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Price Volatility of Base Metals and Steel

A Case of a Large Automotive Manufacturer

Master's thesis in Supply Chain Management

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ABSTRACT

Price volatility is experienced by almost all commodities. Geopolitical pressures, pandemics, and material shortages are only a few of the possible causes to the price volatility. The thesis thus studied the characteristics and impact of base metal and steel price volatility on a large automotive manufacturer. The base metals and steel materials were chosen, as the thesis were in collaboration with the large automotive manufacturer. The thesis applied both quantitative and qualitative methods. Firstly, a literature study was initiated to identify causes of price volatility and impact on organisations. The characteristics were then quantified, to enter the regression analysis. The variables were analysed through an iterative, bivariate, and multivariate regression process. The findings resulted in a descriptive model, that interpret price volatility. Further, the findings from the impact of price volatility were then interpreted to create the interview questions. The interview results were then analysed in comparison with both the findings from previous literature and the results of the regression analysis. The regression analysis resulted in three models. The results concluded a significant price volatility spillover between energy commodities and the dependent variables. Further, inflation and industrial production were both found to have polynomial relationships with base metals' price volatility. For steel, polynomial relationships were found with both industrial production and the input materials. The qualitative analysis found both direct and indirect impacts on the case corporation. Increased risk premiums were the direct impact of volatility. The indirect impact was related to the suppliers' financial distress, which was due to cash flow volatility impacting their financial performance. Suppliers' financial distress increased the risk of bankruptcy, which transferred as a cost to the case corporation due to long integration times. For future studies, it would be of interest to include the impact of supply and demand as independent variables in the multivariate regression. Lastly, the quantification of the indirect costs identified in this thesis would be of value.

Keywords: *Price volatility, commodities, raw materials, base metals, steel, business impact, regression analysis, automotive manufacturing, purchasing*

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Contents

1 Introduction

Industries and economies worldwide are affected by commodity price volatility. The price volatility is affected by numerous factors, such as wars and recessions (Fernandez, 2008). Both base metals and steel are common components in numerous industries, and the price volatility thus impacts many manufacturers' spend significantly. Price volatility is defined in previous commodity price volatility literature as the standard deviation over a time period (Prokopczuk, Stancu, & Symeonidis, 2019). The thesis therefore, utilise the standard deviation rolling over twelve months as a measurement of price volatility. Moreover, as the thesis is conducted in collaboration with a large automotive manufacturer, the analysis is limited to the base metals and steel commodities' price volatility. Understand the price volatility and its organisational impact is thus of great value to the case corporation. This thesis adds knowledge to the research by combining an analysis of the price volatility of the base metals and steel prices, with an analysis of the organisational impact. Further, the background is presented to broaden the scope of the issue, which crystallises into a purpose. The purpose is then divided into two research questions followed by the thesis' limitations.

1.1 Background

In recent years, the prices of raw materials and commodities have become increasingly volatile. This volatility can be explained by an increasingly uncertain global economy, vast shifts in demand, the pandemic of Covid-19, and the Russo-Ukrainian war (W. Liu & Chen, 2022; Shang, Chen, Zhang, & Wei, 2021). The pandemic resulted in container and material shortages as well as geopolitical complications that heavily constrained the supply worldwide (Yazir, Sahin, Yip, & Tseng, 2020). The constrained supply leads to increasing prices and hoarding behaviors (Baddeley, 2020). Moreover, many raw materials and commodities traded on various material exchanges have been heavily impacted by financial speculators (Brogaard, Ringgenberg, & Sovich, 2018). For organisations, price volatility can be devastating. Not only does it contribute to economic uncertainty and requires heavy strategic and administrative work to mitigate, it can also damage organisations' cash flow.

Commodities of various sorts have been traded for centuries (Banerjee, 2013; Pratap, 2011). Local markets have been an intersection between supply and demand, and the trade between them enable society to grow (Catharina, 2010). The markets enable more effective pricing, leading to increased innovation and purchasing power (Petram, 2014). As society grows, the markets increase in size and scope (Dolfsma, Finch, & McMaster, 2005). More commodities are traded across the globe at a price determined by international factors. Additionally, the global system introduces new aspects to the commodity markets. However, the global trade of the commodities, increases the sensitivity of the system, leading to volatility (Ji & Fan, 2012). The connected markets are thus influenced by events, that were previously unnoticed.

The base metals material group at the case corporation consisted of copper, aluminium, tin, nickel, lead and zinc. Each metal has its unique properties and are individually traded at commodity markets (Helmenstine, 2019). The metals are commonly used in manufacturing, construction, and electronics (CME Group, 2019). The unique properties, in combination with the vast application areas, result in base metals' being a large spend in many organisations. Historically, the prices of all base metals have been stable as the market was old and mature (Jacks, O'Rourke, & Williamson, 2011). However, the increased demand, in combination with the finite amount of base metals, resulted in an increasingly volatile market (Ge & Tang, 2020). Similar to base metals, steel is used in numerous industries such as construction, automotive, electrical equipment, and domestic appliances (World Steel Association, 2019). As the demand for such products increases with an expanding world population and economic growth, the demand and price volatility for steel follows (Alvarez & Skudelny, 2017). Base metals' and steel's high spend, in combination with increased price volatility, bring large uncertainties in the industry. Understanding price volatility and the impact on corporations were thus of great interest.

The case corporation's total spending on conventional materials such as base metals and steel is increasing heavily, as the business is growing. With an increasing spend, the volatility of prices has a greater impact on the organisation's financial performance. The case corporation has no clearly defined strategy to measure or mitigate price volatility. By understanding the price volatility's impact on the case corporation, the organisation can thus proactively manage the associated risks.

Furthermore, there has been previous research conducted on the topic of price volatility in the raw material and commodity markets (Fernandez, 2008; Jacks et al., 2011; Prokopczuk et al., 2019). However, previous research on the topic of price volatility has not focused on a specific set of metals or alloys. Previous literature focused on a broader commodity segment, analysing metals, agriculture, bananas, cattle, and coffee beans simultaneously (Gozgor, 2019; Jacks et al., 2011; Ma, 2013). By researching a narrower scope of raw materials and commodities, deeper analysis and comparison can be conducted. In the scope of the case corporation, the study also bring business value as the case corporation can mitigate the impact of price volatility in the raw material and commodity markets. Additionally, previous studies focused on the quantitative part, without considering the organisational impact of the price volatility (Fernandez, 2008; Jacks et al., 2011; Prokopczuk et al., 2019). The studies mainly explain and examine the price volatility based on macroeconomic and country-specific factors. By combining quantitative macroeconomic analysis with qualitative volatility impact analysis, new findings can fill this gap in the literature. Moreover, analysing different departments at the case corporation nuanced the volatility impact on an organisation.

1.2 Purpose

There have been several studies on price volatility throughout the years (Agénor & Aizenman, 1997; Fernandez, 2008; Gozgor, 2019; Jacks et al., 2011; Ma, 2013; Prokopczuk et al., 2019; Tang, Zhang, & Shen, 2021; Weidman, Miller, Christofferson, & Newitt, 2011).

Broad commodity segments were investigated and analysed regarding both macro- and microeconomic factors(Agénor & Aizenman, 1997; Tang et al., 2021; Weidman et al., 2011). However, current literature lacks an understanding of the characteristics of price volatility specifically for the base metals and steel. As base metals and steel are major components in many manufacturers' spend, the price volatility's impact should therefore be analysed. The combination thus enabled companies to understand price volatility whilst simultaneously foreseeing its effect on the organisation.

The purpose of this master´s thesis is thus twofold. Firstly, to understand price volatility by examining the corresponding characteristics of the base metals and steel. The understanding of price volatility introduces an instrument that anticipates volatile price environments. Secondly, understanding how price volatility affects organisations, specifically the case corporation, is also a purpose.

1.3 Research questions

The purpose was clarified by creating two research questions. These research questions consider different aspects of the subject, whilst still being intertwined. The first question address the understanding of the price volatility characteristics while the second the organisational impact. The two research questions are as follows:

RQ1: What are the main characteristics of price volatility for base metals and steel?

RQ2: What is the impact of price volatility on the case corporation?

1.4 Limitations

All dissertations require limitations. These limitations narrow the scope and enable a deeper and more profound analysis of the subject. The limitations of this thesis are mainly related to the commodity selection and the case corporation.

Firstly, the thesis is limited to the prices of steel and base metals purchased by the case corporation. A narrow selection of commodities results in a deeper analysis and conclusions specific to the context of the case corporation. The limitation thus provides increased business value to the case corporation and fills the gap in previous research. Furthermore, the frequency and length of the historical price data limit the results. The price volatility of base metals and steel is analysed on months, as it is the most frequent and longest historic time period available. The longest available time period range from 2004 to 2021 and is thus used.

Secondly, since the thesis is in collaboration with the case corporation, the impact on other organisations was not investigated. The results are therefore only analysed from the case corporation's perspective. Analysing the issue from other stakeholders in the value chain or from the perspective of competitors, was not in the scope of this thesis. Further, all interviewees were operating solely within the case corporation. The results were thus limited to the case corporation and was not representative of the automotive industry.

2 Literature study

A literature study was conducted and provided the thesis with an appropriate foundation that will also assist the later quantitative analysis. The literature used for this thesis was constituted by scientific articles and other relevant and reliable sources on the matter of price volatility in the raw material and commodity markets. An overall understanding of the commodity markets is presented, followed by the characteristics of price volatility in the selected markets. Lastly, literature on the organisational impact of price volatility is presented.

2.1 Commodity markets

Commodities are substances or products that can be traded, bought, or sold (Cambridge Dictionary, 2021). There are four main types of commodities that are categorised by either source or use. Energy commodities consist of oil, natural gas, coal, and renewable energy. Metals are another type of commodity and include precious metals and industrial metals. Agricultural and livestock are the last two categories of commodities (Rodeck, 2020). Furthermore, commodities can also be divided into soft and hard commodities (Teall, 2018). Hard commodities are mined or extracted natural resources, while soft commodities are agricultural products such as wheat or livestock. These categories differ regarding the extracting of resources, although both are defined as a commodity.

Further, there are different types of commodity markets which are referred to as spot markets and derivatives markets (Rodeck, 2020). Derivative markets involve the trade of financial contracts that use the spot markets as underlying assets. Buying and selling futures contracts on the futures exchange are the most common way to trade commodities. The owner of such contracts gains control of the underlying asset at some point in the future, at an agreed price (Gorton & Rouwenhorst, 2006). Trading in futures has been conducted for centuries and evidence shows that trading in rice commodity futures was conducted eight thousand years ago in China (Teall, 2018).

Many different investors are trading commodities. Commercial organisations that need the commodity for their service offering or manufacturing is the predominant investor of commodities (Williams, 2011). Additionally, financial investors trade commodities to add diversification to their financial portfolios (Bansal, Kumar, & Verma, 2014). Rodeck (2020) explains that financial investors place bets on the expected future price of the commodity to make profits. These investors also increase the liquidity of the markets thus increasing the competitiveness of the pricing (Williams, 2011). Additionally, commodities have been a store of value against inflation, exchange rates, and uncertainties (Bird, 1984).

Liquidity is an important aspect to consider when explaining the structure of the commodity markets. Firstly, several elements facilitate the liquidity of the commodity markets (Williams, 2011). The liquidity of the market increases when more of the elements are present in the market. Standard quantities are one of these elements. Prices can thus be established per standard quantity, rather than the aggregate amount. An open, transpar-

ent and non-discriminatory delivery method is additionally an element that increases the liquidity of a market (Hecht, 2021). Williams (2011) states that liquidity is also affected if the commodity has standard grades. Having standard grades enables trade without inspection of the commodity that is being traded.

Commodity futures and other financial products are also traded on several markets. Markets can vary depending on geographical location or traded commodity. Chicago Board of Trade (CBOT) established in 1848, is one of the most influential markets (Siler, 1989). CBOT offers today a wide range of options and futures contracts that vary from agricultural to treasury bonds. London Metal Exchange is another prominent commodity exchange that is focused on metals.

2.2 Global factors with impact on price volatility

Base metals and steel are heavily influenced by the factors of the global economy as they are either traded on spot markets or produced to import and export. It was therefore of interest to this thesis to understand how these factors explain the volatility of commodity prices. Supply, demand, and cycles of the commodities including macro-economic factors such as business cycle, industrial growth rate, and energy commodities are such factors.

2.2.1 Supply and demand

Supply relates to the availability of goods and services while demand relates to consumption. In the case of low supply and high demand, customers compete on getting hold of the resources and thus drive up the prices. Consequently, companies invest more in supply to feed the demand, trying to reach an equilibrium. Together, the equilibrium between supply and demand therefore heavily affects the prices of all goods and services (Janvier-James, 2012; Moore, 1925).

Vasishtha (2022) explains that the supply and demand's impact on global shocks, therefore volatility, has changed over time. Global demand influences the volatility of commodity prices to a larger extent than previously, whilst the global supply effects remain relatively low (Jacks & Stuermer, 2013). Demand shocks rather than supply shocks drive most of the price fluctuations regarding the real commodity price. Similarly, Kilian and Zhou (2018) argues that the demand is one of the main dependent variables of the real price of commodities. Subsequently, the demand shocks, mentioned by Vasishtha (2022), heavily affect the price behaviors such as volatility. Further, Gargano and Timmermann (2014) states that the volatility is closely linked to emerging economies' demand, like China and India. To measure the demand for industrial commodities, Gargano and Timmermann (2014) use the Kilian index as a variable. This index is similarly advocated by Kilian and Zhou (2018) and was initially proposed by Kilian (2009). However, this index was only available on a yearly frequency.

The time from the first discovery to a decision to invest in the construction of a metal mine take several years due to national policies (García & Guzmán, 2020). The time increases the short-term volatility of the metal prices since an equilibrium of supply and demand

is more difficult to achieve due to this lag. A similar conclusion is found by Gargano and Timmermann (2014), stating that the mismatch between supply and demand heavily influences the volatility of spot market prices. An increase in supply is thus lagging behind an increase in demand. Regnier (2007) found that the price volatility was higher for metals than in the other globally traded commodities. Furthermore, the inelastic supply of commodities could explain price volatility. However, metals are closely linked to emerging economies such as China, which is also stated by Gargano and Timmermann (2014). Moreover, by-products can also be affected by fluctuations in the main product. Changes in the production of the main product thus influence the supply curve of the by-product mineral and increase the price volatility.

Price elasticity is a central aspect to consider when analysing the demand (Gallo, 2015a). The price elasticity determines how the demand shifts depending on the price of a product. Additionally, Elayan, Catik, Balcilar, and Balli (2021) states that the price elasticity is dynamic and may differ between time periods. According to Lijesen (2021), the price elasticity corresponds to the macroeconomic environment. In terms of commodities, it is common that products' price elasticity differs in magnitude between different commodities. Fernandez (2007) exemplifies that the price elasticity of steel tends to be lower than the base metal aluminum. Moreover, the price elasticity of commodities also tends to differ across geographical regions.

2.2.2 Steel production

Iron ore is one of the main raw materials to produce steel, and the price of iron ore thus heavily influences the price of steel (Plaizier & Nachtergaele, 2010). According to the authors, the influence contributes to a significant spillover of price volatility between iron ore and steel. The spillover occurs as producers tend to pass over cost changes to the end customers. Additionally, recycled scrap steel is also used in the production of steel.

