Company Performance in Non-ferrous Metal Markets

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Abstract

Non-ferrous metals have played an integral role in the development of humanity, whether during the Bronze Age, during the Industrial Revolution or in developing Information Technology to the standards of today. However, for long little attention has been paid to the industry that extracts and produces these metals. Matters changed with the dawn of this millennium: China's growth trajectory led to an explosion in metal demand and prices that both were heavily hit by the financial crisis in 2008. Caught in a period of high capacity expansions mining companies that were originally used to down-to-earth and stable environments were suddenly forced to compete in highly volatile terrain.

Based on an early attempt to test profitability models for non-ferrous metal miners (Slade 2004) and further qualitative assessment of the mining industry's profitability (Crowson 2001) as well as the great metals boom (Humphreys 2010) this dissertation focuses on the quantitative analysis of non-ferrous metal markets and its participants. In order to further develop the understanding of these markets we scrutinize how non-ferrous metal miners have coped with this highly dynamic market environment and what drove their profitability from 2002 until 2012.

For that purpose, we analyze at first the overall non-ferrous metal market and subsequently seven non-ferrous metal markets independently, namely the aluminium, copper, manganese, molybdenum, nickel, titanium and zinc market. To do so, we built a unique dataset comprising operational as well as financial performance indicators of the mining business units that participate in the selected non-ferrous metal markets. Based on this dataset we give an in-depth overview on the market development between 2002 and 2012. In addition, we leverage existing insights on general company performance determinants to derive measures and test these potential profitability determinants given the collected dataset.

To point out some of the most relevant findings, we have found that metal prices, growth in demand as well as in supply, competition concentration and the miners' efficient capital usage as well as their diversification has positively influenced the miners' profitability in the overall non-ferrous metal market. In contrast, maritime transport cost, market capital intensity, market size and in particular the companies' sizes have impacted the miners' profitability negatively during the observation period. For the single metal markets, the more liquid and mature markets of aluminium, copper, nickel and zinc prove to react more sensitively to cost variables such as transport, energy and capital intensity. The relevance of market metal prices was confirmed for all markets apart from molybdenum whose returns were instead negatively affected by the copper price.

The dissertation is composed in English and was supervised by Prof. Dr. Hagen Lindstädt from the Institute of Applied Business Studies and Management (IBU) at the Karlsruhe Institute of Technology (KIT).

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Abbreviations

Al	Aluminium
BLUE	Best Linear Unbiased Estimator
CAGR	Compound Annual Growth Rate
CapEx	Capital Expenditures
CAPM	Capital Asset Pricing Model
CIF	Cost, Insurance and Freight
Comp.	Company
Cu	Copper
CRSE	Cluster Robust Standard Errors
EBIT	Earnings before interest and taxes
EBITDA	Earnings before interest, taxes, depreciation and amortization
etc.	Et cetera (and so forth)
et al.	Et alii (and others)
ETF	Exchange traded fund
e.g.	Exempli gratia (for example)
FE	Fixed Effects
GDP	Gross domestic product
GLS	Generalized Least Squares
geogr.	Geographic
H	Hypothesis
HHI	Herfindahl-Hirschman Index
i.e.	It est (that is)
IFRS	International Financial Reporting Standards
i.i.d.	Independently and identically distributed
Inc.	Incorporated
IPO	Initial Public Offering
IT	Information Technology
kgs	Kilograms
kmt	thousand metric ton(s)
Ltd.	Limited
M&A	Mergers and Acquisitions

mio.	Million
Mn	Manganese
Mo	Molybdenum
mt	Metric ton(s)
mtpa	Metric ton(s) per annum (per year)
Ni	Nickel
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
OPEX	Operational Expenditures
p.a.	Per annum (per year)
p.	Page
pp.	Pages
R&D	Research and development
RE	Random Effects
RMG	Raw Materials Group
ROM	Run of mine
SCP	Structure Conduct Performance
SEC	US Securities and Exchange Commission
S&P	Standard & Poors
t	thousand
Ti	Titanium
TiO_2	Titanium Dioxide
UK	United Kingdom
US	United States
US$	U.S. dollar(s)
USGS	United States Geological Survey Institute
VCE	Variance-Covariance matrix of the Estimator
VIF	Variance Inflation Factor(s)
vs.	Versus
WTO	World Trade Organization
Zi	Zinc

1 Introduction

1.1 Motivation

No science is older than metallurgy[1] and no substance has been as important as metal in the story of man's control of his environment.[2] Advances in agriculture, in trade and in transport, in cookery, in medicine and in warfare would have been impossible without metal and non-ferrous metals in particular. The entire Industrial Revolution, from steam to electricity, along with the entire Information Revolution, from simple slide rules to high-performance computing would have not taken place without metals: whether in food[3] or in hardware, in transport or in energy, in construction or in luxury, in medicine or in cutlery, human kind's development and economic growth have depended on metals and their availability.[4]

And so far, there is no reversing trend in sight; demand for metals is hitting unseen heights.[5] Driven by close to exponential population growth coupled with rising urbanization and increases in global wealth the global consumption of metals is ever increasing. Industries such as the construction, energy, automotive, aerospace, mechanical engineering and medical industry depend on metals and in particular on non-ferrous metals[6] such as aluminium, copper, zinc or nickel. These metals are particularly important given their irreplaceable characteristics regarding thermal, electrical, isolating and strengthening properties coupled with their low weight.

This ever increasing demand is satisfied by two sources: Metal mining and metal recycling. While research on recycling is advancing most metals are still produced from primary sources, meaning

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1 Its history can be traced back to 6000 BC and by 4000 BC deep shafts were cut into the hillside in the Balkans, to excavate copper ore. See Radetzki 2009, p.178.
2 See Street, Alexander 1994.
3 Copper, manganese, zinc, cobalt, chromium, molybdenum, and selenium are all required as enzyme cofactors or prosthetic groups, and human disease results if the diet is deficient in the metals, see for example Florea et al. 2012, p.1.
4 See Street, Alexander 1994.
5 See Ng 2013.
6 Non-ferrous metals comprise essentially all metals apart from iron and its alloys.

mining.[7] In general, metal mining enjoys surprisingly little attention given that metals are consumed or utilized in their many applications such as smart phones, lap tops, creams or toothpastes on a daily basis. Nonetheless, negative incidents such as the Chilean mining accident in 2010 start to pull global attention to the topic. Given worldwide media coverage through online sources more than 1 billion viewers around the world watched the final rescue of the buried men.[8]

