (4 weeks), quarterly (12 weeks) and annual (52 weeks). The sample consists of 31 firms with complete weekly stock returns from May 2008 to December 2015. Standard errors of the coefficients are corrected to be heteroscedasticity and autocorrelation-consistent.

Table 5.3 Structural Change in Steel Price Exposures

Risk horizon	1 Week		4 Weeks		12 Weeks		52 Weeks	
Sub-period	1	2	1	2	1	2	1	2
Observations	100	295	97	292	89	284	49	244
Mean	0.1819	0.2591	0.3748	0.3624	0.3055	0.2075	0.5195	0.9845
Median	0.1905	0.2432	0.3617	0.2911	0.3674	0.1494	0.4645	0.7987
Standard deviation	0.1936	0.2292	0.4120	0.3360	0.4188	0.5969	0.7231	1.1398
Minimum	-0.2141	-0.1045	-0.5634	-0.1594	-0.6000	-1.3546	-0.9328	-1.6260
Maximum	0.5528	0.7740	1.0868	1.1295	0.9989	1.6053	1.7741	4.6958
No. of positive cases:	26	26	25	28	26	21	26	28
No. of significant cases:								
positive cases at 5% level	2	3	11	4	8	3	13	22
positive cases at 10% level	6	3	15	5	12	5	15	24
negative cases at 5% level	0	0	0	0	0	0	1	1
negative cases at 10% level	0	0	0	0	0	0	3	2

Notes: Table 5.3 presents the exposure coefficients of steel price risks as estimated from Model 1 using weekly data. Specifically, the regression results of two sub-periods are reported separately to investigate structural change for the event of pricing regime shift. Sub-period 1 (i.e. 23 May 2008 to 23 April 2010 in this study) represents the sample period when long-term contracts (LTCs) were still leading iron ore prices, while Sub-period 2 (i.e. 30 April 2010 to the end of December 2015 in this study) represents the sample period when the long-term contract (LTC) pricing mechanism started to shift towards shorter-term pricing schedules. In addition, this table reports the regression results under different risk horizons using overlapping data: weekly (1 week), monthly (4 weeks), quarterly (12 weeks) and annual (52 weeks). The sample consists of 31 firms with complete weekly stock returns from May 2008 to December 2015. Standard errors of the coefficients are corrected to be heteroscedasticity and autocorrelation-consistent.

Table 5.4 Correlation Between Iron Ore And Steel Prices and Returns

Panel A	
Correlation between:	
Iron ore and steel prices	0.8376 ***
Iron ore and steel returns	0.5777 ***

Panel B	
Standard deviation of the return of:	
steel:	0.0181
iron ore:	0.0437
return spread between steel and iron ore:	0.0364

Notes: Panel A presents the correlation between iron ore and steel prices, as well as the correlation between iron ore and steel returns during the entire sample period. The price index used as the proxy of the iron ore spot price is sourced from the Metal Bulletin Iron Ore (MBIO)'s 62% Fe fines import Qingdao, North China. The steel price index used is sourced from MySteel's Chinese Steel Composite Price Index. *** denotes that both correlations are at 1% significance level. Panel B presents the standard deviation of the returns of steel and iron ore prices, and of the return spread between these two commodities.

Table 5.5 Structural Change in Exposure To Return Spreads between Iron Ore and Steel Prices

Risk horizon	1 Week		4 Weeks		12 Weeks		52 Weeks	
Sub-period	1	2	1	2	1	2	1	2
Observations	100	295	97	292	89	284	49	244
Mean	0.0073	-0.0401	0.0012	0.0077	-0.1211	-0.0044	-0.0539	0.3634
Median	0.0191	-0.0431	0.0313	-0.0016	-0.1438	-0.0034	-0.0598	0.3571
Standard deviation	0.1311	0.0979	0.1630	0.1216	0.2185	0.1801	0.2425	0.3822
Minimum	-0.2081	-0.2211	-0.3587	-0.2636	-0.4993	-0.4438	-0.6284	-0.4559
Maximum	0.2080	0.2185	0.2762	0.2623	0.3686	0.3289	0.4198	1.2339
No. of positive cases:	16	8	17	15	9	15	12	26
No. of significant cases:								
positive cases at 5% level	0	1	0	2	3	3	3	20
positive cases at 10% level	0	2	1	3	3	3	5	23
negative cases at 5% level	0	0	2	1	10	3	7	2
negative cases at 10% level	0	0	3	2	13	3	10	3