Historically, iron ore has been characterised by a stable price and yearly contracts. However, as stated by Ma (2013), iron ore prices have become highly volatile following the global financial crisis. Both Plaizier and Nachtergaele (2010) and Ma (2013) state that a cause could be the structural change in the pricing mechanism initiated by the main iron ore suppliers. After the financial crisis, suppliers have been moving from yearly contracts to quarterly contracts. The new pricing system closely follows the spot market prices of China and thus increased the dependency on supply and demand dynamics as well as the impact of financial speculators. Moreover, a significant increase in demand from steel-producing countries like China increased the prices. IEA (2021) further states that this increase can also be explained by the increasing demand for steel from India and Africa, driven by both population and Gross Domestic Product (GDP) growth. According to Bekaert et al. (2021) both the European and North American markets follow the same dynamics.

According to EURIC (2020) 35,5 percent of the global crude steel production was produced with the use of recycled scrap steel instead of the use of iron ore. In the US, Bureau of International Recycling (2020) report that approximately 69 percent of crude steel production is from scrap steel. In the EU, both Willeke (2017) and Bureau of International Recycling (2020) report that over 54 percent of crude steel is produced using recycled scrap steel. Furthermore, apart from the use of iron ore or scrap, there are other regional differences in the production process of steel. Bekaert et al. (2021) state that 67 percent of crude steel production in the US is conducted via electric arc furnaces. In the EU, 40 percent of the production is produced through electric arc furnaces and the majority through coking coal.

2.2.3 Commodity cycles

A strong feature of commodity prices is their cyclical behavior (Reitz & Westerhoff, 2006). Commodities fluctuate in price with certain regularities which have a significant effect on consumers, producers, and countries (Arango, 2006). Subsequently, according to Rachuri (2021), commodity cycles are a complex economic phenomenon in the commodity markets that are heavily influenced by geopolitical events. The fluctuations, in combination with the significant effect on consumers, producers, and countries, make the cycles interesting to analyse. Cashin, McDermott, and Scott (2003) report, that the average length of a commodity cycle is 68 months when defined as peak-to-peak. Reitz and Westerhoff (2006) state that the average price falls during slumps in a commodity cycle were 46 percent and increased by 42 percent during booms. The authors' further state that these fluctuations are challenging for policy makers.

Additionally, supercycles span over a larger time frame than ordinary commodity cycles and influence and characterise the commodity markets. Erten and Ocampo (2013) state that supercycles of commodities differ from short-term fluctuations connected to microeconomic factors. The authors explain that the cycles tend to have upswings for a time of 10-35 years and complete the cycle after 20-70 years. The two cycles of the late nineteenth century and post-World War two were two cycles driven by a resurgence of demand for raw materials (Heap, 2005). Further, these cycles tend to be demand-driven and commodity prices have a strong correlation during this time (Pindryck & Rotemberg, 1990). Maranon and Kumral (2019) indicates that the real price of base metals and minerals would be affected by economic cycles of 45-60 years.

Moreover, shorter price cycles within the commodity sector also exist. Labys, Kouassi, and Terraza (2000) state that these cycles can span for less than twelve months. The authors further state that the second type of cycle was identified which spans close to two years. The last commodity cycle peaked in 2008 when the price of crude oil went up to 147 USD per barrel (Rachuri, 2021). Moreover, a new cycle has supposedly begun in 2018, when the price of base metals rose by approximately 62 percent within a year.

2.2.4 Industrial growth rate

Industrial growth rate refers to the rate at which a country's industrial production output increases or decreases during a time period. As industrial production is an essential factor in a country's economy, it is a suitable indicator of an economy's growth and current state (Worrell, 2004). In previous literature, the indicator has been used to both explain and predict the commodities price volatility.

The growth rate of industrial production is a significant variable influencing the commodity prices (Gargano & Timmermann, 2014). The authors explicitly state that the variable is suitable for predictive analysis of commodities. Kilian and Zhou (2018) states that the most advantageous measurement of global industrial production is the Purchasing Power Parity-weighted index of Organisation for Economic Co-operation and Development (OECD). The index is available on a monthly frequency and focused on the variation and is thus closely linked to volatility. Moreover, the author mentions the significant downside of this index is that some countries do not share their production statistics. Further, emerging economies such as China have a significant impact on the volatility of commodity prices and is preferably reflected in the variable (Gargano & Timmermann, 2014). However, Prokopczuk et al. (2019) measures the industrial growth rate via the index Industrial Production (IP) and reaches a statistically significant model of price volatility. The index is available on a monthly frequency, similar to the index by OECD, and is reported by the Archival Federal Reserve Bank of St. Louis.

2.2.5 Energy commodities

Energy-related costs play a crucial role in industrial companies since it greatly influences the decision-making (Vacha & Barunik, 2012). Financial investors and industrial entities both find interest in energy commodities, due to its investment and energy-generating properties. The global primary energy sources are oil, coal, and natural gas (Herrera et al., 2019). Herrera et al. (2019) states that the price of the different energy sources has an intimate relationship with the world's economic and political state.

The strong connection between energy and non-energy commodities' index prices is clear, in the short term across certain quantiles of the conditional distribution, according to Khalifaoui, Baumöhl, Sarwar, and Výrost (2021). Furthermore, the global energy commodity market positively significantly affects the majority of the global non-energy commodities, in different market states. The energy commodities oil, natural gas, and coal, were markets of high price volatility (Regnier, 2007). Similar to Khalifaoui et al. (2021), Ji and Fan (2012) found a significant link between the price volatility of the energy commodities and the non-energy commodities, especially concerning crude oil. The link was strongly correlated during recessions such as during the global financial crisis in 2008. Regnier (2007) use the Producer Price Index (PPI) to measure and compare the volatility of energy prices. PPI is an aggregation of output prices from producers excluding taxes, transportation, or discounts (Wright, 2016). The index is available by OECD on a monthly frequency and by annual growth rate.

Oil is potentially the most essential energy commodity. Overall, the oil market has a long and mature history and is known to be relatively inelastic to demand changes (Ge & Tang, 2020). The oil price is generally explained by the interactions and expectations between actors in both the physical and financial markets (Kaiser, 2020). The oil price is one of the most volatile global commodity prices, according Kumar, Tiwari, Raheem, and Ji (2020); Regnier (2007), and Ji and Fan (2012) present a significant spillover of price volatility between oil and metals. Furthermore, it is clear that the volatility of the historical oil price has been heavily impacted by supply shortages, seasonality, and geopolitical events (Dogan, Majeed, & Luni, 2021; Henriques & Sadorsky, 2011; Kaiser, 2020; Regnier, 2007). To cope with the volatility impact caused by supply shortages, many actors implement strategies such as the creation of strategic physical reserves. The US holds large reserves of petroleum to control the supply, and thus the prices. Brent and West Texas Intermediate (WTI) were the two most influential oil price benchmarks, although new benchmarks are gaining ground (Palao, Ángel Pardo, & Roig, 2020).

Natural gas is used for generating electricity and heat. The market of natural gas is a global market characterised by heavy competition (Long, Moore, & Wenban-Smith, 2003). The heavy competition started due to a structural change in the market between the late 1970s and 1990s, mainly driven by government policies (Hailemariam & Smyth, 2019). In the short term, gas price volatility is determined mainly by supply, seasonality, and the physical constraints in its infrastructure. The physical implications of gas distribution are one of the major factors in its short-term price volatility. Moreover, in the long term, there is a significant spillover in price volatility from the oil market to gas (Long et al., 2003; Mandaci, Çaglar Caglia, & Taşkinb, 2020). On the contrary, Hailemariam and Smyth (2019) found that the main driver of natural gas price volatility was the demand shocks. However, the authors also concluded that supply shocks play a significant role in price volatility.

Another essential energy commodity is coal, which is used worldwide for electricity and industrial production. Batten et al. (2019) states that thermal coal accounted for over 37 percent of the world's electricity production in 2016. Moreover, the price of coal is heavily determined by the forces of the Australian market due to its product quality, technical constraints, strategic geographical location, and the coal extraction nature. However, Batten et al. (2019) found that the volatility of these prices closely relates to the demand of China. Even though China is one of the largest producers of coal, coal is further imported from Australia. Moreover, since the discovery of oil, many of coal's application areas have been substituted with oil (Zamani, 2016). Coals high environmental impact and inconvenience to transport, compared to oil, contributed to the transition. If the price of one increases due to supply disruptions, it is likely that the demand for the other is increasing.

2.2.6 Business cycles

A business cycle is a complex economic phenomenon that may vary depending on the country (Polak & Tinbergen, 2004). Generally, it can be defined as the cyclical pattern and movement of the overall economy. The cycle influences all markets and was thus affecting the price cycle of commodities. A rising business cycle is characterised by increasing employment rates and investments while a falling cycle is characterised by economic uncertainty. The business cycle is often individual to each country, however, there is empirical evidence that shows how bilateral trade between countries increases the correlation of the countries' business cycles (Baxter & Kouparitsas, 2005).

Previous research has shown that the commodity markets closely follow the business cycles (Erten & Ocampo, 2013; Ge & Tang, 2020). Moreover, Ge and Tang (2020) empirically concluded that the correlation includes metal prices. A peak in the economy thus increases metals' prices. Vasishtha (2022) state that the price volatility of the whole commodity market is heavily influenced by global macroeconomic shocks. Moreover, Prokopczuk et al. (2019) concluded that the volatility of commodity markets was strongly related to global economic uncertainty.

> *"We find that commodity market volatility comoves with economic and financial uncertainty. This temporal dependence is much stronger during recessions than during expansions"*
> - Prokopczuk et al. (2019)

Additionally, the price of globally traded commodities tends to follow the global business cycles (Gargano & Timmermann, 2014; Kilian & Zhou, 2018; Prokopczuk et al., 2019). Gargano and Timmermann (2014) advocates the use of global GDP as a variable to explain the impact of the economic situation on the volatility of commodity prices. GDP is a widely used and standard measure of value created in a country in a certain time period through the production of goods and services (OECD, 2022). The measure is one of the most important indicators of economic activity. Similar to Gargano and Timmermann (2014), Ge and Tang (2020) found that the commodity price returns serve as a significant predictor of the worldwide GDP. In other words, the author managed to predict the next quarterly GDP with statistical significance, using commodity price returns as an independent variable.

Moreover, the quote further states that the dependence on economic uncertainty was stronger during recessions than during expansions. A similar conclusion was found by both Gargano and Timmermann (2014) and Vasishtha (2022). Moreover, Vasishtha (2022) argues that during global recessions, both the demand and the supply are disrupted. Subsequently, as is stated by Prokopczuk et al. (2019), the highest dependence in the time span 1990-2015 was during the global financial crisis in 2008-2009.

From the perspective of metal prices, World Bank (2021) describes that price jumps and collapses in the markets, depending on major global economic events. Similar to the general commodity market, the dependence was stronger during recessions (Gargano &

Timmermann, 2014; Kilian & Zhou, 2018; Prokopczuk et al., 2019). World Bank (2021) state that the price volatility is fairly synchronised before and after the recessions and that the effect of the recessions has an asymmetric impact on the price of metals. The effect on the volatility thus differs when entering the recession and recovering from a recession. The increased amount of fiscal spending could be a cause of this asymmetric impact. However, Vasishtha (2022) states that the commodity prices during the recession of 2020 sharply rebounded, in contrast to the statement by World Bank (2021).

2.3 Financial factors with impact on price volatility

Financial and economic factors influence a wide range of commodities worldwide. Macroeconomic factors influence international trade, imports, and export from numerous markets. Inflation, economic policies impact, and currency exchange rates were identified through previous literature as suitable variables to analyse.

2.3.1 Inflation

Inflation is the rate of price increases over a given time (IMF, 2022). The broad indicator of inflation measures the overall price increases or cost of living in a specific country. There are however several different ways of measuring inflation. Jongrim, Kose, and Ohnsorge (2021) include the six different measurements of inflation of headline Consumer Price Index (CPI), food CPI, energy CPI, core CPI, producer price index, and GDP deflator. One of the most common measurements is headline CPI. IMF (2022) explain that CPI is based on the cost of a basket of items containing housing expenses among others. The basket of goods changes over time depending on consumer behavior. Core consumer inflation is another commonly used to measure of inflation. Core consumer inflation focuses on the underlying and persistent trends of the CPI by excluding certain volatile elements such as food and energy. The GDP deflator, however, provides broader coverage than the other measurements since it calculates the overall inflation, not only for consumers (IMF, 2022).

Inflation and commodity prices have also been studied in previous literature. From the perspective of Brazil, Moreira (2014) states that higher volatility in commodity prices leads to higher inflationary expectations. Similarly, Siami, Sima, Hudson, Alexandre, and Lyford (2019) explains that there is a connection between commodity price volatility and inflation. Additionally, the correlation corresponds with the conclusion by Zaremba, Umar, and Mikutowski (2019), the author although emphasises that the correlation changes over time. Similarly, Ciner (2011) highlights the long-term positive correlation between commodities and inflation. Ciner (2011) also argues that the correlation is only detected when the frequency dependency is accounted for in the regression, which suggests nonlinear dynamics between commodity prices and inflation. Additionally, commodity futures returns were positively correlated to unexpected inflation, although to varying extent depending on the commodity (Kat & Oomen, 2007).

Further, the growth rate of the CPI can be used to measure the inflation of the global economy on commodity markets (Gargano & Timmermann, 2014; Prokopczuk et al., 2019). However, CPI includes the prices of foods and energy which were highly volatile and may reflect short-term price changes. A more representative and long-term measure could be the core inflation, which excludes foods and energy prices (Rich & Steindel, 2005). Core inflation can be based on the CPI or the core personal consumption expenditures (PCE) index. The core inflation via PCE is used by the Federal Reserve of the United States to indicate inflation. Further, commodities are used as financial instruments to hedge against inflation (Spierdijk & Umar, 2013). Spierdijk and Umar (2013) state that energy, industrial metals, and live cattle were especially suitable for hedging against inflation. Additionally, industrial metals continue to add inflation protection in portfolios, although the hedge will likely be more nuanced in the future (Craig & Lam, 2021).

2.3.2 Economic policies

In general, policies are utilised by countries to direct and guide its markets. Policies that are used appropriately can drive investments, technology, production, and other macroeconomics within countries (Shaikh, 2020). Depending on the purpose and type of policy, policies could be created through government command or market incentives (L. Liu et al., 2021).

Regnier (2007) argue that the understanding of price volatility in the commodity markets in general, allows importing and exporting countries to target their policies. Such targeting can reduce risks and negative financial impacts. The US government has invested heavily in strategic petroleum reserves to stabilize the supply. With prices closely linked to the supply, it is possible to control the prices of petroleum. With an increasing global awareness of sustainability, environmental regulations and policies were increasing. Moreover, L. Liu et al. (2021) concludes that commanding and controlling environmental regulations harm countries' industrial growth.