Apart from the harsh conditions under which these metals are extracted the depletion of these non-renewable resources and its potential impact on society has also increased the interest of researchers and the broader public on the topic.[9] The fear of depletion coupled with strong demand from emerging markets, above all from China[10] resulted in sky-rocketing metal prices during the start of the millennium.[11] As a consequence, returns in the commodity markets greatly out-performed returns on common stocks until the financial crisis hit the market in 2008: As high as the returns in the commodity markets were before the crisis in 2008 as low they remained after the crisis.[12]

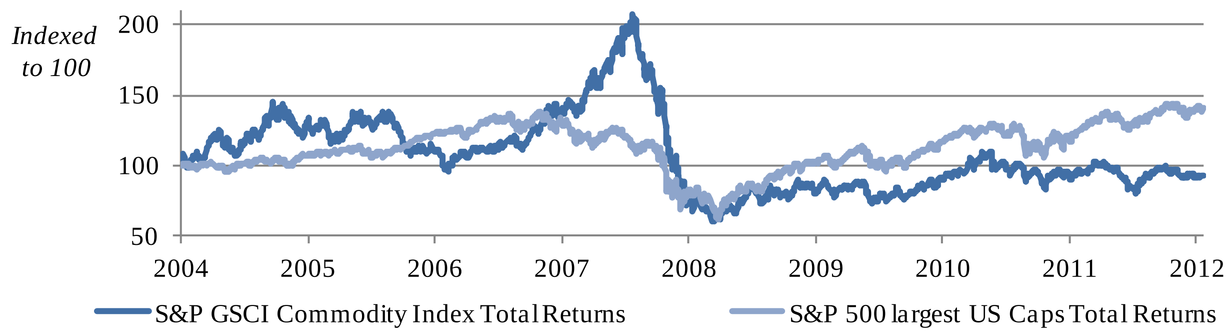

Figure 1 - Total Return of the S&P GSCI Commodity Index versus the S&P 500 Index[13]

The resulting volatility put commodity markets in general and metal producers in particular under pressure and fundamentally changed the competitive landscape within and beyond the metal industry:

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7 "In spite of significant efforts in a number of countries and regions, many metal recycling rates are discouragingly low, and a 'recycling society' appears no more than a distant hope,", see UNEP – International Resource Panel 2011, p.23.

8 33 miners were trapped for over 69 days 700 meters underground in a copper-gold mine, see CBC News 2010.

9 See Rosenau-Tornow et al. 2009, p.161.

10 China's demand originated from its annual double digit growth between 2000 until 2008, see The World Bank 2015.

11 See Figure 4 - Development of precious metal prices in the United States from 1968 until 2010.

12 See Figure 1.

13 See Standard&Poors 2015.

On the one hand, the constant metal undersupply and the resulting increase in metal prices until 2008 led to a shift of power from the manufacturing sectors to the mining industry.[14] In addition, the high returns also provided free cash flow to the established miners to pursue consolidations and accelerate new asset development. On the other hand, many low-cost metal operations were ramped up in the heavily consuming Asia increasing the competition in the metal markets due to their geographical proximity to end markets.[15]

As long as demand was surging the newly established competition did not trouble the established miners. Nevertheless, when the credit crunch and sovereign debt crisis during 2008 and early 2009 led to a sharp down-turn in prices mining markets were purged of idle capacity, high cost assets and inefficient producers.[16]

Altogether, the start of this millennium, often cited as the latest commodity super cycle[17] marked times of high dynamics for the mineral and metal industry: first spoiled by high prices then hit by a sudden implosion of prices, first gaining market power towards their end customers then facing increased competition from new market entrants. Mining companies that were originally used to down-to-earth and stable environments were suddenly forced to compete in highly volatile terrain.

Owing to little transparency and unavailability of data[18] we so far lack a detailed understanding on how the different metal markets and miners were able to cope with the dynamic market shifts and whether these shifts actually led to structural increases in these formerly rather low profitability markets of mining.[19]

1.2 Aims and objectives

As mentioned above the mining industry long operated at low profile drawing little public attention to its operations and undertakings. Incidents like the Chilean mining accident, the discussions

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14 See Humphreys 2010, p.2.

15 In 2001, the Chinese Government's 10th Five Year Plan stated that Chinese companies would be encouraged to invest in strategic natural resources, especially also overseas. The 12th Five-Year Plan (2011-2016) called for the acceleration and expansion of these investment, see The Climate and Finance Policy Centre, Greenovation Hub 2014, p.40.

16 See Ng 2013.

17 See Cuddington, Jerrett 2008.

18 See Crowson 2001, p.33.

19 See Crowson 2001, p.36.

around sustainability and depleting raw material sources led to increased interest in the field. In addition, many mining companies were seeking financial support in the beginning of the millennium in order to accelerate the development of new assets.[20] To do so, formerly privately held or state owned mining companies, such as the two mining giants Glencore or China Moly went public.[21] Coupled with an expanding adoption of international reporting standards and an increase in globally traded volumes, both physically as well as financially, truly global metal markets established and the transparency of these metal markets fundamentally changed.

The overall relevance and demand of metals, the recent developments in the mining industry described in 1.1 paired with the now available transparency and data on the industry constitutes the starting point of our work: We aim to examine how mining markets and companies coped with the above described dynamics in the metal markets.

Thereby, we focus on the largest and most transparent non-ferrous[22] metal markets as these markets provide sufficient data to conduct the required analyses.[23] Plus, we focus on the eleven years from 2002 until 2012 since this time span covers the above described dynamics while sufficient data on the participants and their performance in the selected markets is reported and available.

Against the background of the recent developments and trends in the metal markets we thus seek to elucidate two fundamental questions in this dissertation, namely:

- What drove or impacted profitability of primary non-ferrous metal producers from 2002 until 2012?
- How did profitability drivers differ between non-ferrous metal markets from 2002 until 2012?

Prior to setting out on this journey to identify and analyze the performance determinants across non-ferrous metal markets we have to ensure a profound understanding of the industry as well as of the research beyond metals and mining. We have to generate the required data and utilize the appropriate analytical techniques to ensure significant and meaningful results. Altogether, we can thus deduct the following objectives for this thesis:

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[20] See 1.1.
[21] See Wearden 2011 and Reuters 2012.
[22] The iron ore market's size and regional organization would go beyond the scope of this dissertation. For a profound analysis see Bielitza 2012, pp.13-84.
[23] For more details also see 2.1.6.