Notes: Table 5.5 presents the exposure coefficients for spread risk as estimated from Model 2 using weekly data.

$$R_{i,t} = a_i + \beta_{m,i} \times R_{mkt,t} + \beta_{spread,i} \times R_{spread,t} + \beta_{coking\ coal,i} \times R_{coking\ coal,t} + \delta R_{FX,t} + \varepsilon_{i,t}$$

where $R_{mkt,t}$, $R_{spread,t}$, $R_{coking\ coal,t}$ and $R_{FX,t}$ are the market return, the return spread between iron ore and steel, the change in coking coal price and the change in exchange rate, respectively. Cross-sectional distributions of the exposure coefficients are reported. The results reported are regressed from return spreads calculated as: $Return\ spread = R_{steel} - R_{iron\ ore}$.

Again, the regression results of the two sub-periods are reported separately to investigate structural change for the event of pricing regime shift. Sub-period 1 (i.e. 23 May 2008 to 23 April 2010 in this study) represents the sample period when long-term contracts (LTCs) were still leading iron ore prices, while Sub-period 2 (i.e. 30 April 2010 to the end of December 2015 in this study) represents the sample period when the long-term contract (LTC) pricing mechanism started to shift towards shorter-term pricing schedules. In addition, this table reports the regression results under different risk horizons using overlapping data: weekly (1 week), monthly (4 weeks), quarterly (12 weeks) and annual (52 weeks). The sample consists of 31 firms with complete weekly stock returns from May 2008 to December 2015. Standard errors of the coefficients are corrected to be heteroscedasticity and autocorrelation-consistent.

Chapter 6. Conclusion

The steel industry is exposed to commodity price risks, such as iron ore and steel price risks. The increasing volatility of iron ore prices due to the pricing regime shift is what the steel producers especially need to consider when managing their financial risks. This study investigates the commodity price exposures of the Chinese steel producers. In total, 31 steel producers listed on the Chinese stock markets are examined for the sample period from May 2008 to December 2015.

When Hypothesis 1 of this study is tested, the regression results using weekly data show that, in general, the stock returns of the Chinese steel firms are negatively correlated with iron ore and coking coal price changes and are positively correlated with steel price changes, but almost all results are only significant under longer risk horizons.

The study further tests Hypothesis 2, examining the structural change in iron ore prices in relation to the commodity price exposures facing the Chinese steel producers. Exposures are analysed separately for two sub-periods: May 2008 to April 2010, and April 2010 to December 2015. When the results for both sub-periods are compared, the evidence does not show significant changes of iron ore price exposure coefficients between the two sub-periods. The exception again is for the annual risk horizon which shows a significant increase in the sensitivity of the stock returns to the iron ore price changes.

To test Hypothesis 3 on whether a natural hedge is in existence between steel and iron ore price changes, the study analyses a risk factor for the return spreads between the two commodities. In general, the exposure coefficients of return spreads are found to be lower than the combined coefficients of steel and iron ore price changes, indicating that a natural hedge is possibly in existence. However, the significant number of positive cases for the spread risk exposures in Sub-period 2 implies that steel producers need to manage their risks of return spreads between steel and iron ore consequent to the pricing regime shift.

One possible explanation for some of the conflicting or insignificant results in this study is that the exposure coefficients observed actually represent the firms' post-hedging exposures. Although up to the end of 2015, only one of the 31 firms used commodity derivatives for financial hedging[24], over half of the firms are involved in operational hedging activities such as investing in iron ore and coking coal mining projects (Chang et al., 2014) and holding shares in mining companies. However, whether these hedging activities serve their purpose is for future research to explore. In further research, it would be interesting to investigate the exposure levels before hedging activities, and to explore the existing risk management procedures and hedging activities used by the Chinese steel producers and their influence on commodity price risks.

This study focuses on a single industry, the steel industry, and on a single country, the Chinese market. The benefit of examining a single industry in a single region is that, within the homogeneous environment, one would expect the firms to face the same input and output exposures; thus, the researcher can make more specific hypotheses. In addition, the examination of the exposures to both input and output risks in this study is another extension of earlier work. Indeed, the Chinese steel industry offers a representative sample to the world's steel industry due to its leading status of steel production, and the structural change in iron ore prices provides a natural experiment to test the iron ore price exposures facing the steel producers.