Siami et al. (2019) explain the importance of understanding commodity price volatility to create accurate monetary policies. The authors found that the volatility in commodity price indices overshoots the long-term equilibrium price during monetary policy impulses. Moreover, Apergis, Chatziantoniou, and Cooray (2020) found no significant difference in the impact between conventional and unconventional monetary policies on the volatility of commodity prices. However, the author concluded that the unconventional policies were more pronounced across all commodity types of their research, including metals. Further, the unconventional policies had a greater impact on the economic uncertainty. The monetary policies may thus affect the commodity markets through its impact on the economic uncertainty. Both Dogan et al. (2021) and Shaikh (2020) explain that economic policy uncertainty is negatively associated with investments. Investors, therefore, tend to postpone their investment decisions, which in the long term negatively impact the overall economy. Moreover, Ahmed and Sarkodie (2021) found that economic policy uncertainties had a causal relationship between oil and currencies. Additionally, evidence suggests that economic policy uncertainties had positive effects on metals' future returns during a rising

market. Lastly, the authors concluded that the commodity market can predict economic policy uncertainty, suggesting a relationship between the two. Economic policy uncertainty is often quantified via the US Economic Policy Uncertainty (EPU) index (Shaikh, 2020).

2.3.3 Currency exchange rates

Currency exchange rates are affected by the world's economy and impact the price of all internationally traded goods and services (James, Marsh, & Sarno, 2012). These rates affect worldwide inflation through import costs and commodity prices. Thus, the topic of exchange rates was of interest to any global actor like governments, media, or businesses.

Chen and Rogoff (2003) concluded that some currencies were heavily correlated with commodity prices, like the currencies of Australia, Canada, and New Zealand. Sankararaman et al. (2018) found that the Japanese yen negatively correlated to commodity prices. Countries with an economy that relies on exporting commodities often have a currency that fluctuates with their exporting commodities (Chen & Rogoff, 2003). Cashin, Céspedes, and Sahay (2004) however states that only a third of the commodity prices correlate to their respective currency in the long run. Further, strong causal effects were observed by Belasen and Demirer (2019) For several commodity-exporting countries' currency and their respective exporting commodity. Further, the authors explain that the causal effects were largely in the direction of currencies affecting commodities. Additionally, the causal effect from the currencies to commodities was also affecting volatility and not only returns (Belasen & Demirer, 2019). The causality also became more present during the recession of the financial crisis of 2007-2009.

The US dollar specifically also influences the price of commodities to a certain extent. Kowalski (2021) explains that the dollar influences the commodity prices, due to it being the benchmark in the pricing mechanism for most commodities. The author further states that the benchmark is used due to the stable economy of the United States. The benchmark enables the US dollar to influence the price of commodities that are not traded within the country. According to the author, the dollar and commodity prices negatively correlate. Additionally, the US exchange rate influence the spillover of the volatility between commodities and currencies (Antoakakis & Kizys, 2015).

Moreover, in the model presented by Prokopczuk et al. (2019), the United States Dollar (USD) index was used to measure the effect of exchange rates on the volatility of some commodities. More specifically, the index measures the return on the trade-weighted US dollar against major currencies. Similarly, Antoakakis and Kizys (2015) analysed how the exchange rate between the US dollar and other currencies, in combination with other factors, influenced the transmission of volatility towards certain commodities.

2.4 The impact of price volatility on organisations

All organisations are exposed to the risk of commodity price volatility (Zsidisin, 2011). Once the price volatility can be explained, it is possible to understand commodity price volatility's real impact on organisations (Henriques & Sadorsky, 2011). Further, fluctuations in commodity prices can have devastating impacts on organisations' supply chain and financial performance (Gaudenzi, Zsidisin, & Pellegrino, 2021). Understanding both the price volatility itself as well as the impact enables risk mitigation. Gozgor (2019) use the agricultural commodity market to empirically test the effect of price volatility on economic integration in 133 countries. The author found that price volatility has a statistically significant negative effect on economic integration in these countries.

Organisations' investment decisions are heavily impacted by uncertainties (Alaali, 2020; Henriques & Sadorsky, 2011). In an ideal world with perfect information, organisations would always be able to conduct optimal investments. However, such investments were generally either over or under the optimal investment. The authors explicitly exemplified oil price volatility as an uncertainty that affects many organisations' strategic decision-making. Gaudenzi et al. (2021) found that commodity price volatility can be mitigated through investments in flexible supply chain capabilities, as it enables greater support from executive management in the decision-making process. Furthermore, Henriques and Sadorsky (2011) found that with increasing uncertainty in oil price, investments are postponed until the uncertainty has been resolved. Furthermore, the authors identified a negative correlation between investments and oil price volatility. Additionally, after some point in increasing uncertainty, the need for organisational strategic growth takes over, resulting in higher investments. Lastly, there is a positive correlation between investments and cash flow (Alaali, 2020; Henriques & Sadorsky, 2011).

Moreover, the price volatility of input materials leads to fluctuations in the end-products price (Moheb-Alizadeh & Handfield, 2018). The influence varies depending on the industry, whereas the petrochemical and automotive industry are especially impacted, due to a dependence on oil and nonferrous metals respectively. Moreover, by understanding how the input variables' volatility affects the end-products' cost, the purchasing can be optimised, which leads to increased profit (Moheb-Alizadeh & Handfield, 2018). The savings can be used to increase strategic investments, such as market differentiation or flexibility in the supply chain (Henriques & Sadorsky, 2011; Zsidisin, 2011).

Gransberg and Kelly (2008) state that price volatility increases the likelihood of subcontractors enlarging their risk premiums. The increased risk premiums assure the subcontractor of continued profitability at higher prices, although resulting in a cost for the purchaser. Minton and Schrand (1999) conclude that volatility in the cash flow is associated with higher costs of accessing external capital. Additionally, cash flow volatility increases the likelihood of the firm needing access to capital markets. The risk of a shortfall in the cash flow, due to its volatility, cause firms to forgo investments, thus indicating a cost (Minton & Schrand, 1999). Lastly, Hussain, Rus, and Al-Jasif (2019) states that cash flow volatility negatively affects the dividend pay-out behavior, in emerging countries.

Additionally, Weidman et al. (2011) states that price volatility leads to higher costs and risk for suppliers, contractors, and owners which cause financial distress for all involved parties, exemplified in the construction industry. Moreover, higher volatility raises financial intermediate spread including the producers' cost of funds, resulting in lower employment and higher incidence of default Agénor and Aizenman (1997). High volatility thus increases the financial distress on the company itself through its suppliers. Tang et al. (2021) states that volatility in profitability leads to a considerable loss in aggregated total factor productivity.

3 Methodology

This section is dedicated to presenting the methodology that was used to conduct this thesis. The overlying design of the research is presented first, followed by the process of the data gathering. Moreover, the processing of data is described as well as how the organisational impact on the case corporation was identified. Lastly, the methodology of ensuring the research quality is presented.

3.1 Research design

The thesis research design was an in-depth single case study of a large automotive manufacturer. The case corporation has been anonymised as per the corporation's request. According to Bell, Bryman, and Harley (2019), a single case study aim to research the complex nature of a specified case. The case could be limited to either a single organisation, location, or person. The design was suitable for the thesis as it was conducted in collaboration with the case corporation. The overall research design applied to this specific case was described in Figure 1. Multiple kinds of data were collected via literature studies, interviews, and quantitative data via the resources of the case corporation.

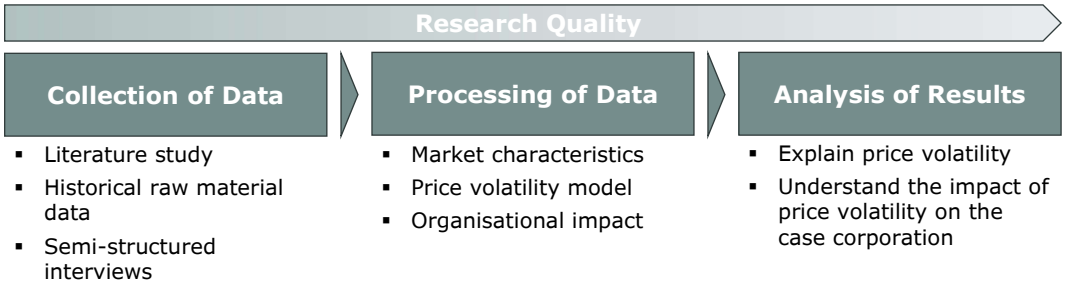

Figure 1: An overview of the research design created for the thesis

As a single case study design enables an in-depth analysis of a specific context of an organisation, the results are often of high value to the case corporation (Bell et al., 2019). Consequently, a common issue with case studies is how the researcher form theory from the findings of the empirical data. The methodology should therefore ensure that the thesis can be replicated in other organisations. Moreover, Bell et al. (2019) states that case studies can be used to tune or redefine already existing theories instead. Subsequently, this thesis took inspiration from previously proven concepts and methods. Further stated by Bell et al. (2019), a case study is often associated with qualitative research methodologies, although both quantitative and mixed methods are widely used in case study research. To tailor the research methodology for the requirements of the case corporation, both quantitative and qualitative methods were used. Moreover, since the thesis was related to a specific case corporation, the commodity markets were limited to the ones affecting the case corporation. The selection was selected based on general criteria as well as criteria specific to the case corporation.

3.1.1 Research methodology

Mixed methods research is a research methodology using both quantitative and qualitative research within a single project (Bell et al., 2019). Furthermore, the research methodology is commonly used with the case study research design. A mixed-method research methodology fit the research questions and the requirements of the case corporation. The structure of the mixed methodology can be seen in Figure 2.

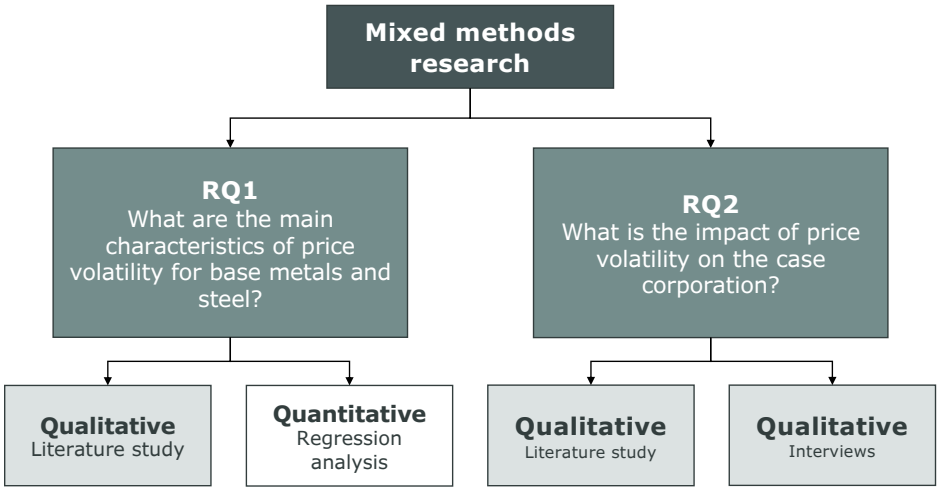

Figure 2: The structure of the mixed methods research methodology that was created for the thesis

Research question one (RQ1) was answered via both a qualitative and quantitative method as it adheres to the literature study and the OLS regression analysis respectively. The literature study was conducted before the regression analysis, as it identified the main characteristics to quantify. Further, the regression analysis was based on these characteristics as independent variables. The second research question (RQ2) was also answered via qualitative methods. The literature study served as a foundation to create an interview structure that identified the impact of price volatility in the case corporation.

3.1.2 Commodity selection

The number of examined commodities determined the depth of the thesis. To reach a sufficient depth, the number of analysed commodities was limited. The limitation of commodities was conducted based on the aspects of data availability, economic impact, and material characteristics. Data availability greatly influenced the selection of commodities. Accessible resources such as internal documentation and databases' content limited the data. For instance, the commodity had to be either publicly traded or available by internal sources at the case corporation for it to be included in the thesis.

Furthermore, an economic impact from the commodities on the case corporation had to be present. The presence of the economic impact assured that the volatility of the chosen commodities could be analysed within the organisation. The economic impact factor also ensured the thesis's business value and longevity to the case corporation. Moreover, the

commodities in the thesis had to have similar characteristics such as being a metal or alloy. The similar characteristics enabled a comparison between the studied variables, which broaden the analysis. Additionally, commodities with similar characteristics were more likely to be impacted by related factors. The ability to categorise the commodities into groups to be analysed on a higher level was also needed. Therefore, the commodities shared similarities that allowed the possibility to arrange them into different groups such as metals or alloys.

Table 1: A summary of the selection of groups and commodities

Material group	Raw material / Commodity
Base metals	Copper Aluminium Tin Lead Nickel Zinc
US Steel	US Cold rolled coil US Hot dipped galvanized coil US Hot rolled coil
EU Steel	EU Cold rolled coil EU Hot dipped galvanized coil EU Hot rolled coil

The requirements of the literature study resulted in the selection of the commodities base metals and steel as study objects, see Table 1. Additionally, the steel subjects were divided into two separate groups due to the regional differences in price. Each group contained hot-rolled coil, cold-rolled coil, and hot-dipped galvanized coil. These products were chosen as they were the steel products of highest spend in the case corporation. Further, the base metals were only one group based on the materials.

3.2 Collection of data

A literature study was conducted to identify the markets' main characteristics. These characteristics served as input for the quantitative analysis as independent variables. The quantitative analysis was based on quantitative data collected mainly via the case corporation's resources. Moreover, the main additional data collected to answer the second research question was qualitative, in form of interviews and literature study. The second type of qualitative data was collected through semi-structured interviews.

3.2.1 Literature study structure

One of the most crucial parts of any dissertation is to study the literature in the subject area (Bell et al., 2019). Wallén (1996) states that without a theoretical background and assumptions a researcher does not know what empirical data to research. The literature study was thus especially important in the thesis since the quantitative part was based on

the findings in the literature study. The literature study served as a foundation for understanding which variables were to be included in the quantitative analyses. The literature study also identified themes and concepts that were essential in the understanding of the overall subject of the commodity market and prices.

Using different sources of information is important to consider when conducting a literature study. The information must be credible, relevant, and accessible to be collected and analysed. Information was mainly collected through scientific articles found on the research engines *Research gate, Google scholar* and *Chalmers library*. The searches on these databases were initially limited to the subjects *commodity market, raw material market, price volatility,* and *organisational impact* to get a broad understanding of the scope. The broadened understanding of the overall subject enabled more detailed keywords that were better suited for this thesis. Bell et al. (2019) argues that the use of synonyms and opposites of the keywords could be useful when conducting a literature study. The detailed keywords were thus *base metals, steel, oil, coal, natural gas, cost of price volatility, supplier impact, customer impact, short-term, long-term, political impact*, and *financial impact*.

The literature study was conducted throughout the entire thesis, with a strong focus before the quantitative analysis. It was necessary to conduct a large part of the literature study before the quantitative analysis as it was based on these findings. Moreover, Patel and Davidsson (2019) states that the volume of the collected literature must be evaluated. The collected literature must be sufficient to answer the specific questions adequately. An iterative process of evaluating if the literature was sufficient to answer question one, was therefore conducted.

3.2.2 Historical commodity price data

There are several methods to collect quantitative data such as historical commodity price data. Secondary analysis and official statistics were methods described by Bell et al. (2019), which were used in this thesis. The secondary analysis method is a method of collecting data from either organisations or companies (Patel & Davidsson, 2019). The collection of historical price data was therefore classified as secondary data and not primary. The method enabled confirmation of the data validity through cross-checking and deeper analysis due to time savings. The quantitative data was mainly collected via the resources of the case corporation and cross-checked with online resources of other companies' public data. Cross-checking quantitative data is important to ensure the precision of the gathered data (Wallén, 1996).