1. Build an in-depth understanding of non-ferrous metals, of value creation in mining and of the mining industry and structure for the markets under research.
2. Distill potential performance determinants from research on the economics of mining as well as metal markets and on company performance analyses beyond these markets.
3. Develop the required dataset to measure the identified profitability determinants and select appropriate statistical techniques to test these potential profitability determinants.
4. Combine all of the above to gain a holistic view on the relevance of identified profitability determinants in the overall non-ferrous metal market.
5. Test the identified profitability determinants and compare the results thereof among different markets and findings for the overall non-ferrous metal market.

1.3 Structure of the thesis

According to the outlined objectives above this thesis is structured in seven chapters. These are structured as follows:

In chapter 2, we first give an introduction to non-ferrous metals at first in general and thereafter more specific for the single markets under research. We do so by generally explaining the value creation in mining, the metal production process, the consumption, the metal prices and the development of metal markets overall. Subsequently, we clarify the choice of the seven metal markets for the in depth analysis in this dissertation. For a better understanding of these seven markets, we then give details on each of the seven markets explicating for each of the metals its specific characteristics, its countries of origins, the generated sales per producer, noteworthy dynamics in the producer landscape and a short outlook of the metal.

In chapter 3, we give an overview on research regarding the economics of metal markets and general profitability determinants. First, we focus on research that has analyzed the economics of mining and metal markets. Subsequently, we also summarize the most important findings in the more general field of research on company performance determinants to cover performance drivers that so far have not been covered in the analyses of metal markets economics. Based on this, we deduct the hypotheses that build the basis for the analyses in this dissertation. Thereby we distinguish two sets of hypotheses. First, we deduct hypotheses for the analysis of the overall non-ferrous metal market. Secondly, we formulate hypotheses for each of the single metal markets because we expect some profitability determinants to only affect single non-ferrous metal markets.

Thereafter in chapter 4, we explain the data, variables and the selected model that are required to test the postulated hypotheses. We do so by first analyzing and summarizing the underlying data and their characteristics that constitute the dataset. Subsequently, we describe the performance measure and potential performance determinants as endogenous and exogenous variables and lastly we explain the choice and specification of the statistical model.

In chapter 5, the hypotheses for the overall non-ferrous metal market will be analyzed. Since the dataset has been uniquely generated for this analysis, we first give a short qualitative overview of the underlying non-ferrous metal market variables explained in chapter 4. After the qualitative overview, we present the quantitative analyses results supported by an explanation of the underlying analysis process and a test on the robustness of the results. At last, we conclude the chapter with a discussion and evaluation of the results.

After the analysis of the overall non-ferrous metal markets, chapter 6 focuses on scrutinizing the single metal markets individually. This is done by different quantitative analyses on subsets of the entire dataset comprising only observations from one single metal market at a time. Following the analyses and evaluations of the single metal markets, the findings from the single markets are compared with the originally postulated hypotheses. Last but not least, the findings from the single metal markets are compared with the findings from the overall market analysis.

Finally in this chapter 7, we reconcile the results of the dissertation with the objectives that were formulated in chapter 1 and give an overall conclusion distilling the results of chapter 5 and 6. Thereafter, we briefly discuss potential implications for research and the mining industry, point out the limits of the conducted analyses and deduct areas for further research.

2 Background of the research topic

In the following chapter, a short introduction to non-ferrous metals and its mining is given, first in general and subsequently more specifically to the seven non-ferrous metal markets under research.

2.1 Introduction to non-ferrous metals

In metallurgy, metals are divided into ferrous and non-ferrous metals whereby a non-ferrous metal is any metal that does not contain iron in appreciable amounts. Generally, non-ferrous metals are more expensive than ferrous metals, and are hence mostly used for certain desirable properties such as low weight, higher conductivity, non-magnetism or resistance to corrosion.[24]

2.1.1 Introduction to value creation in metal mining

In the common understanding metal producers are assumed to be occupied by metal production only. However, the value creation of metal miners normally consists of four essential steps: Exploration, metal production, logistics and sales. As explained in Figure 2 each of these four steps is vital to drive company performance for very differing reasons.

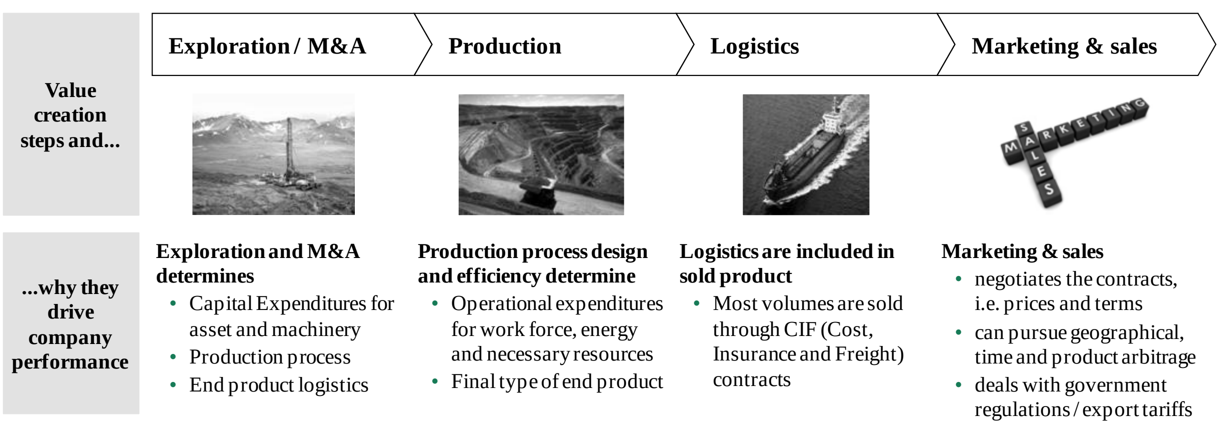

Figure 2 - The four steps of value creation in metal mining[25]

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24 See Fahlman 2011, 2011, p.204.
25 See Whyte, Cumming 2007.

For mining companies, smart exploration of its future assets or M&A of junior mining companies constitutes the solid foundation for a well performing business since this selection process determines the company's capital expenditures on the asset and the machinery required to produce the desired metal. In addition, it will determine required shipping routes to the final consumer markets.[26]

The production process itself is largely dependent on the type of assets: both the mine's type – whether it is an open cast or an underground operation – and the type of extracted mineral will define the required process steps to obtain the metal. The design and efficiency of these process steps then determines the required operational expenditures.[27]

The fact that logistics or logistics management is also part of a miner's value generation is often neglected by the broad public. But since most of the non-ferrous metals are traded on a global rather than regional or national scale logistics – mostly of maritime nature – and logistical capacity along with its associated cost may also influence a miner's profitability.[28]

Together these three value creation steps, exploration, production and logistics will essentially determine the company's cost competitiveness and thus its position on the commodity cost curve along with its performance.