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[24] Based on the annual reports of all the sample firms in this study, only one firm used iron ore derivatives to hedge iron ore price risks during the sample period.

A limitation of this study is that it only reports the regression results for the entire sample period (between 2008 and 2015) and for two sub-periods (May 2008 to April 2010 and April 2010 to Dec 2015). Future research can be conducted by analysing regression results for each year to observe the possible coefficient changes for each risk factor. In addition, other financial risks, such as currency exchange and interest rates, could be investigated for the Chinese steel industry to expand this research topic.

Meanwhile, the current literature on risk exposures facing non-financial firms is extended by this study to a different industry. This study provides empirical evidence to steel producers about the types of financial risks to which they are exposed, and at what level. This will potentially be useful information for firms in more efficiently and effectively managing their financial risks and, if necessary, in selecting suitable hedging strategies. The results of this study and their implications present information to possibly assist the financial market regulators in China to establish relevant policies and regulations that can support the steel industry and stabilise the Chinese financial markets in general. Indeed, at the current stage, hedging strategies and the types of financial derivatives able to be adopted by the Chinese steel producers to manage their commodity price risks are still limited. The establishment of iron ore futures on the Dalian Commodity Exchange is a great breakthrough for both the Chinese steel industry and the global markets in that the Chinese steel producers now have easier access to the financial derivatives of iron ore, and the rapidly increasing trading volume of iron ore futures contracts in China creates a new benchmark and provides guidance for the global iron ore prices and demand. By studying the volatility of commodity prices and the relevant exposures faced by the steel producers, the regulators will hopefully develop and implement more financial products or investment policies that can assist firms with financial risk management, especially commodity price risks.

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Appendices

Appendix 1. Sample Firms Involved in Significant Coking Coal-Related Transactions or Business Relationships

Table A.1 Sample Firms with Significant Positive Exposures to Coking Coal Prices under the Annual Horizon

CSRC Code	Name of the Sample Firms	$\beta_{coking\ coal}$	Coking coal-related transactions or parties
000708.SZ	DAYE SPECIAL STEEL	1.1547***	(1)
000717.SZ	SGIS SONGSHAN	1.0089***	(2)
002075.SZ	BEIJING SHAGANG GROUP	2.5617***	(3)
600010.SH	BAOTOU STEEL	1.1272***	(1)
600022.SH	SHANDONG IRON & STEEL	1.3089***	(2)
600117.SH	XINING SPECIAL STEEL	0.7130***	(2)
600282.SH	NANJING IRON & STEEL	0.4389***	(2)
600569.SH	ANYANG IRON & STEEL	0.3237**	(2)
600581.SH	BA YI IRON & STEEL (*ST)	1.0217***	(1)
600782.SH	XINYU IRON & STEEL	0.3851***	N/A
600808.SH	MAANSHAN IRON & STEEL	0.7143***	(1)

Notes: Table A.1 reports on the 11 firms that presented positive exposure coefficients to coking coal price changes ($\beta_{coking\ coal}$) under the annual horizon during the whole sample period. The following codes are used to represent the business or parties related to coking coal production and transactions in which the firms are involved:

(1) the controlling shareholder of the sample firm produces and trades coking coal;
(2) the sample firm itself produces and trades coking coal; and
(3) the sample firm purchases coking coal from a related party (namely a sibling company).
N/A indicates that the firm is not involved in any of the above relationships or transactions.

** and *** next to coefficients denote significance at the 5% and 1% level, respectively. Data are extracted from sample firms' annual reports.

Appendix 2. The "Daily Price Limit" Rule

To stabilise the Chinese stock markets, both the Shanghai Stock Exchange and the Shenzhen Stock Exchange have implemented the "daily price limit" regulation on all stocks listed on the two stock exchanges. According to term 3.4.13 of the Trading Rules of Shanghai Stock Exchange (2006), the exchange imposes the daily price limit on the trading of stocks and mutual funds, with a daily price up/down limit of 10% for stocks (except for the first day of public listing), and a daily price up/down limit of 5% for stocks under special treatment (ST shares or *ST shares). The stock is under special treatment (ST) if the firm issuing the stock has experienced two consecutive years of annual losses: the title of the stock will be changed to *ST if the firm of the stock has experienced three consecutive years of annual losses. In this study, the stocks of four firms are under special treatment during the sample period.