The historical commodity price data was a time series dataset. The dataset consisted of prices from each commodity specified earlier in Table 1, resulting in a total of 12 columns. The time series started in January 2004 and ended in December 2021. Further, the prices were on a monthly frequency, resulting in a time series of 204 data points. The number of data points was limited to the availability of data. For some of the commodities, it was possible to find older data, however, for others, it was not. As the dataset had to be in the same number of data points, it was limited by the shortest time series.

3.2.3 Semi-structured interviews

Further, the primary information was gathered through qualitative interviews with several interviewees at the case corporation. Patel and Davidsson (2019) describe qualitative interviews as interviews with a low degree of structure. Semi-structured interviews were the method, which was a qualitative interview form with limited structuring. The interviewee was thus able to answer the questions with great flexibility and use of their own words. The questions were formed around certain subjects rather than specific questions, to provide a more flexible approach to the interviews. Semi-structured interviews enabled a deeper understanding of the topic since the questions were not limited to the interviewees' knowledge of the subject. Bell et al. (2019) describes that the semi-structured interview process enables the interviewers to ask further clarifying questions if a significant reply was presented, thus increasing the flexibility and comprehensiveness of the information gathered.

The semi-structured interviews were used to answer research question two. Combining the literature study with the results of the quantitative analysis served as the framework for the interview structure. The interview structure was created after the literature study and the quantitative analysis to increase the understanding. The understanding resulted in an interview structure around the themes *impact of price volatility, impact of price trends, impact on suppliers,* and *impact on financial margins*. Further, by conducting the literature study and the analysis of quantitative data first, an adequate selection of interview subjects could be initiated, see Table 2. The selected subjects were firstly based on departments within the organisation that relates to the subject of the thesis, such as the purchasing, business control, or the raw material team. The involvement of different departments increased the nuance of the primary data. Furthermore, key personnel were identified within the departments and requested participation. Moreover, by involving several people in the organisation, a more chronological understanding of the subject could be achieved (Bell et al., 2019).

Table 2: Description of interviewees from the case corporation

Int.	Role	Department	Mode	Date	Time
1	Purchasing Director	Purchasing	Online	2022-04-05	25 min
2	Purchasing Director	Purchasing	Online	2022-04-07	20 min
3	Raw Material Analyst	Raw Material	Physical	2022-04-25	30 min
4	Business Controller	Business Control	Physical	2022-04-25	30 min
5	Business Controller	Business Control	Physical	2022-04-28	25 min
6	Business Controller	Raw Material	Online	2022-04-29	25 min

There were several different modes of interviewing to choose from, such as physically in-person, telephone interviews, and computer-assisted online interviews (Bell et al., 2019). The semi-structured interview process, concertedly with multiple interviewees living abroad, resulted in the main use of computer-assisted interviews. Additionally, Patel and Davidsson (2019) argues that the interviewer must consider the use of body language since it

may affect the interviewee. By using the physical and computer-assisted interview modes, the body language and expressions of the interviewee could be considered. The computer-assisted interviews were conducted through the software *Microsoft Teams*. Moreover, the interviewees were made anonymous to increase the credibility and comprehensiveness of the collected qualitative data.

3.3 Research procedure

The replicability of any dissertation is of great concern. Chronologically presenting and explaining the different steps in this thesis consequently increase the replicability. This section thus presents the steps and execution that were conducted in the thesis. Firstly, the data preparation followed by the quantification of the market characteristics was presented. Moreover, how the volatility model was formed and how the organisational impact was identified were then presented.

3.3.1 Data preparation

Processing of data can be divided into quantitative and qualitative processing (Bell et al., 2019; Patel & Davidsson, 2019). Both forms of processing were used to answer each research question. Additionally, the research questions were descriptive. The general aim of descriptive analytics is to understand both past and current events (Appelbaum, Kogan, Vasarhelyi, & Yan, 2017). Descriptive analytics, or descriptive statistics, consist of visualisations such as graphs, dashboards, or key performance indicators (KPIs) among others (Dilla, Janvrin, & Raschke, 2010; Patel & Davidsson, 2019). Park, Bellamy, and Basole (2016) conclude that the use of appropriate visuals can provide aid in identifying complex patterns. With the stock market as a reference, Paye (2012) states that volatility is caused by uncertainty in several macroeconomic variables. By studying the historical development of the selected commodities and the characteristics from the literature study, the variables' possible effects on the commodity's volatility were thus identified. Descriptive analytics were hence suitable as the method for quantifying the market characteristics.

Before the collected data could be visualised and described, the raw data had to be prepared. Data preparation with missing information is a crucial part of descriptive dissertations (Bell et al., 2019). All datasets were reviewed and corrected in terms of missing data, to increase the reliability of the results. Additionally, to compare the different datasets, the time periods were aggregated to fit the dataset of the highest time-frequency. The highest time-frequency in the datasets of this analysis was monthly.

Visualisations were used as a tool for understanding how the data sets correlate. To create the visualisations of the prepared data, the main software used was Microsoft Power BI. Power BI was chosen above other software, such as Excel, due to its possibility to integrate and build on for future usage by the case corporation. The visualisations were mainly utilised to prepare for the analysis. A vital criterion for visualisations is to integrate relevant views and perspectives that highlight the points of interest (Park et al., 2016).

3.3.2 Quantifying market characteristics

To apply the methodology of the regression analysis, data concerning dependent variables and independent variables had to be collected. These variables were, as previously described, identified through the literature study. Data regarding the selected dependent variables, base metals, and steel, were acquired through the London Metal Exchange and Bloomberg. Steel can be categorised as several different products, but only three were chosen in this study. The selected independent variables are presented in Table 3.

The first identified indicators in the literature study were supply and demand. These variables exist for all the different base metals and steel that were included in the thesis. However, due to data availability issues, the full data could not be acquired for all commodities. The indicator was therefore excluded from the thesis. Commodity cycles were the second identified indicator that could affect the volatility of the base metals and steel. The Bloomberg Commodity Index tracks the prices of futures contracts on the physical commodity market and was thus a suitable measure. The index minimises the concentration of a single commodity or sector, to measure the basket of commodities accurately. The index is rebalanced and reweighted overtime to ensure that the index represents the movements of all the commodities equally. The index was however discarded due to its inclusion of the analysed variables and the poor availability.

The industrial growth rate was the third variable identified in the literature study. Several different measures and indices could be found in this category, however, the industrial production index, gathered from Federal Reserve Economic Data (FRED) was chosen. The index was chosen since it measures the output of a broad range of industries and companies. Additionally, the frequency of the data was in months, the preferred frequency. Nevertheless, the financial indicator only measures the output from the United States. The industrial production index were the most adequate, however, due to data availability.

Moreover, the literature study further identified energy commodities to influence the price volatility of other commodities. Specifically, energy commodities such as oil and coal. For oil, the Brent price was used as the measure, due to it being an intercontinental exchange. Another alternative would have been West Texas Intermediate, but due to its North American origin, it was discarded. Further, two different datasets were found on coal prices, varying from the extraction site of Australia and South Africa. Both datasets corresponded to the time frame of the previous subject and were presented monthly. Moreover, both datasets were transformed into the price volatility of oil and coal, respectively. As the literature study found that there was a volatility spillover from oil and coal to other commodities, it was of significant interest.

A significant component in steel production was iron ore which was thus included in the analysis. The price of iron ore was gathered from FRED on a monthly frequency. Similar to the energy commodities, the price was also transformed into the volatility of iron ore. Moreover, scrap steel can be a component in steel production as stated in the literature study. However, scrap steel was found to be too closely related to crude steel and was thus excluded from the data analysis.

Additionally, business cycles were identified in the literature study as an influential factor in price volatility in the studied markets. Business cycles could be measured in several different ways, and for several different markets. GDP was however chosen, due to its global presence and ability to present the international business cycle. Moreover, inflation was also found in the literature study to have an impact on the price volatility of base metals and steel. Due to data availability, global inflation could not be used. The inflation thus had to be from the most adequate market available which resulted in the OECD region. Additionally, there are several different forms of inflation. Core inflation and consumer price index were compared to the indices to find the most influential variable. The comparison resulted in the selection of the consumer price index as the variable for the regression.

Table 3: Quantifying the market characteristics

Research area	Independent variable	Source
Supply and demand	-	-
Commodity cycles	Bloomberg commodity index	Bloomberg
Industrial growth rate	Industrial production (IP)	FRED
Energy commodities	Brent oil price	U.S. Energy Information Administration
Energy commodities	Australian coal price	World Bank
Production	Iron ore price	FRED
Business cycle	World GDP	Bloomberg
Inflation	Consumer price index (CPI)	OECD
Economic policy	Economic policy uncertainty	US EPU
Currency exchange rates	US dollar index	Yahoo Finance

Economic policies were also recognized in the literature study as an important factor that influences the volatility of the base metal and steel. Economic policies can be quantified in several ways, varying from corruption to government effectiveness. However, a more general indicator was preferred since it would provide more clarity to the analysis. Lastly, the exchange rates were found to potentially impact the volatility of base metals and steel. Moreover, the dollar's value specifically was mentioned to impact the price and volatility of several commodities, including base metal and steel. The US dollar index was thus suitable since it measures the value of the US dollar in comparison to a basket of currencies with the United States' most significant trading partners.

3.3.3 Forming the volatility model

Volatility is generally defined as the standard deviation over a specific time-frequency, as per the current literature on price volatility in the commodity markets (Prokopczuk et al., 2019; Regnier, 2007). The standard deviation was calculated as the square root of the sum of the variance for the specified time period. The volatility was thus measured through the 12-months rolling standard deviation, see Equation 1:

$$\sigma = \sqrt{\sum_{i=1}^{N} \frac{(P_t - \overline{P})^2}{N-1}} \tag{1}$$

where P was the price, $\overline{P}$ was the sample mean price, and N was the number of observations. Several different analytical methods could then be used to create a volatility model. Calvello (2020) describes five different methods for performing statistical analysis. Mean and standard deviation are the first two methods described, which aim to compare data to reach conclusions. These methods are dependent on outliers and only provide a basic analysis of the subject. Additionally, these methods only compare the variables separately, and not combined, which was disadvantageous for this thesis. Regression is the third method and describes the relationship between a dependent variable and an independent variable. The method compares several variables but ignores much of the outliers' effect on the results. Furthermore, hypothesis testing and sample size determination are the last methods. Hypothesis testing assesses if a certain argument or conclusion is true for the data set. The method was unsuitable since the purpose was to find the explanation rather than to test a certain theory. Lastly, sample size determination is the analysis for reducing the size of a certain sample. This method was not used since the case study research design already limited the sample size of what commodity to use. Regression analysis was thus concluded to be the most applicable method for this thesis.

Regression analysis is a mathematical way of sorting out what variables impact a specific function (Gallo, 2015b). A regression analysis investigates the correlations between variables and the function to be able to either predict or describe the relationships. Bivariate analysis and multiple analysis are two different approaches to regression. The bivariate analysis focuses only on the correlation between two data sets whereas the multivariate focus on several. This thesis considered several characteristics of the volatility, and thus used a multiple regression. The multiple regression analysis method was also used by Prokopczuk et al. (2019) who applied this methodology to analyse 25 different commodities' volatility. The thesis had a similar purpose, which further argued for the use of multiple regression in this thesis. However, the authors analysed a wide scope of commodities such as lumber, cattle, platinum, and gasoline, whereas this thesis only analyse one the commodity. Moreover, Schmueli (2010) explains that statistical modeling, such as multiple regression, is suitable for causal explanation, description, and prediction. Since this thesis aimed to explain and possibly predict the volatility in commodity prices, it was a suitable method. Lastly, Gargano and Timmermann (2014) found that predictability of commodity prices has its strongest performance using multivariate regression analysis.

Before the regression analysis could be initiated, the data had to be prepared. The preparation consisted of aggregating the data sets to a common frequency as well as managing missing data. Moreover, the step was necessary for the regression, since the data cannot be analysed if it's presented in different forms and frequencies. This preparation was executed through Python in Power Query. When the data had been prepared it was possible to conduct the actual regression analysis, which was performed in Python.

To find what variables influence all of the different base metals and steel products, an index was created for each material group. Additionally, the steel group was divided into the US and EU steel prices, as this is in line with the case corporations spend. The three indices of base metals, US steel, and EU steel were thus created. Each component of the indices was equally weighted to provide an understanding of what variables influence the entire bucket of base metals and steel products. Bivariate regression was then conducted with every independent variable for each index. By examining all variables concerning the different indices, internal differences could be found between the indices. Additionally, linear and second-degree polynomial regression was conducted to identify potential polynomial relationships. Lastly, the same analysis was conducted for each base metal and steel product. However, these results were too specific to each product that it did not provide enough value to either the business or the research to be included in the thesis.

The output of the bivariate regression was then analysed based on the adjusted R^2 values and p-values. These indicators of the regression were stating how significant, if significant, the different independent variables were. Firstly, an independent variable had to provide an adjusted R^2 higher than 0,05 in the regression. The R^2 is an indicator that shows what percentage of the variation within the dependent variable is explained by the independent variable (Thieme, 2021). The adjusted R^2 is the same variable although it adjusts the value depending on the number of indicators in the regression. More independent variables lower the score thus ensuring that the independent variables contribute to the model's performance. The limit was set to ensure that the independent variables that moved forward to the multivariate regression contributed to the volatility of the commodities in question.

Additionally, the p-values of the bivariate regressions contributed to the decision of whether an independent variable would be included in the multivariate regression model. The P-values were calculated using the t-static from the T-distribution (Thieme, 2021). The p-value explained the significance of the coefficient. A p-value lower than 0,05 conclude that the null hypothesis, the independent variable was not affecting the dependent variable, can be rejected with a confidence interval of 95 percent. The limit of 95 percent is commonly used in statistics for determining the significance of a variable and was thus used. Conclusively, for the variable to be considered significant the adjusted R^2 had to exceed 0,05 and p-values had to undercut 0,05.

In addition, the dependent and independent variables were plotted visually in Power BI to identify potential lag in the relationship. When lag was identified, the bivariate regression was re-executed with the adjusted independent variable. Once the adequate independent variables had been identified, the multivariate regression of these independent variables was implemented in a Python script to process the Power BI report through Power Query. The results were analysed with regard to the previously determined significance limits. The variables that did not meet the requirement were excluded from the multivariate model. The process was then iterated until all of the independent variables met the significance requirements and a final model could be presented.

3.3.4 Identifying the organisational impact

Once the price volatility could be explained quantitatively, it was of interest to understand the organisational impact. By combining the literature study and the findings from the semi-structured interviews, it was possible to answer the second research question. To elaborate, the literature study provided guidelines for the content of the interviews. The interview questions were based on observations gained from the literature study, thus providing volatility-specific subjects. The questions were however broad, to enable discussion decoupled from the literature study.

The semi-structured interviews provided empirical data specific to the case corporation. The empirical data from the interviews were analysed concerning the findings from the literature study. It was of interest to identify similarities between the empirical data and the literature. Contrastingly, the differences were also of interest to understand the cause behind it. To summarise, the organisational impact on the case corporation was analysed based on current literature and empirical findings from the interviews.