Finally, marketing and sales capabilities will decide upon the conditions and terms under which the produced metal is sold. This value creation step which is also often forgotten about comprises not only negotiating contracts and their terms but also metal trading. The latter offers options for arbitrage on three different dimensions: geographical arbitrage meaning different prices for the same material in different regions, product type arbitrage meaning purifying or impurifying the product yielding excess margins and time arbitrage meaning stocking when prices are low and vice versa.[29]

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26 See Stevens 2011, pp.4.
27 See Runge 1998, pp.36.
28 See Mangan 2011, pp.131.
29 See Crabbe 1998, p.17.

2.1.2 Production of non-ferrous metals

The typical production process of non-ferrous metals starts with mineral extraction followed by mechanical and chemical processing and finally smelting and manufacturing.[30] The degree to which mining players are involved in this value chain differs substantially among metal markets. However, most mining players focus on the production of metal oxides or ingots due to the complexity of potential end market uses.

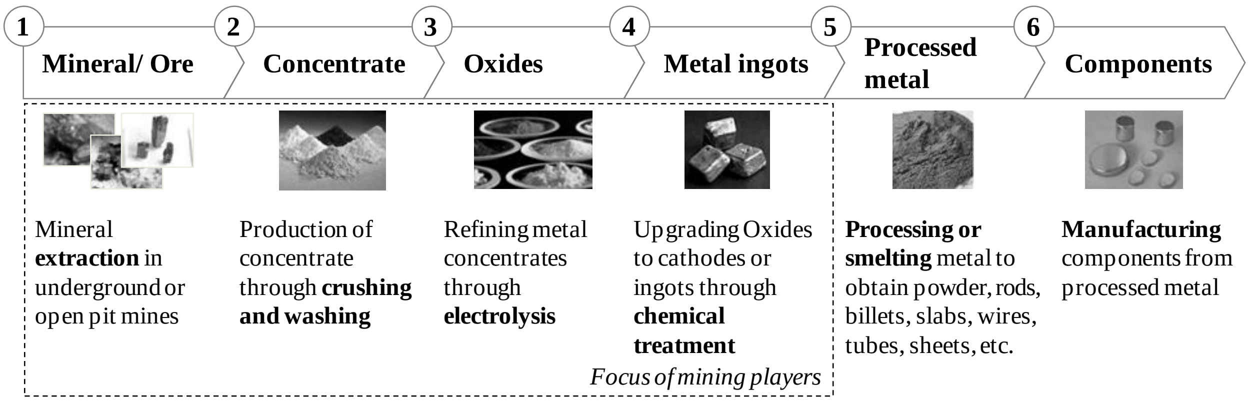

Figure 3 - Typical production process of Non-Ferrous Metals[31]

According to their production volumes the largest non-ferrous metal markets are aluminium, copper, manganese, zinc, titanium and nickel. Precious metals such as gold and silver and more exotic metals such as lead, cobalt, tungsten, niobium or tantalum are also non-ferrous but due to their scarcity or difficulty to produce not extracted in comparably large volumes.[32]

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[30] See Figure 3.

[31] See Young 2008, pp.2.

[32] See U.S. Geological Survey 2003-2012, pp.25.

Table 1 - Global annual production volumes of most important non-ferrous metals[33]

Metal	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Gold	2.5	2.4	2.5	2.4	2.4	2.3	2.5	2.6	2.7	2.7	2.8
Silver	19	20	20	20	21	21	21	23	24	26	26
Tin	265	264	280	302	300	299	307	265	253	240	230
Molybdenum	131	159	186	187	212	218	220	244	264	259	270
Nickel	1,330	1,360	1,460	1,560	1,740	1,610	1,450	1,710	1,960	2,220	2,490
Titanium	6,334	6,504	6,704	7,582	7,748	7,694	6,691	6,959	7,239	7,230	7,550
Zinc	9,530	9,600	9,930	10,300	11,100	11,800	11,500	12,200	12,800	13,500	13,500
Manganese	8,778	9,914	10,980	11,939	11,987	13,248	11,156	15,114	15,997	15,800	17,000
Copper	13,800	14,700	15,000	15,100	15,500	15,600	16,000	16,100	16,100	16,900	17,900
Aluminium	28,000	29,900	31,900	33,900	37,900	39,700	37,100	41,200	44,400	45,800	47,600

All values are stated as metal content in thousand metric tons

Apart from primary production many metals are also produced by recycling scrap. The end of life recycling rate, i.e. which share of the scrap is being recycled at the end of life of the metal product differs substantially depending on end usage and metal. Due to their higher value, precious metal products are generally recycled at higher rates than other non-ferrous metals.

Table 2 - End of life recycling rates and Old scrap ratios of metals[34]

Metal	**End of life recycling rate** (% of total scrap metal)	**Old scrap ratio** (% of total metal flow)
Gold	92%	>80%
Lead	72%	95%
Silver	70%	>80%
Tin	75%	50%
Molybdenum	30%	48%
Nickel	57%	70%
Titanium oxide	91%	11%
Zinc	45%	35%
Manganese	53%	48%
Copper	48%	51%
Aluminum	55%	45%

The end of life recycling ratio means the percentage of a metal in discards that is actually recycled. The old scrap ratio expresses the percentage of how much of the global metal flow is satisfied by recycled metal.[35]

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33 See U.S. Geological Survey 2002-2014.

34 UNEP – International Resource Panel 2011, p.31.

35 The old scrap ratio for precious metal is in general higher than for other non-ferrous metals, meaning that recycled volumes constitute a higher share of global production for precious metals than for other non-ferrous metals. This is due to the maturity of the precious metal market in combination with the historic high value of the recycled product.

2.1.3 Consumption of non-ferrous metals

Non-ferrous metals in general offer a vast range of properties and hence also end markets.