3.4 Research quality

The quality of a dissertation greatly influences the society's value gained from the result. All aspects of quality thus have to be regarded throughout the thesis. Credibility, validity and reliability are three aspects that influence the quality of a thesis. The aspects were thus discussed and presented in this section, accompanied by research ethics.

3.4.1 Credibility

As is stated by Patel and Davidsson (2019), when collecting data there are many uncertainties to consider regarding credibility. To minimize uncertainties, what is being researched must be understood. According to Wallén (1996), the interpretations and analysis of data are meaningless if the collected information was not legitimate and authentic. Processing non-credible data will lead to non-credible results. The credibility of both the primary and secondary data was therefore reflected upon to ensure credible results of the thesis.

Primary data were data collected in direct relation to the thesis. As the primary data consisted of interviews, interviewee validation was necessary to consider. Bell et al. (2019) describes interviewee validation as a process where the researchers provide the interviewees with an account of their findings. Therefore, the interviewees were presented with the findings after the interview. The process enables the interviewee to ensure the quality and correctness of the findings, thus increasing the credibility of the results.

The secondary data consisted of the literature study and the quantitative data collection. To secure the credibility of these sources of information, the source's credibility was analysed. Individual assessment of the source was thus conducted for analysing the legitimacy of the source. Institutions and established companies were considered legitimate, whereas the legitimacy of others was investigated. Furthermore, both the literature study and quantitative data gathering were conducted so that the data provided a broad view of

the topic (Patel & Davidsson, 2019). Moreover, historical price data was collected via the spot markets through the case corporation to ensure accurate and measurable data points. This price data was cross-checked with other companies' public data to assure a high precision of secondary data, as advocated by Wallén (1996). Data concerning the internal price change requests were collected via the case corporation's internal databases and were assumed to be credible data.

3.4.2 Validity

Validity is the process of using data correctly and ensuring the precision of the results (Wallén, 1996). Patel and Davidsson (2019) presents three methods to assure the validity of a report, where content validity is the first. Therefore, a logical evaluation of the content of the literature study was conducted. The interview structure and questions were also analysed thoroughly to ensure the thesis' purpose was covered. Further, the second method to increase validity is to consider the coeval validity (Patel & Davidsson, 2019). The information gathered from the interviewees was therefore compared to the literature to ensure its relevance. All the conducted interviews were ensured using this method, thus assuring the validity of the report further. Moreover, communication validity, the third validity assurance method by Patel and Davidsson (2019), was ensured by enabling the interviewees to see the result of the thesis. The validation increased the results' validity as the interviewees could confirm the findings.

Regarding the quantitative analysis, the risk of spurious relationships between variables was also considered when choosing regression analysis as the methodology. A spurious relationship is defined as a relationship between two variables that are being influenced by a third variable Bell et al. (2019). This relationship could cause a false positive and influence the thesis' results and conclusions. By using both bivariate and multivariate regression, the risk of spurious relationships was decreased. Additionally, aggregation of the historical price data was an important aspect to consider. If aggregation was not considered, the risk of variable estimates being distorted or false model rejections was significant (Bansalad, Kikub, & Yaroncd, 2016; Ivancica, Diewertb, & Foxc, 2011). The historical price data of the different commodity markets were available with different time frequencies and thus had to be aggregated to a common frequency. The time series dataset with the lowest time-frequency had the frequency of months. Therefore, all datasets of higher frequencies were aggregated to a monthly frequency.

Additionally, a risk associated with the aggregation of time series is that details, patterns, or parameters may remain unidentified. Bansalad et al. (2016) state that financial modeling without considering time aggregation heavily understates the impact of high-frequency volatility. In this thesis, the ability to compare the commodities was valued higher than the potential loss of details. However, before any data set was aggregated, the data sets were reviewed in its non-aggregated form to identify if any crucial and immediate patterns could be identified in the high-frequency volatility.

3.4.3 Reliability

Reliability measure the resistance from objects randomly influencing the thesis in unknown directions (Patel & Davidsson, 2019; Wallén, 1996). A reliable report should thus conclude the same results if the process were to be repeated. To ensure reliability in the interview process, two interviewers were present to minimise individual opinions or reflections affecting the results. Two interviewers also enabled one to focus on follow-up questions, and one to focus on notes. The process is advocated by Patel and Davidsson (2019) to increase the reliability of a thesis.

Reliability was also considered for the quantitative analysis. By visually controlling that the gathered data corresponds similarly to the public data, its reliability could be assured. Further, the test-retest reliability method was used to increase the reliability of the thesis. The test-retest reliability method consists of repeating the same test on the sample at different points in time (Middleton, 2021). The method was suitable since the expected outcome should not differ substantially. However, since the time frame was large, compared to the intervals of testing, the method provided limited improvement of the reliability.

3.4.4 Research ethics

The goal of scientific research is to collect credible information that benefits individuals and society (Patel & Davidsson, 2019). However, scientific research has to balance the benefits of the society with the integrity of the individual (Wallén, 1996). Additionally, Bell et al. (2019) emphasises that research ethics is necessary to consider, to ensure the integrity of the thesis and the reputation of research in general. This thesis has therefore considered several aspects of ethical research to ensure that the societal benefits of the thesis do not outweigh the integrity of the individuals.

Council (2002) have formulated four different ethical requirements for conducting ethically viable scientific studies, that this thesis followed. Information is the first requirement and states that the interviewee should be informed about the purpose of the dissertation (Patel & Davidsson, 2019). The requirement was fulfilled through verbal communication before the interviews to ensure that the interviewee was aware of the thesis' purpose. Further, Bell et al. (2019) emphasises that informed consent is a necessary principle to consider when conducting ethical research. The principle, similarly, to the previous requirements by Patel and Davidsson (2019), strives to inform the interviewee of the content and purpose of the interview. The purpose and additional information about the thesis were therefore provided before the interview.

The third requirement by Council (2002) attends the confidentiality of scientific research. Patel and Davidsson (2019) argue that all information of the involved interviewees should be stored and treated carefully to not allow external access. Bell et al. (2019) also stresses the importance of privacy in ethical research, which is connected to the consent requirement earlier presented. The interviewees' information was, therefore, anonymized to ensure both privacy and confidentiality. By having anonymous interviewees, their data are less sensitive than before, thus minimising the damage that a breach could have on individual

integrity. Additionally, the information was treated carefully and stored to disable external access. Further, the anonymization increases the objectivity of the dissertation, which is an ethical principle stated by Resnik (2020). The principle of Human Subjects protection is also fulfilled through this privacy measure.

The last ethical requirement by Council (2002) is the utility requirement. The requirement states that the collected data should only be used for scientific research (Patel & Davidsson, 2019). Moreover, the collection and processing of data are further emphasised by Bell et al. (2019) within ethical research. Data management was thus necessary to consider and weigh the maximal potential benefit gained from the data in comparison to individual privacy. Additionally, the data were reviewed before publication to ensure that no sensitive information was shared.

Lastly, All European Academies (2017) state four principles to battle the practical, ethical, and intellectual challenges of research studies. These were reliability, honesty, respect, and accountability. As presented in the previous section, the reliability principle was met. The honesty principle was undertaken throughout the report by reviewing, undertaking, and communicating the research in a transparent, fair, full, and unbiased way. Respect for colleagues, research participants, and all stakeholders was also accounted for. Lastly, the accountability principles were accounted for by stating the authors' names and openly publishing the report. Through this publishing, external stakeholders can examine the results and which the authors stand accountable.

4 Results

The results section aims to provide a foundation for the analysis and conclusion. First, the case corporation's purchasing organisation is described based on observations conducted throughout the thesis. The section then presents the findings from the bivariate and polynomial regressions, followed by the final multivariate regression. Lastly, the interview results are presented.

4.1 Introduction to the case

The thesis collaborated with the purchasing organisation of the case corporation, which was responsible for purchasing all direct materials. The sourcing strategy of this organisation mitigated risks by having multiple suppliers for each component or raw material. However, how many suppliers for each component or raw material could vary and depend on the availability. Moreover, business insights on prices, market structure, geopolitics, and regulations are provided to the purchasers by a designated team. The designated team monitors and forecasts the price development of all raw materials purchased by the case corporation. To mitigate the financial impact of increasing prices the team have certain strategies in place. These strategies consequently mitigate some of the price volatility in the raw material markets.

Furthermore, the purchasing organisation lacked a clear definition of price volatility. When observing the organisation, the main measurement of volatility was found to be the variation of total cost between the fiscal years. In the literature study, numerous definitions of price volatility were identified. Price volatility can be explained as the variations, fluctuations, or swings of price during a certain time period. Furthermore, the most common definition in commodity price volatility literature is the rolling standard deviation. This definition was adapted to the case corporations' available data, resulting in a definition of 12 months rolling standard deviation with a monthly frequency.

4.2 Regression analysis on price volatility

Firstly, the results consisted of a bivariate regression analysis of the independent and dependent variables individually. Secondly, polynomial regression was conducted to identify potential correlations in a second-degree polynomial form, for each dependent variable. Finally, the regression analysis resulted in three different multivariate models to explain the price volatility in the dependent variables base metals prices, US steel prices, and EU steel prices respectively.

4.2.1 Bivariate and polynomial regression

Numerous variables were suitable to describe the volatility of base metals, see Table 4. The volatility of the oil price (Oil_σ) showed a significant correlation to the price volatility of base metals. With an R^2_{adj} above 0,35, it explained a relatively large portion of the volatility. However, the oil price itself had no explanatory property over base metals' price volatility, with both a negative R^2_{adj} and a high p-value. The coal price and coal volatility

(Coal_σ) were found to significantly impact the price volatility of base metals, although only in linear form. Moreover, GDP explained volatility to a large extent and proves statistically adequate. The CPI and EPU indexes showed poor explanatory properties to the volatility of base metals. Moreover, neither of the two was statistically significant. However, by adjusting the CPI for its 6 months lag, the regression resulted in a statistically significant explanation. The relationship was only found for the base metals, and the lag was thus not identified for the steel prices. Additionally, the US dollar index (USD index) and the Industrial Production (IP) index were statistically significant.

Table 4: Single variable regression on the 12 month rolling standard deviation of the base metals price index

Independent variable	R^2_{adj}	Coefficient	p-value
Oil	-0,0049	$3,2 \cdot 10^{-5}$	0,9229
Oil_σ	0,3504	0,0104	$6,8 \cdot 10^{-21}$
Coal	0,0613	0,0010	0,0002
Coal_σ	0,3113	0,0066	$2,7 \cdot 10^{-18}$
CPI	0,0009	0,0084	0,2777
CPI_{adj}	0,0473	0,0291	0,0010
GDP	0,115	-0,0302	$4,1 \cdot 10^{-7}$
USD index	0,0771	-0,0042	$3,43 \cdot 10^{-5}$
IP	0,0722	-0,0064	$6 \cdot 10^{-5}$
EPU	0,0073	-0,0002	0,1156

The CPI showed poor explanatory properties in its linear form although displaying a highly effective correlation in its lag-adjusted and second-degree polynomial form, seen in Table 5. Moreover, the table shows that some variables became statistically insignificant in its linear form while still significant in its squared form. For instance, IP was not statistically significant but the squared values of IP were. In this case, the linear variable was then excluded from the regression as it would not benefit the final model.

Table 5: Second degree polynomial regression on the 12 months rolling standard deviation of the base metals price index

Independ. var.	R^2_{adj}	Coeff. 1	Coeff. 2	p-value 1	p-value 2
Oil + Oil^2	-0,0047	0,0022	$-1,3 \cdot 10^{-5}$	0,3078	0,3091
Coal + Coal^2	0,0566	0,0009	$1,88 \cdot 10^{-7}$	0,3853	0,9708
CPI_{adj} + CPI^2_{adj}	0,3673	-0,1765	0,04868	$2,4 \cdot 10^{-14}$	$7,9 \cdot 10^{-20}$
IP + IP^2	0,2302	-0,0020	0,0009	0,2058	$5,7 \cdot 10^{-10}$

Similar results were achieved with the bivariate regression for the US steel price volatility, although with the addition of the iron ore, seen in Table 6. As in the previous regression for the base metals, the linear variables oil price, IP, and EPU variables were not found to be significant. The results however presented a significant volatility spillover between oil and US steel. Further, iron ore price, and especially the volatility of this price (Iron_σ) was

proven to have a significant effect on the US steel index volatility. Additionally, the coal price and volatility significantly impacted the volatility of US steel. Further, the GDP was found to have a significant impact on the volatility of US steel volatility. The USD index, however, did not influence the results to a significant extent.

Table 6: Single variable regression on the 12 month rolling standard deviation of the US steel price index

Independent variable	R^2_{adj}	Coefficient	p-value
Oil	-0,0043	-0,0002	0,7075
Oil_σ	0,2141	0,0147	$1,9 \cdot 10^{-12}$
Iron	0,0726	0,0014	$5,7 \cdot 10^{-5}$
Iron_σ	0,3194	0,0102	$7,8 \cdot 10^{-19}$
Coal	0,3074	0,0039	$4,7 \cdot 10^{-18}$
Coal_σ	0,6365	0,0171	$1,7 \cdot 10^{-46}$
CPI	0,1516	0,0791	$5,2 \cdot 10^{-9}$
GDP	0,0927	-0,0493	$5,7 \cdot 10^{-6}$
USD index	-0,0022	0,0014	0,4588
IP	0,0006	-0,0031	0,2904
EPU	0,0227	0,0005	0,0178

Some variables had strong non-linear correlations to the volatility of US steel prices, see Table 7. A slightly improved R^2 for the oil price was the result of the regression. The results were, however, insignificant since the p-values exceeded five percent. Further, polynomial and linear iron price improved the adjusted R^2 whilst still having acceptable p-values. Additionally, the coal price in both polynomial and linear forms increased the adjusted R^2 values. Inflation in its polynomial form, in combination with its linear form, had a much higher R^2 and a lower p-value than previously. IP squared resulted in a significant increase in performance compared to its linear form. Moreover, the coal price squared was both significant and with a relatively high correlation. However, the volatility of coal prices was higher. The same result was found for the iron ore price squared.

Table 7: Second degree polynomial regression on the 12 months rolling standard deviation of the US steel price index

Independ. var.	R^2_{adj}	Coeff. 1	Coeff. 2	p-value 1	p-value 2
Oil + Oil^2	0,0015	0,0054	$-3,5 \cdot 10^{-5}$	0,1649	0,1431
Iron + Iron^2	0,1433	-0,0066	$3,3 \cdot 10^{-5}$	0,0007	$3,9 \cdot 10^{-5}$
Coal + Coal^2	0,4016	-0,0049	$4,2 \cdot 10^{-5}$	0,0022	$3,7 \cdot 10^{-8}$
CPI + CPI^2	0,4325	-0,1965	0,0544	$2,3 \cdot 10^{-10}$	$1,6 \cdot 10^{-19}$
IP + IP^2	0,1999	0,0058	0,0019	0,0465	$1,5 \cdot 10^{-11}$

The results of the bivariate regression on the EU steel price can be seen in Table 8. Similar to the US steel regression results, the oil, USD index, and EPU were found to be inadequate for the model. However, a volatility spillover was identified from oil, iron, and coal to EU

steel. The results differ from the US steel with regards to which extent the volatility spillover occurs for the volatility of steel in the EU. Moreover, the iron ore price and coal prices were affecting the price volatility in EU steel less than for the US steel. Further, both inflation and GDP had decreased their respective adjusted R^2, compared to the US steel. Industrial production did however increase its impact, although still insignificant.