Table 3 - Non-ferrous metals, their properties and major consumption purposes

Metal	Properties	Consumption purpose and end use
Gold[36]	• Good conductivity and ductility • Resistance to corrosion/ oxidation • Lack of toxicity	**Jewelry** (45%) **Investment** (45%): Hedge against economic disruption/ devaluation **Industry** (10%): Electronics connectors, chemistry, medicine
Lead[37]	• High density • Good ductility • Low melting point	**Industry**: Lead-acid batteries (80%), Rolled and extruded products (6%), Pigments (5%), Ammunition (3%)
Silver[38]	• Very good conductivity • High reflectivity • Catalytic properties	**Jewelry** (18%) **Investment** (28%): Net investment, de-hedging and coins/medals **Industry** (54%): Photography, Electronics
Tin[39]	• Good ductility • Resistance to corrosion • Low toxicity	**Industry**: Solder (52%), Tinplate (16%), Chemicals (13%), Brass & Bronze (6%)
Molybdenum[40]	• Very high melting point • High strength	**Industry**: Alloy (86%), Chemical catalytic application (14%)
Nickel[41]	• Magnetic at room temperature • Resistance to corrosion	**Industry**: Alloy (89%), Electroplating (8%), Chemicals (3%)
Titanium[42]	• Resistance to corrosion • Highest strength to density ratio	**Industry**: Pigment (95%), Aerospace& Marine (3%)
Zinc[43]	• Resistance to corrosion • Low melting point	**Industry**: Galvanizing (50%), Alloys (17%), Brass and Bronze (17%), Zinc Semi-manufactures (6%), Chemicals (6%), Others (4%)
Manganese[44]	• Deoxidizing properties • Low price	**Industry**: Alloys (95%)
Copper[45]	• Good conductivity • High tensile strength • Good ductility	**Industry**: Electrical wires (60%), Roofing / plumbing (20%), Industrial machinery (15%)
Aluminium[46]	• Low density • High conductivity • Resistance to corrosion	**Industry**: Transport (25%), Construction (25%), Packaging (17%), Electrical (12%), Machinery (10%), Consumer durables (6%)

36 See World Gold Council 2014.
37 See International Lead & Zinc Study Group 2015.
38 See The Silver Institute 2015.
39 See International Tin Research Institute 2008.
40 See London Metal Exchange 2015a.
41 See London Metal Exchange 2015b.
42 See U.S. Geological Survey 2002-2014.
43 See International Lead & Zinc Study Group 2015.
44 See Zhang, Cheng 2007.
45 See London Metal Exchange 2015b.
46 See London Metal Exchange 2015b.

Apart from the mechanical or structural requirements of the end product of a non-ferrous metal, its price and its potential substitutes are the most important drivers for the non-ferrous metals' consumption.

With regards to end usages we can differentiate precious metals such as gold and silver and industrial non-ferrous metals. While industrial non-ferrous metals are almost purely used for production and manufacturing of industrial goods, precious metals are also used for investment or hedging purposes and jewelry.

2.1.4 Prices of non-ferrous metals

When analyzing non-ferrous metal prices one ought to differentiate between precious non-ferrous metals and industrial non-ferrous metals. While precious metals are commonly priced in US dollars per troy ounce, prices of industrial metals are generally denominated in US dollars per pound or metric ton. Nevertheless, units are merely a question of denomination. What primarily puts precious and industrial metals apart are the fundamentals that drive their prices.

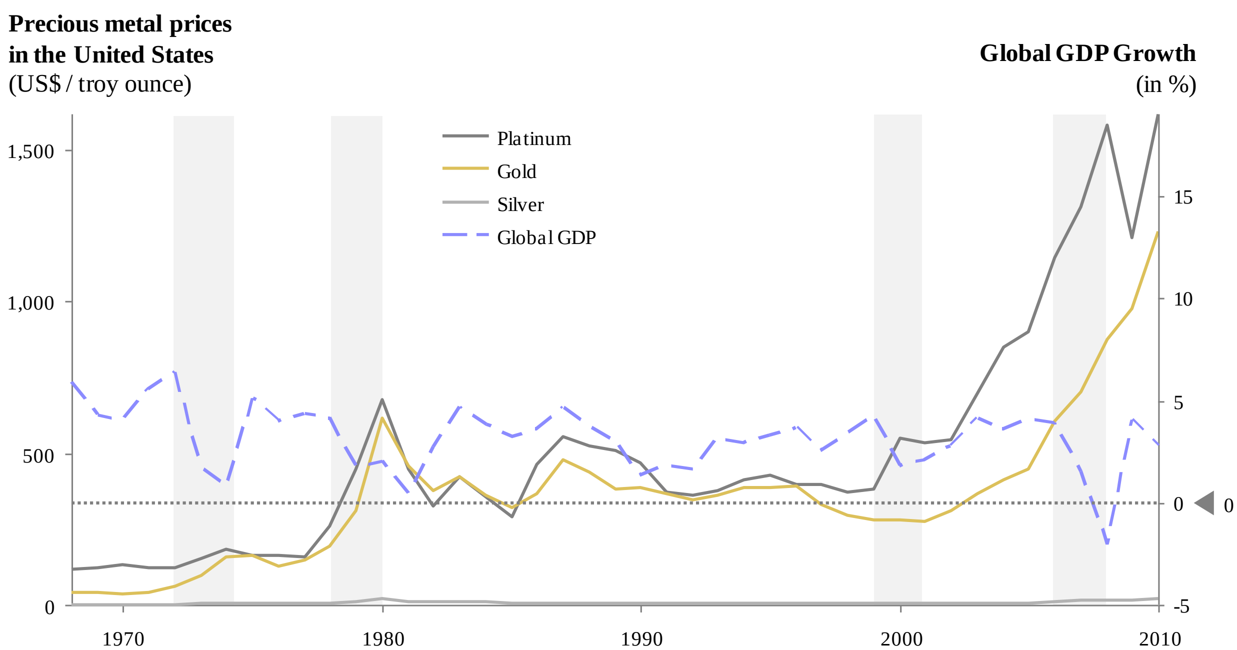

Figure 4 - Development of precious metal prices in the United States from 1968 until 2010[47]

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[47] See U.S. Geological Survey 2013.