Table 8: Single variable regression on the 12 month rolling standard deviation of the EU steel price index

Independent variable	R^2_{adj}	Coefficient	p-value
Oil	-0,0009	-0,0004	0,3658
Oil_σ	0,145	0,0079	$1,2 \cdot 10^{-8}$
Iron	0,0511	0,0008	0,0007
Iron_σ	0,3459	0,0068	$1,4 \cdot 10^{-20}$
Coal	0,2326	0,0022	$9,5 \cdot 10^{-14}$
Coal_σ	0,6423	0,0112	$1,3 \cdot 10^{-47}$
CPI	0,1076	0,0435	$9,9 \cdot 10^{-7}$
GDP	0,0908	-0,0317	$7,04 \cdot 10^{-6}$
USD index	-0,0047	0,0002	0,8590
IP	0,0009	-0,0021	0,2777
EPU	-0,0001	0,0001	0,3138

The results of the polynomial regression on the EU steel price can be seen in Table 9. The results display that EU steel was unaffected by the oil price, regardless of linear or polynomial form. Similarly, to the US steel, the iron and coal prices increase its impact on the volatility of EU steel when combined with its polynomial form. Furthermore, the inflation and industrial production significantly increased their impact on EU steel volatility when used in linear and polynomial forms.

Table 9: Second degree polynomial regression on the 12 months rolling standard deviation of the EU steel price index

Independ. var.	R^2_{adj}	Coeff. 1	Coeff. 2	p-value 1	p-value 2
Oil + Oil^2	0,0095	0,0040	$-2,7 \cdot 10^{-5}$	0,1111	0,0794
Iron + Iron^2	0,0896	-0,0032	$1,63 \cdot 10^{-5}$	0,0149	0,0023
Coal + Coal^2	0,3332	-0,0035	$2,78 \cdot 10^{-5}$	0,0012	$1,19 \cdot 10^{-7}$
CPI + CPI^2	0,3751	-0,1311	0,0345	$4,79 \cdot 10^{-10}$	$1,74 \cdot 10^{-17}$
IP + IP^2	0,2522	0,0044	0,0014	0,0163	$1,52 \cdot 10^{-14}$

To summarize, the bivariate regression provided results on how well the different independent variables explain the dependent variables by themselves. It was found that some variables had a linear correlation to the dependent variables while some have a second-degree polynomial correlation. Additionally, the results showed that the polynomial form of some variables cancelled the linear form.

4.2.2 Multivariate regression

After identifying the suitable independent variables from the bivariate regression, the suitable independent variables formed a multi-variate regression model. In this model, some of the variables were found insignificant in combination with the others and were thus removed. For the base metals, the independent variables of GDP and coal price was cancelled out and no longer statistically significant. By combining all remaining variables that were found statistically significant for the base metals the model in Equation 2 was created. The model consisted of five independent variables. CPI and IP had a polynomial relationship to the second degree. The model explained the volatility of base metal prices with an adjusted R^2 of 0,60. This model was plotted against the real price volatility of the base metal can be seen in Appendix A.

$$\begin{aligned} BM &= 0,464 + 0,005 \cdot Oil_{\sigma} + 0,002 \cdot Coal_{\sigma} - 0,003 \cdot USD - 0,129 \cdot CPI_{adj} \\ &+0,032 \cdot CPI_{adj}^2 + 0,004 \cdot IP + 0,001 \cdot IP^2 \end{aligned} \tag{2}$$

In the case of the US steel prices, the independent variable CPI was cancelled out both in its linear and squared form. Moreover, the GDP was also cancelled out resulting in six independent variables in total. The model explaining the volatility of US steel prices can be seen in Equation 3. In addition to the second-degree polynomial relationship of IP, there was a similar polynomial relationship with the iron ore and coal prices. The model adjusted R^2 was 0,76. The model was plotted against the real price volatility of the US steel can be seen in Appendix B.

$$\begin{aligned} Steel_{US} &= 0,355 + 0,004 \cdot Oil_{\sigma} - 0,003 \cdot Iron_{\sigma} - 0,004 \cdot Iron + 0,001 \cdot Iron^2 \\ &-0,004 \cdot Coal + 0,001 \cdot Coal^2 + 0,014 \cdot Coal_{\sigma} + 0,010 \cdot IP + 0,001 \cdot IP^2 \end{aligned} \tag{3}$$

Similar to the US steel price volatility model, CPI and GDP was cancelled out for the EU model. In addition, the iron ore price volatility was cancelled out resulting in five independent variables in total. Similar to the two previous models, second-degree polynomial relationships existed. Specifically, for the independent variables iron ore price, coal price, and the IP index. The model explaining EU steel price volatility can be seen in Equation 4, and the model's adjusted R^2 was 0,77. This model was plotted against the real price volatility of the EU steel can be seen in Appendix C.

$$\begin{aligned} Steel_{EU} &= 0,272 - 0,003 \cdot Oil_{\sigma} - 0,002 \cdot Iron + 0,0001 \cdot Iron^2 - 0,003 \cdot Coal \\ &+0,0001 \cdot Coal^2 + 0,010 \cdot Coal_{\sigma} + 0,006 \cdot IP + 0,001 \cdot IP^2 \end{aligned} \tag{4}$$

To summarize, the three models were constituted by slightly different variables due to each variable's statistical significance. The models were constituted of five to six independent variables. Additionally, the adjusted R^2 of the models were slightly different, where the adjusted R^2 for steel was higher compared to the base metals.

4.3 Interviews on the impact of price volatility

The interviews provided empirical data on the impact of price volatility in the case corporation. Some hedging strategies were identified during the interview process, however, the strategies hedged against price increases rather than its volatility. Indirect costs, in connection to the volatility of the base metals and steel, were identified. Additionally, the organisation lacked consensus and a definition of price volatility.

Interviewee 1 stated that the impact of commodity price volatility has been countered via purchasing strategies that were based on the average price of a time period. Meaning that the peaks and dips were able to cancel each other out and thus, smoothing out the volatility in purchasing costs. The main strategy was to implement a raw material agreement, specifying the price and how the volatility was distributed between the case corporation and the supplier. If the volatility cancels itself out via the average price, there was no impact of volatility according to interviewee 1. In times of high price volatility, interviewee 6 mentioned that almost all suppliers want to initiate a raw material agreement to protect themselves against the volatility. Suppliers were able to protect themselves as there was generally a rule in the agreement that suggest a split in price volatility risks. The case corporation often takes 70 percent of the price volatility and the supplier 30 percent. The interviewee further stated the impracticality of establishing a raw material agreement, from the case corporation's perspective.

Therefore, the case corporation had to prioritise the suppliers that represent approximately 80 percent of the total spend. Moreover, interviewee 1 also stated that there was not always a raw material agreement in place, where the raw material was purchased at a one-time price instead. This can lead to both savings and increased costs depending on the price volatility.

Additionally, interviewee 3 stated that the organisation's investment strategies were impacted by price volatility. In times of high price volatility, investments tend to result in increased capacity to increase the flexibility of the supply chain. On the contrary, interviewee 5 did not experience any changes in terms of investments or the decision-making process during periods of high volatility. Furthermore, interviewee 4 stated that the case corporation provided a supply chain finance system, that enables suppliers to trade invoices and thus decoupling the credit aspect of the agreements.

Interviewees 1 and 2 stated that there were hidden costs related to commodity price volatility. During volatile prices, the suppliers were experiencing financial difficulties in terms of cash flow. These difficulties can be explained by two causes. Firstly, the payment terms of the case corporation result in at least a three-month lag where the supplier had to provide the products before they get paid. Secondly, when a rising economy, producing companies such as the case corporation tend to order more volumes, and prices thus increased. These price increases were affecting the suppliers negatively in terms of cash flow, as previously mentioned. However, when the economy declined, the demand was lower, and the suppliers were therefore not compensated for the losses during the increased price. On the contrary to the statements by interviewee 1, interviewee 2 did not

see any issues in terms of volatility for the suppliers if the average prices were going down. Furthermore, interviewee 4 stated that the transparency between the case corporation and the suppliers regarding the cash flow differs. The interviewee explained that the analysis of the cash flow volatility cost, therefore, was greatly limited. Moreover, interviewee 5 stated that the pure size of the case corporation disabled the cash flow volatility, transferred from commodity, to influence the credit score of the organisation. Additionally, no further costs associated with the volatility of the cash flow were identified by the interviewee.

All interviewees stated that suppliers tend to ask for re-negotiations in situations of high volatility or especially during trends of increasing prices. During the crisis of the Covid-19 pandemic and the Russo-Ukraine war, interviewee 3 stated that the number of such requests has increased significantly. Interviewee 1 further explained that suppliers generally wanted to increase their risk premiums through the raw material agreements as price volatility increased. Interviewee 6 stated that suppliers had to provide extensive fact base information to justify possible changes to the existing agreement, typically cost breakdowns indicating the suppliers' increased costs. Re-negotiations come with certain increased administrative costs for the case corporation. Interviewee 1 mentioned that the case corporation was therefore not always as eager to re-negotiate the agreements when prices were going down. Similar conclusions were presented by both interviewees 3 and 4, although additionally mentioning that low spend categories were not worth renegotiating. However, interviewee 6 explained that for commodity groups of significant spending or importance, the case corporation does request re-negotiations of raw material agreements as such commodity groups contribute to significant savings. The importance of a supplier could also be based on the uniqueness of the supplied component. If the component was unique and crucial for the production line, even a small supplier can have a devastating impact on the production.

Furthermore, it was stated by interviewee 3 that the organisational structure of the purchasing department and the magnitude of agreements, made it difficult to keep track. It was not financially possible to keep track and re-negotiate every agreement for every price change. This was in line with a statement by interviewee 6, who also explained that the high turnover of buyers creates information losses. The high turnover resulted in historical data being lost, due to the buyers independently being responsible for market correction follow-ups. The interviewee explained that there was currently a system being built to track this information.

Interviewees 2, 3, and 4 further stated that the case corporation tends to support suppliers in situations of financial difficulties. According to interviewee 6, the team of financial service had a robust system to oversee the suppliers' finances. The case corporation's support could be via temporarily decreased payment terms, advanced payments, or additional monetary support. The reason for the case corporation to aid their suppliers was to nurture the relationships as well as minimize the cost of finding new suppliers. Interviewee 6 stated that the case corporation's relationship with suppliers was generally not transactional but most often a collaboration. There have been cases where suppliers

have gone bankrupt due to increased prices or price volatility. The case corporation thus needs to put in additional work and money in finding new suppliers as well as work on building new relationships. Interviewee 4 mentioned that a supplier switch takes a long time, thus the purchasing organization takes a proactive approach to assess cases of risks. Interviewee 6 further explained that suppliers going bankrupt results in massive costs for the case corporation, depending on the supplier. The case corporation, therefore, works proactively to mitigate the risks, including the participation in Suppliers' restructuring programs, according to interviewee 4.

Moreover, interviewee 3 mentioned that suppliers may be in financial difficulties regardless of commodity prices. Financial difficulties at the supplier may happen through, thin margins, increased interest rates, or increased costs of logistics. The case corporation thus tends to financially aid suppliers in general due to their strong financial position in the value chain. The compensation was however lagging behind the suppliers, according to interviewee 4. The supplier compensation received due to increased commodity costs depends on the contractual obligations and can take six months to arrive. Interviewee 4 also mentioned that during times of financial difficulties, the case corporation may support the suppliers in terms of negotiations with the tier 2 suppliers. The case corporation, therefore, leverages its significant negotiation power in the value chain to increase the length of payment terms for the supplier. Interviewee 4 explicitly exemplified a situation with a steel of a special grade, where the prices recently increased heavily.

Additionally, the financial aid from the case corporation varied depending on the dependency rate. Interviewee 4 stated that the case corporation was less keen on financially aiding suppliers that were less dependent on the case corporation. The interviewee argued that financially aiding or renegotiating these agreements would not change the financial condition of the company significantly. However, special exceptions were also in operation. Interviewee 4 and 6 mentioned that suppliers with rare and exclusive components were offered different solutions to mitigate supply chain disturbances due to the scarcity of these kinds of components. The lack of a unique production component could stop an entire production line. Furthermore, interviewee 6 explained that it was important to balance the supplier dependency rates. A lower supplier dependency generally results in a lower risk of financial uncertainties, and thus lowered the need for financial aid from the case corporation. However, the case corporation has a lower negotiation power, over the low dependent suppliers, which can significantly affect cost savings.

5 Discussion

Connecting the results with the literature study enabled broad discussions regarding both the quantitative and qualitative results of the thesis. The discussion section thus presents the findings from the regression and semi-structured interviews in relation to previous studies. The discussion was then crystallised to present the main findings of the thesis.

5.1 Explaining price volatility

During the regression analysis, several variables succeeded and failed to meet the requirement of statistical significance. The understanding of why certain variables contributed to the volatility model, whilst others not, broadened the view on the subject. Additionally, the broadened view enabled a deeper and more thorough analysis to be conducted.

5.1.1 Significant variables

The bivariate regressions resulted in both significant and insignificant variables. The significant variables were then included in the multivariate regression for further analysis. The magnitude of these variables was however of interest for further discussion. The subsection, therefore, discussed the output of the bivariate regression in terms of statistically significant variables.

Firstly, the price volatility of oil greatly affected the volatility of both base metals and steel. Previous studies from Ji and Fan (2012), conclude a significant volatility spillover from oil price to other commodities. The results, therefore, confirmed the literary finding and clarified the extent and magnitude of the volatility spillover. However, differences in the spillover magnitude were identified between the base metal and the steel. The base metals were affected by oil to a greater extent than steel. Investors utilise base metals and oil as financial instruments to a greater extent compared to steel (Rodeck, 2020). The greater magnitude of the spillover between oil and the base metal could thus be explained due to both being subject to investors' speculation. The extraction and purification could additionally be more heavily dependent on oil for the base metals, thus experiencing a stronger connection between the two commodities. The magnitude of oil volatility spillover was also greater for US steel compared to EU steel. The difference in magnitude could be explained by the difference in production methods between the regions. The production independent variables in steel could be either iron ore and coking coal, or scrap steel as stated by Plaizier and Nachtergaele (2010). The results thus indicate that the production of steel in the US was more reliant on oil compared to their European counterparts.

Further, coal price and coal volatility were also examined in the bivariate regression. The price of coal was found to be significant for the base metals and steel. The magnitude however greatly differed between the base metals and steel. For base metals, the coal price affected the volatility to a minor degree, although only significant in linear form. Steel, however, was greatly affected by the price of the coal, with increased magnitude in polynomial form, indicating a more complex relation to the price. The increase in

magnitude could be explained by coal being an input factor in the steel-making process. The US and European steel also had differences, where the US steel volatility was more affected by the price of coal. The findings indicated either that the US produced more steel from iron ore and coal, or that their energy production was more dependent on coal. The results of Willeke (2017) implied that EU steel production depended more on the input variable coal compared to the US steel production. The results were thus more seemingly affected by the energy production used to produce steel.