Price of precious metals, and of gold above all, have historically proven to be uncorrelated with stocks or bonds on average and even in market crash environments.[48] Therefore, investors have always fled from stocks and bonds towards investments in gold or other precious metals whenever markets went through turmoil. This in turn has generally led to rising prices of precious metals during economic downturns.[49]

Prices of industrial non-ferrous metals on the contrary did not rise when global GDP declined. Since demand and hence prices for most of these metals have been driven by demand for industrial goods, prices for these metals have generally been positively correlated to global GDP growth.[50]

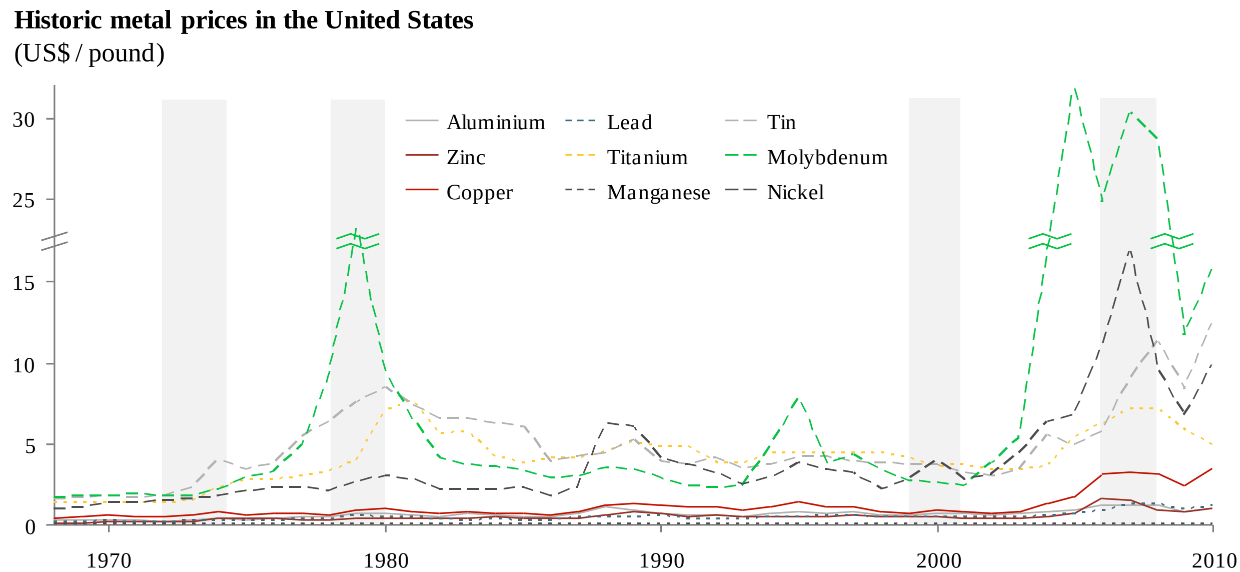

Figure 5 - Price development of industrial non-ferrous metals in the United States[51]

Independent of the type of non-ferrous metal, their respective prices have increased and partially dropped extremely since the dawn of the new millennium.[52] During the past 15 years, prices of most of these metals have shown very high compound annual growth rates (CAGR).

48 See Baur, Lucey 2010.
49 See light grey areas in Figure 4.
50 See Borensztein, Reinhart 1994.
51 See U.S. Geological Survey 2013.
52 See Table 4.

Given these dynamics recent research has come to the conclusion that commodities are entering a new supercycle.[53] They see the urbanization and industrialization of China as the main growth driver, with the impact of its recent slowing still to be understood.

Table 4 - Metal prices and their growth rates between 2000 and 2010 in the US

Metal	**US metal prices** (US$/pound)		**CAGR** 2000 - 2010
	2000	2010	
Aluminium	0.75	1.04	3%
Copper	0.88	3.48	13%
Lead	0.44	1.09	9%
Manganese	0.0011	0.0039	12%
Molybdenum	2.55	15.80	18%
Nickel	3.92	9.89	9%
Tin	3.70	12.40	12%
Titanium	3.53	4.87	3%
Zinc	0.56	1.02	6%

2.1.5 Development of metal markets

The development that mature commodity markets such as the oil, gas or gold market have undergone can now also be observed in less mature non-ferrous metal markets. As summarized in Table 5 one can differentiate four development stages that commodity including non-ferrous metal markets normally go through.[54]

These differing stages of development or maturity apply to most commodities. The speed with which commodities develop from one maturity level to another then depends on the volumes traded in the respective market combined with the value over volume ratio. If the value over volume ratio is comparably low regional markets evolve with high differences in regional commodity prices, as for example in the case of iron ore, wheat or corn.

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53 See Cuddington, Jerrett 2008.

54 See London Metal Exchange 2015b.

Table 5 - Development stages of commodity markets

Stage	Market development	Commodity
I	Small and intransparent market, most commodity volumes are sold on a client to client relationship. Commodity producers with little incentive to publish volumes, cost or achieved prices.	• Rare earth • Exotic metals
II	Increase of globally traded commodity volumes and of commodity spot sales leads to development of standardized contracts.	• Manganese • Titanium
III	Based on standardized contracts commodity indices emerge that increase transparency and increase the amount of potential market participants and desired risk positions. Exchange traded instruments evolve.	• Molybdenum • Lead • Tin • Nickel • Zinc • Copper • Aluminium
IV	Liquidity and transparency of markets are very high. Commodities are used as investment vehicles, especially for hedging against economic disruption or devaluation or mere speculation.	• Silver • Gold • Oil and gas

2.1.6 Selection of metal markets under research

This study aims at identifying and analyzing performance determinants across primary non-ferrous metal production markets. Hence, when selecting the different markets for further research we have to ensure that they are – although different in many aspects - comparable with regards to data availability and underlying drivers.

As noted in 2.1.3, precious metals are – to a large extent – utilized for investment purposes that manipulate the metal's demand and price independent of the miner's production cost. However, the metals' demand and price highly influence the miner's profitability and performance. Hence, a precious metals miner's performance highly depends on financial and economic trends that are complexly linked to the global economy rather than on the metal's industrial demand and supply. In addition, precious metals are recycled at high rates.[55] Thus, the share of metal production from primary producers and thereby the share of the market under research is smaller in precious than in other non-ferrous metal markets. Given that we want to analyze mining companies in metal

[55] See 2.1.2.

markets that are driven by industrial demand and primary metal supply we exclude precious metals from the further analysis in this study.[56]

Apart from this restriction on the markets under research we have to ensure the availability of sufficient data on a producer level in order to enable the quantitative regression analyses of company performance. Even though privatization and globalization of many commodity markets has increased the transparency on company data and performance in many non-ferrous metal markets data availability is still limited.