Furthermore, coal price volatility was also found to have a significant effect on the price volatility of the base metals and steel. Similar to the coal price, steel was affected to a greater extent. The magnitude of the volatility spillover was however immense for both studied groups of materials. Coal was comparable to oil in the case of energy commodities, as stated by Zamani (2016). The coal price volatility thus co-moved with the volatility of oil, which reflects the impact found on base metals and steel.

Iron ore is another input variable in steel production. The price and volatility of iron ore were included in the bivariate regressions for the steel. The price of iron ore only affected the volatility to a minor extent for both groups of steel. However, when the regression was conducted in both linear and polynomial forms, the explanatory property of the variable increased. The increase points towards a complex relationship between iron ore price and the volatility of steel. Additionally, a considerable price volatility spillover from iron ore to steel was found. The spillover confirms previous findings presented by IEA (2021).

The USD index was also found to significantly impact the volatility of the base metals. Since the base metals were subjects to investing, their connection to the US dollar was seemingly stronger, compared to steel. Other factors explaining the difference in significance were potentially that steel was more regionally dependent compared to base metals. Moreover, macroeconomic factors influenced the volatility of both base metals and steel. Industrial production was significant when performed in both linear and polynomial form, for all studied commodities. The variable was, however, insignificant when only the linear form was considered. The magnitude of the combined linear and polynomial relationship was nevertheless significant. GDP was another factor that influenced the volatility of both base metals and steel. The GDP represented the global business cycle, and its effect on the volatility was thus not surprising. Similarly, both Ge and Tang (2020) and Erten and Ocampo (2013) stated that the business cycle affects the pricing of commodities.

The last significant variable identified, in the bivariate regression, was inflation. Inflation explained all the studied materials, although to a different extent. Similarly, Siami et al. (2019) suggested a strong correlation between commodities and inflation. Firstly, the inflation variable was significant for steel and increased its magnitude when performed in both linear and polynomial forms. Nonetheless, the inflation variable was insignificant in its regular form for base metals, in the bivariate regression. However, when the inflation was adjusted six months forward the impact increased, and became statistically significant. The adjusted inflation, both in linear and polynomial form was significant and substantially increased the magnitude of the variable's effect on base metals price volatility.

The relationship between inflation and base metal price volatility was thus probably causal, as inflation explained the base metal volatility with a six-month lag. As stated by Rodeck (2020), investors utilise commodities like base metals for hedging portfolios and other financial activities, which may explain these six months lag. The findings suggest that the hedging effect stabilises the relation between the supply and demand for six months. Additionally, the relation in which inflation affects volatility has a great complexity since it was firstly adjusted and then performed in both linear and polynomial forms. Ciner (2011) similarly concluded that the dynamics between inflation and commodity prices should be complex and non-linear. However, no findings in the literature suggested a six-month lag.

5.1.2 Insignificant variables

The bivariate regression analysis resulted in several variables being statistically insignificant. Variables that were deemed statistically insignificant were excluded from the analysis. The subsection thus focused on analysing why some variables could not explain the volatility for the respective material group.

Furthermore, the oil price was not found significant for either base metals or steel. Since price volatility and price are different parameters, the correlation between the two was not certain. The price environment represents the differences in supply and demand rather than the consistency of the difference. Moreover, the results were improved but not statistically significant by transforming the oil price to the second-degree polynomial. The findings thus suggest that the oil price neither affected the price volatility of base metals nor steel, regardless of its linear or polynomial form. The unimproved results from the polynomial form indicated that price changes, regardless of direction, were not connected to the volatility. Additionally, the EPU was not found to be significant in any of the investigated material groups. The index includes several specific countries and regions, including regions without base metal and steel production. Since the index was influenced by these countries, they may affect the significance of the model. Additionally, the EPU may not affect the volatility due to being disconnected for both an indication of supply and demand.

Steel displayed another insignificant variable. The USD index was insignificant for both steel US and EU prices' volatility. The price of the included steel products in the EU was stated in US currency, although likely traded in Euros or other currencies. The USD index would thus not significantly impact the price volatility. Additionally, unlike the base metals, steel was not a global commodity to the same extent. The steel markets were regional, and commonly not used for financial investing. The commodity was thus not traded to the same extent, as base metals, and hence not being significantly affected by the changing value of the US dollar. Furthermore, industrial production in its linear form was statistically insignificant for steel. However, the variable was significant when the industrial production was in polynomial form. The results indicate that the change in industrial production impacts the volatility rather than the direction of the movement of the variable.

5.1.3 Models of price volatility

In the final regression models, some variables were no longer statistically significant although proven significant in the bivariate regression analysis. There could be several reasons why the multivariate regression made previously significant variables, insignificant. The interconnection and co-moving variables were one possible cause. This discussion covers the variables explaining each commodity and the overall performance of these models.

The GDP variable was cancelled out in the multivariate regression for both base metals and steel, as it turned out to be statistically insignificant. The insignificance indicates that another independent variable explains the same price volatility movement to a greater extent. It can be argued that GDP closely follows the price volatility of major commodities such as oil. Since the oil price volatility explained both base metals and steel price volatility, it is possible that this variable cancelled out GDP.

Furthermore, the literature study suggested that the volatility of energy prices should explain the price volatility of commodities. A clear spillover of price volatility between coal and base metals was thus found. Similarly, the volatility of oil prices also shows a significant spillover to base metals. Volatility spillover between oil and the base metals was also found by Ji and Fan (2012). The spillover of coal price volatility could potentially be explained by the substitution between coal and oil, as explained by Zamani (2016). However, neither the actual coal nor oil price was found to explain the price volatility of base metals. The USD index remained statistically significant in its linear form. Moreover, the adjusted and squared inflation showed a strong explanatory property to the price volatility of base metals. Similar to the findings by Ciner (2011), the relationship was non-linear, however, it was not found in the literature study that the relationship could be lagged. Lastly, industrial production has a statistically significant explanatory performance in the model for base metals. Similar to the inflation, the independent variable was also explaining the base metals price volatility in a second-degree polynomial form. A non-linear relationship between base metals price volatility and industrial production has not been found in previous literature.

The regression model for base metals was performing at an adjusted R^2 of 0,6 which means that 60 percent of cases in base metals' price volatility can be explained by the five independent variables. The performance was considered adequate in terms of the relatively few variables used and in relation to the markets' characteristics. Many uncertainties were roaming the raw material and commodity markets, the ability to anticipate volatility was thus deemed useful in numerous applications by the case corporation. For the case corporation, it was valuable to understand which independent variables could explain the price volatility.

For the US steel price volatility model, both the GDP and inflation variables were cancelled out. Inflation's cancellation could potentially be explained by the addition of the iron ore price or price volatility. The independent variables of iron ore price, iron ore price volatility, coal price, and coal price volatility remained statistically significant. The iron ore and coal price volatility showed a significant volatility spillover to the price volatility of US steel,

which corresponds to the findings by Moheb-Alizadeh and Handfield (2018). Moreover, the coal and iron ore price had a non-linear correlation to the US steel price volatility, indicating a complex relationship. Coal being both an input variable in the steel-making process, and used to generate electricity, may explain the nonlinear relation. Lastly, similar to the base metals model, the industrial production variable was statistically significant and with a non-linear correlation to the price volatility of US steel.

The model of US steel price volatility was performing with an adjusted R^2 at 0,76. The overall performance of this model was thus higher than what was achieved with the model for base metals' price volatility. US steel price volatility can thus be explained in a considerable number of cases using the six independent variables. The model of US steel prices had higher performance than one of the base metals, probably due to the independent variables used. In the model of US steel, the variables coal and iron ore were included. This material was used as direct input material in the production of steel. As was found by Moheb-Alizadeh and Handfield (2018), the price volatility in an input material in production tends to result in similar volatility in the end product. The price volatility of iron ore and coal would then have a great impact on the price of steel. In the model for base metals, there was no production-related independent variable included which could explain the difference in the models' performances.

For the model of EU steel price volatility, it was found that GDP, CPI, and iron ore price volatility were cancelled out by the other independent variables. On the contrary to Moheb-Alizadeh and Handfield (2018), no spillover of iron ore price volatility was found for the EU steel in the final model. The lack of volatility spillover could be explained by the high use of scrap steel in the production of steel in the EU. Another explanation could be the regional market characteristics of the iron ore price. The data source originated from the US and the price was thus expressed in US dollars. The data could thus be more influenced by the US iron ore prices than the EU prices due to the source's origin, even though it was stated to be globally representative. Moreover, the spillover from both iron ore price, coal price, and coal price volatility were statistically significant, indicating similar non-linear and complex explanatory relationships as for US steel.

The model of EU steel price was the model of highest explanatory performance, with an adjusted R^2 of 0,77. The performance should provide valuable insights into what factors are explaining the volatility in the EU steel price. Similar to the previous two models, the model suggests complex non-linear correlations to multiple independent variables. Industrial production was one of these independent variables and was common between all three models. Moreover, the model for EU steel was performing better than the model for US steel, with the use of five independent variables instead of six. The combination of higher performance and lesser variables indicates less complex price volatility, or that the variables are explaining the price volatility to a higher degree. In the discussion about the US steel model, the iron ore price volatility had great explanatory properties. This was not the case for the model of EU steel since it was cancelled out in the multivariate regression model. However, the iron ore and coal price still proved statistically significant. The prices

of iron ore and coal, and the price volatility of coal, therefore had significant explanatory properties for the steel price volatility which was in line with Moheb-Alizadeh and Handfield (2018). However, the findings that EU steel price volatility was not explained by iron ore price volatility is thus contradicting to the literature.

All three models included non-linear correlations with different independent variables. This relationship between independent variables and price volatility indicates prices that are characterised by uncertainties and complex relationships. As suggested by the adjusted R^2 of the models, there were more factors to consider to fully understand how the price volatility can be explained. If additional, and accurate, variables would be implemented, the performance could increase. Understanding the real causes of price volatility in raw material or commodity markets requires extensive research and causal analysis. However, the models provide an initial explanation of price volatility and what further investigations are needed. Concerning the literature study, there were no findings that suggested nonlinear relationships between the commodities' prices and the IP, coal price. However, some relationship to steel was expected to be found for the coal and iron ore prices as per the findings of Moheb-Alizadeh and Handfield (2018). Moreover, Ciner (2011) found that the inflation should have a nonlinear relationship to the commodity markets, which was confirmed for the base metals' price volatility, but not for steel.

5.2 Price volatility's impact on the case corporation

Previous research on the impact of price volatility on organisations was scarce and focused on the impact in specific areas within organisations. Therefore, the section combined the findings from the interviews and previous studies to provide more depth to this area. In the case corporation, the purchasing strategy already hedges for some of the direct price volatility. However, there were potential indirect costs related to price volatility.

The case corporation had no clear definition of price volatility before the start of the thesis. Throughout the thesis, the price volatility was therefore measured as the 12 month rolling standard deviation. 12 months rolling standard deviation was the most common method to measure price volatility according to previous literature. The absence of a clear definition may be a cause of the misconception of price volatility that was experienced in the interviews. The misconception could prove as an obstacle to reducing the actual cost of price volatility within the case corporation. Price volatility should therefore be defined as per one of the most common definitions, like the 12-month rolling standard deviation used by Prokopczuk et al. (2019). Moreover, the models of price volatility presented in the results section of this thesis may be used to improve the understanding of price volatility. The models indicate what variables can be used to explain the price volatility and the complexity of the market.

The interviews found that strategic investments at the case corporation typically increased during volatile price environments. Increased investments generally increase the capacity of the supply chain to more quickly adapt to the changing environment. Furthermore, with a high capacity, the risk of losing sales is lower. Similar to the findings of Gaudenzi

et al. (2021), flexible supply chains were found to be a successful method to mitigate price volatility. Additionally, Henriques and Sadorsky (2011) suggested that investments in the industry were often either under-or over-invested which was also found in the interviews. Over-investing would still lead to a resilient and flexible supply chain for the case corporation. However, the risk is that the capacity would not be fully utilized. However, under-investing would result in a supply chain not being flexible enough to meet the demand, in times of high price volatility.

Another finding from both the interviews and the study of Weidman et al. (2011), was the volatility effect on the financial distress of suppliers. Raw material suppliers of the case corporation were generally small and highly dependent on a consistent cash flow. Due to the payment terms between the case corporation and the suppliers, it may take up to three months for a supplier to get compensated for material or components. The delay increased the risk of financial distress for the suppliers, and having a supplier go bankrupt comes with high costs. The interviews found that the implementation of a new supplier could take a long time. It was therefore common that the case corporation either provide different financial solutions or support through negotiations with the second-tier supplier. Negotiating with the second-tier suppliers required resources from the case corporation, but was preferred over the implementation of a new supplier. The case corporation, therefore, argued that the savings in the long term motivate the additional resources needed.

However, some suppliers were more resilient toward price volatility. The interviews suggested that these suppliers were less dependent on the case corporation. Typically, these suppliers had other customers in other industries, meaning that the business was more resilient. From the case corporation's perspective, such suppliers came with lesser costs related to financial distress or financial aid. However, negotiating with a supplier of low dependency might prove to be more difficult. Since the dependency was lower, the case corporation lacked the same negotiation power in the relationship. Lower power in the relationship could therefore lead to lower savings in terms of negotiations of prices. Which approach was the most financially advantageous, requires further investigations and analysis. These suppliers tend to have a higher total spend from the case corporation, making it necessary to ensure that the market corrections were priced in the agreements. The process of ensuring changed pricing results in additional time spent contacting and negotiating with suppliers.

When the price volatility increases, suppliers strive to re-negotiate agreements. The suppliers strived towards gaining agreements that ensure profitability at even higher prices. The case corporation required fact-based decisions for the renewal of agreements, leading to uncertainty about whether risk premiums would be paid to the suppliers. Suppliers also tended to re-negotiate agreements during increasing price trends, regardless of the volatility. The reason was found to mitigate the risk of financial distress. Moreover, in times of decreasing price trends, suppliers increase their thin margins. Typically, the case corporation then also decreases its total spend on materials. By decreasing the spending, the case corporation, therefore, induces financial pressure on the suppliers also in decreasing

price trends. The risk of financial distress for the supplier base was nevertheless monitored by supplier finance divisions within the case corporation. Additionally, a supplier finance program was in place in the case corporation to enable suppliers to reduce their credit risk by trading invoices.

5.3 Implications for a large automotive manufacturer

The first part of the thesis defined price volatility and identified the main characteristics of price volatility of base metals and steel. A defined measure of price volatility, like the 12-month rolling standard deviation, allows an organisation to understand and act on price volatility. Without a clear definition, it's not possible to know whether the organisation is impacted by price volatility or not. Furthermore, with the use of multivariate regression models, it is possible to break down the price volatility into components. If the inflation increases, an organisation can realize that the base metals price volatility will increase after six months.

Furthermore, with a clear definition of price volatility, a large automotive manufacturer can use price volatility as an argument in supplier negotiations. It was found through the case corporation that suppliers tend to request changes in raw material agreements during high financial pressure. This pressure could arise due to price volatility but also through increasing price trends. Suppliers want to renegotiate an agreement to increase their risk premium as they are experiencing a higher risk. However, in the case of an increasing price trend, the risk is not increasing. Hence, a large automotive manufacturer could point to the fact-based definition of price volatility presented in this thesis. Similarly, the automotive manufacturer could use the definition of price volatility to increase the risk premiums when in their favor.