Table 6 - Overview on non-ferrous metals, production volume, end use and data availability[57]

Non-ferrous metal	Primary metal production 2011 (in t metric tons)	Major end use of metal	Production and financial data availability	Analyzed in thesis
PGM	0.5	Investment, Jewelry, Industrial	Medium	No
Gold	2.7	Investment, Jewelry, Industrial	High	No
Silver	23.3	Investment, Jewelry, Industrial	High	No
Cobalt	109	Industrial	Low	No
Antimony	178	Industrial	Low	No
Tin	244	Industrial	Low	No
Molybdenum	264	Industrial	Medium	Yes
Niobium-Tantalum	465	Industrial	Low	No
Magnesium	771	Industrial	Low	No
Nickel	1,960	Industrial	Medium	Yes
Lead	4,690	Industrial	Low	No
Titanium	7,550	Industrial	Medium	Yes
Zinc	12,800	Industrial	Medium	Yes
Copper	16,100	Industrial	High	Yes
Manganese	17,000	Industrial	Medium	Yes
Aluminium	44,400	Industrial	High	Yes

Note: PGM = Platinum Group Metals, Niobium-Tantalum noted in concentrate not metal content

Metal markets with low production volumes such as the cobalt, antimony, niobium, tantalum or magnesium market are generally dominated by few mostly state-owned companies that are not required to publish any data. Other larger and more mature markets such as the lead or tin market are still dominated by privately or family owned companies that also do not publish sufficient data

56 Nevertheless, we want to motivate further and more detailed research in the company performance analysis of precious metals markets.

57 See U.S. Geological Survey 2003-2012.

on annual output, performance or company structure. Since this impedes a thorough quantitative analysis of the respective markets we have to exclude these non-ferrous metal markets for reasons of data availability.

Overall and as can be seen in Table 6, we analyze the company performance in the following seven non-ferrous metal mining markets:

I. Aluminium
II. Copper
III. Manganese
IV. Molybdenum
V. Nickel
VI. Titanium oxide
VII. Zinc

2.2 Status quo and trends in the metal markets under research

In the following, each of the markets under research is shortly introduced. First a quick overview on the main production steps is given. Then the geographical origin of the minerals and metals is stated followed by an overview of the production landscape between 2002 and 2012. Finally, the prices and market trends for each market are discussed.

2.2.1 Aluminium

Although aluminium is the third most abundant element in the earth crust, the common aluminium minerals do not constitute an economic source of the metal. Instead, almost all metallic aluminium is produced from the mineral bauxite. Large deposits of this mineral occur in Australia, Brazil, Guinea and Jamaica.[58]

The metal aluminium is obtained in two production steps that are often geographically separated for both require different input factors. In a first step, bauxite is converted to alumina or aluminium oxide via the Bayer process in which iron and silicon particles are removed from the alumina. This

58 See U.S. Geological Survey 2002-2014.

step is normally conducted at the bauxite mine since it approximately halves the weight of the ore that is further processed. After this refinery the oxide is often transported to countries in which energy is abundant and cheap such as Russia, the United Arab Emirates and Norway because the alumina's final conversion to aluminium requires a lot of energy. Depending on the smelter's location the energy cost represent about 20% to 40% of the entire production cost. The conversion itself is achieved by the Hall-Héroult process.[59]

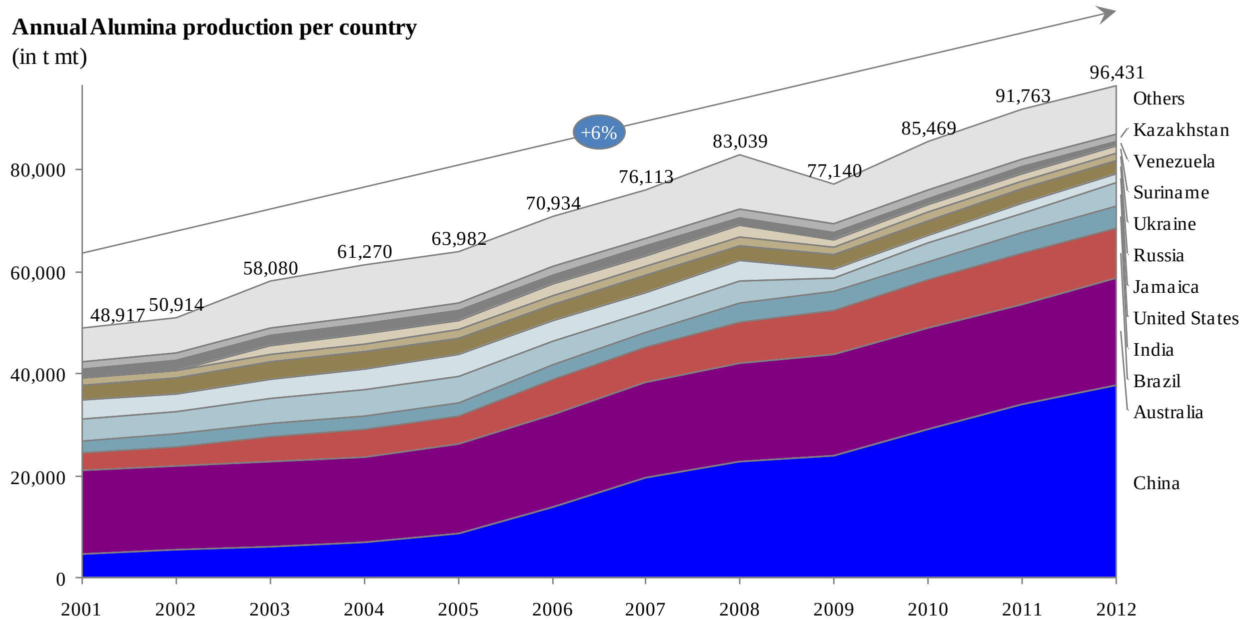

Figure 6 - Annual alumina production per country from 2001 until 2012[60]

Comparing the countries in which alumina and aluminium is produced one can clearly see the shift in production volumes from high energy cost countries such as Australia to low energy cost countries such as Russia, Canada or the United Arab Emirates.[61]

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[59] See Frank 2009, p.483.
[60] See U.S. Geological Survey 2002-2014.
[61] Comparing market shares of countries in Figure 6 and Figure 7.