Lastly, an indirect cost related to the financial distress of suppliers was identified. With the use of the definition of price volatility and regression models, it's possible to anticipate potential suppliers at risk. If the price volatility of base metals or steel is expected to increase, the corporation can proactively mitigate the suppliers' impact. By proactively managing this indirect cost, the corporation reduces the lag in financial compensation and the suppliers may avoid financial distress altogether.

6 Concluding remarks

In conclusion, the thesis found that the price volatility of base metals and steel can be explained through regression analysis. The adjusted R^2 for the three models developed in the thesis ranged from 0,6 to 0,77 with five to six independent variables. The characteristics of the base metals and steel were divided into three categories of energy commodities, input material, and macroeconomic factors. Firstly, oil and coal price volatility were major components of the volatility models, regarding both base metals and steel. Moreover, the input materials in the steel-making process, coal and iron ore, were found to characterise the volatility of the steel price. The impact varied, however, as the volatility spillover existed in the US between iron ore price volatility and steel price volatility, whilst not in the EU. Moreover, macroeconomic factors such as industrial production, inflation, and USD index were identified characteristics. On the contrary to previous literature, the relationship with IP was found to be both polynomial and linear for all studied materials. The inflation and USD index were, however, only found to impact the base metal price volatility. Additionally, the inflation was adjusted six months ahead, both in linear and polynomial form, potentially indicating causality and a complex relationship. The relationship provides insights into previous research as the complex relationship was previously not identified.

Additionally, price volatility has a significant impact on corporations, in this case, a large automotive manufacturer. The results of the thesis can thus be crystallised into three main findings for organisations exposed to price volatility:

1. Definition of price volatility
2. Utilise the definition to decrease risk premiums
3. Quantify the indirect costs

The understanding of price volatility was a central aspect throughout the thesis. It was found that the case corporation lacked a definition of price volatility. The absence of a definition of price volatility led to difficulties in understanding the phenomenon. Additionally, the cost of the commodity price volatility was found to have both a directly and indirectly impact. The risk premiums were identified to directly impact, as suppliers request higher payments when price volatility increases. The regression models presented in the thesis allow corporations to identify when a requested risk premium is legitimate or not. By utilising the definition and measurement of price volatility, suppliers can no longer increase risk premiums without experiencing real price volatility. The indirect cost of price volatility occurs through the financial distress of the suppliers, which corresponds to the findings of the literature study. The price volatility leads to cash flow volatility and thus increased pressure on suppliers. Suppliers, already on thin operating margins, thus experience financial difficulties. The financial difficulties could lead to financial distress and bankruptcy.

6.1 Reflections and future research

The thesis first analysed the price volatility of base metals and steel, followed by an analysis of the impact on the case corporation. The results answered the first question regarding what characterises the price volatility of base metals and steel. However, since the descriptive regression models were not able to explain every case of price volatility, there are further characteristics to be found. One direct and one indirect organisational impact were then identified as an answer to the second research question. Extensive interviewing across the entire case corporation could potentially result in further impacts being identified. However, a large part of the thesis focused on the quantitative analysis which limited the time frame. The complete analysis brought both business value to the case corporation and filled a gap in previous literature on price volatility.

For future research, figures on supply and demand could be included in the regression analysis. Other conclusions on the explanation of price volatility could then be found, bringing additional business and research value. Data on supply and demand was proven difficult to gather, however, could be found through sources like the Copper Study Group or the Aluminum Study Group. Additionally, the balance of dependency rates within the case corporation's suppliers could be further analysed. There were benefits for the case corporation in terms of negotiation power if a supplier is heavily dependent. However, the downside was an indirect financial risk if the supplier would result in financial distress.

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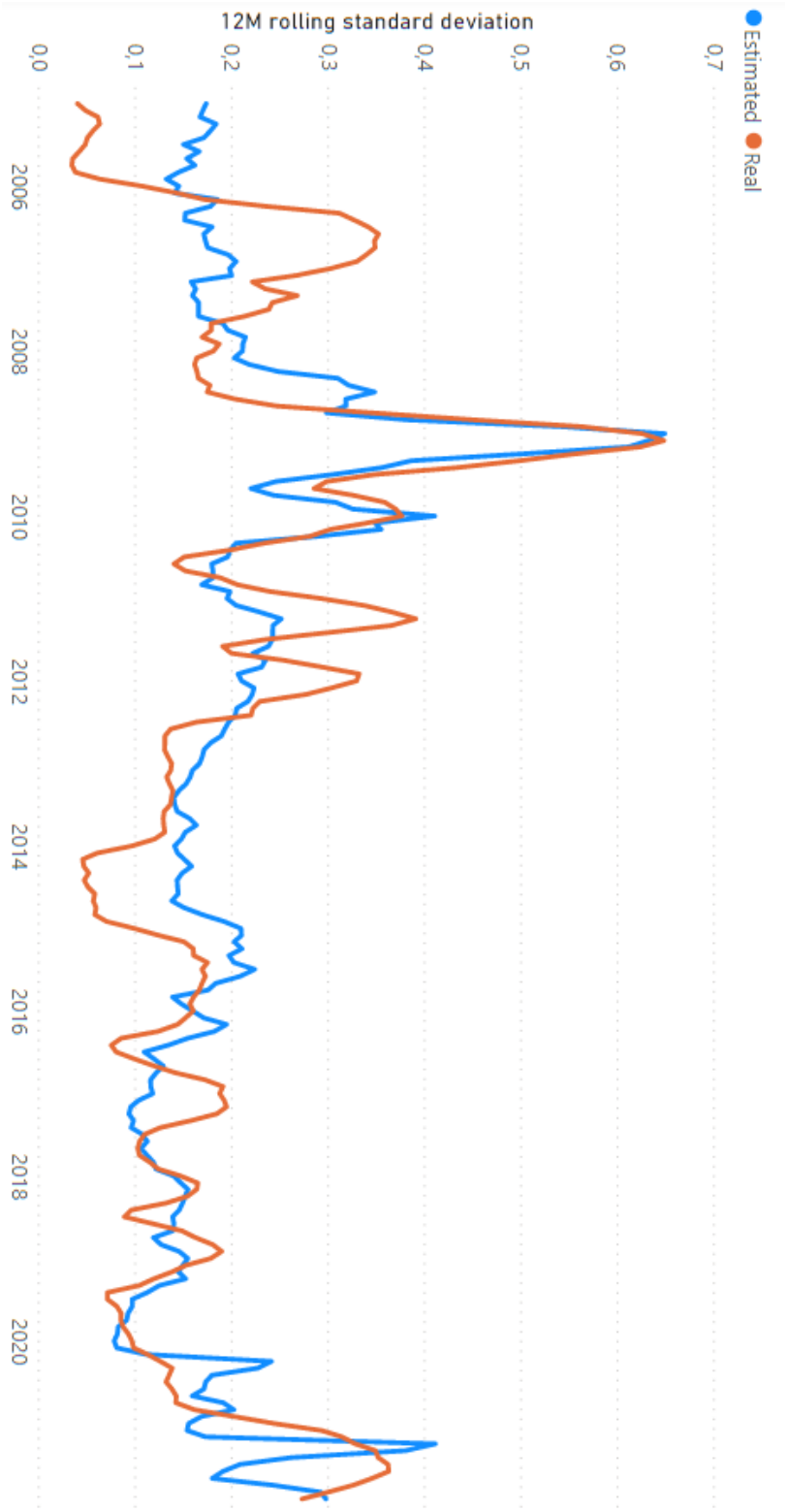
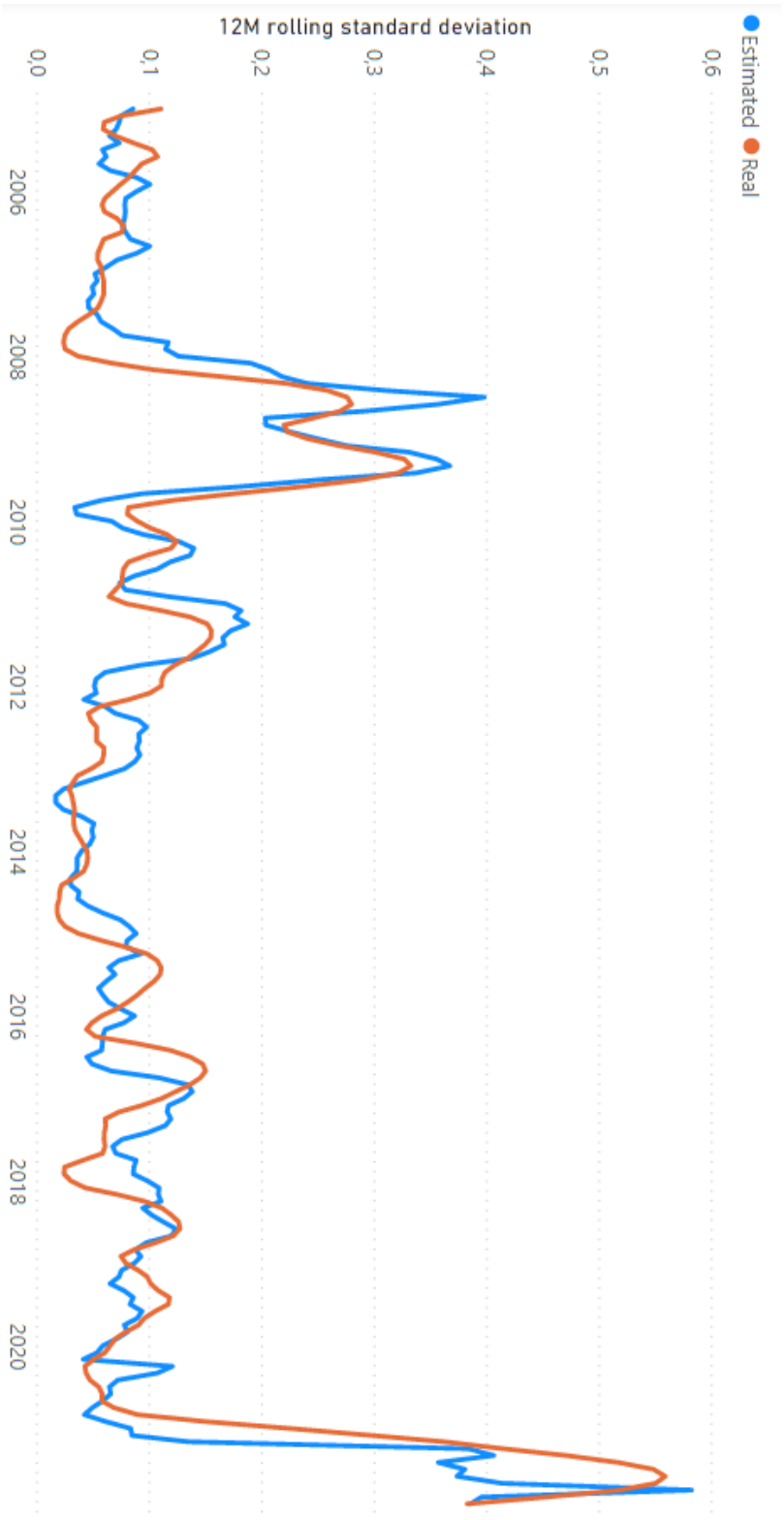
Appendix

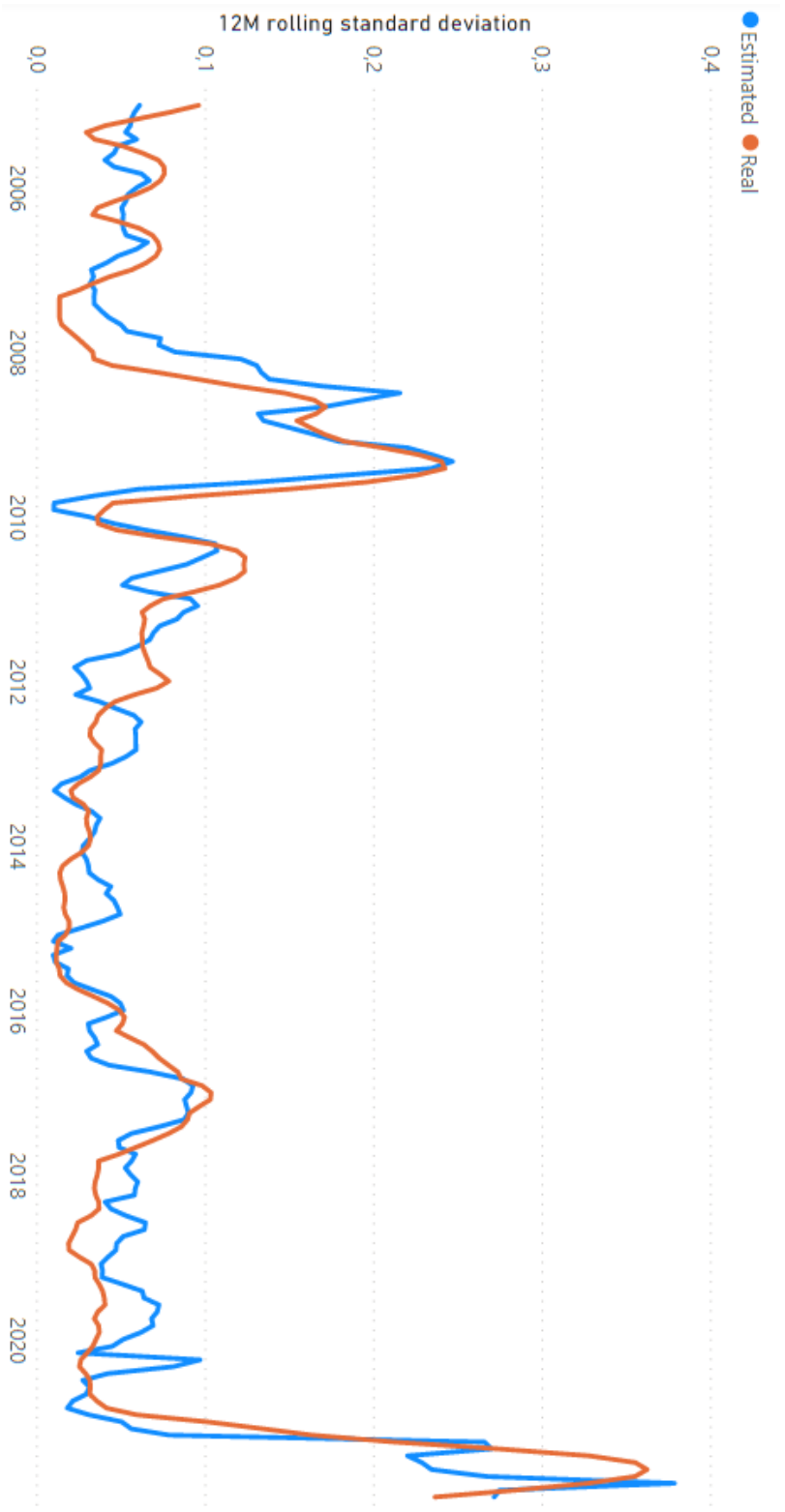
A: Multi-variate regression model on base metals price index



B: Multi-variate regression model on US steel price index



C: Multi-variate regression model on EU steel price index



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