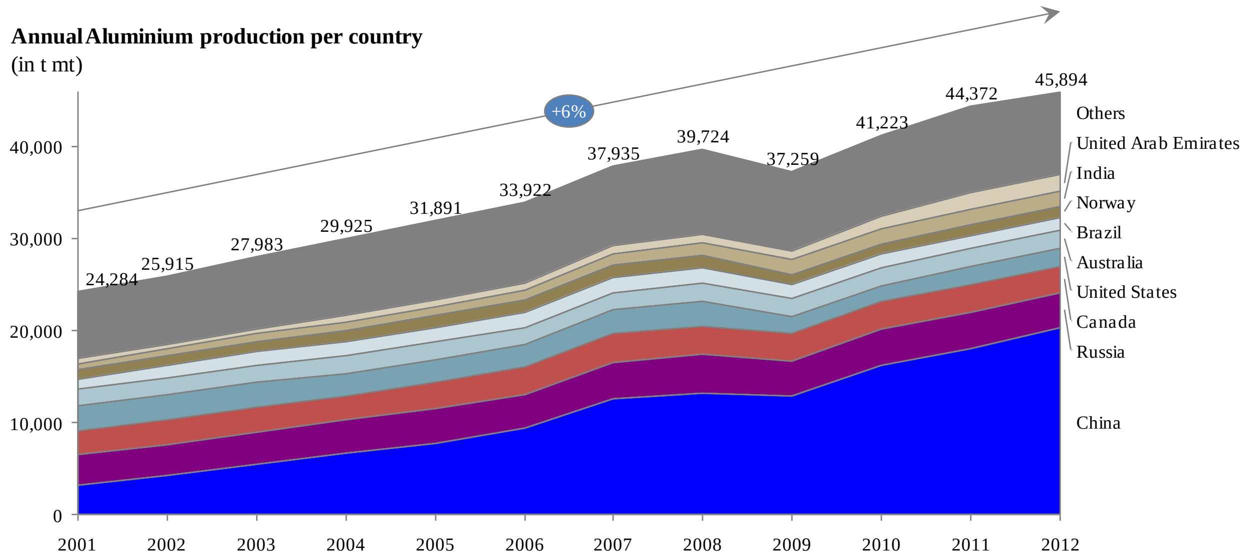

Figure 7 - Annual aluminium production per country from 2001 until 2012[62]

From 2001 until 2012, both the alumina and the aluminium production grew annually by 6% on average. Most remarkably remains the growth trajectory of China, it grew at a CAGR of 21% in the alumina and at a CAGR of 18% in the aluminium market to become the largest producer in both markets by 2012.[63]

Among the aluminium producers that operate proprietary bauxite/ alumina assets and are hence vertically integrated[64] there were four noteworthy changes between 2002 and 2012:[65] For one, Rio Tinto took over Alcan in 2007 which at once made Rio Tinto one of the three biggest producers of aluminium worldwide. Also in 2007, Hydro vertically integrated into the alumina market, now being able to directly supply the required alumina to its smelters.[66] In addition, Rusal also entered the market in 2007 as a newly formed company from the former public company Rusal, SUAL and the aluminium assets of Glencore, all of whom did not publish any data before 2008. And last but

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62 See U.S. Geological Survey 2002-2014.
63 See Figure 6 and Figure 7.
64 We restrict our aluminium market analysis to vertically integrated aluminium producers to ensure integrity across all markets. If we had included pure aluminium smelters in the analysis we would have tried to explain the performance of primary and secondary metal producers with the same profitability drivers although they might differ substantially.
65 See Figure 8 and Figure 9.
66 Beforehand, Hydro had only operated as an aluminium refinery sourcing alumina from third parties.

least in 2011, Vale receded from the aluminium market by selling all its bauxite and alumina assets to Hydro.

Aluminium volumes sold in t mt
(Share of global production volumes)

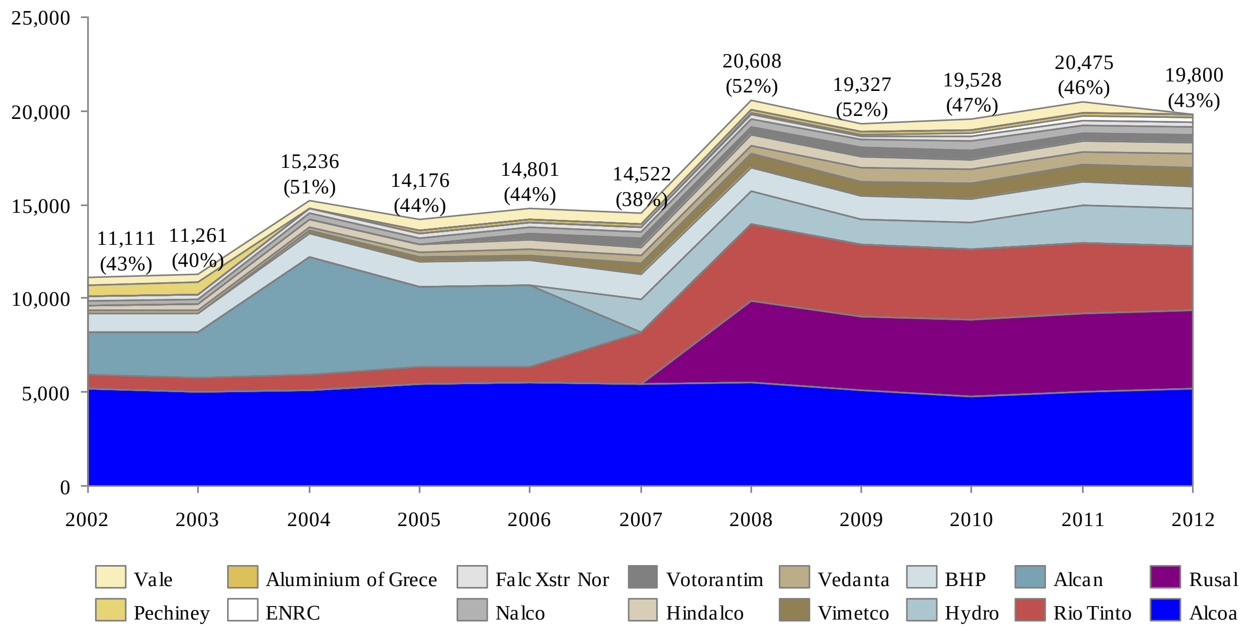

Figure 8 - Development of volume market share in the aluminium market[67]

Unlike most of the other metal prices, aluminum prices only doubled from 2002 to 2007 due to a lot of new capacity coming online during that period. The reported boost of aluminium sales in 2008 can be explained by extraordinarily high volume sales coupled with a very high price of aluminium for the first three quarters of 2008 of US$3000/mt. With the financial crisis kicking in during the fourth quarter of 2008 the metal's price plunged to US$1500/mt. Numerous smelter closures were announced as aluminum prices continued to decline. By June, 2009, more than 50% of primary aluminium smelting capacity was not being used.[68] Until 2012, owing to the still extensive capacity in the market, the aluminium price did never reach pre-crises levels and, as of February, 2015, is still being traded at US$1800/mt.

[67] Data were sourced from single company reports from 2002 to 2012 of mining companies that publish their production and sales volumes.

[68] See U.S. Geological Survey 2002-2014.

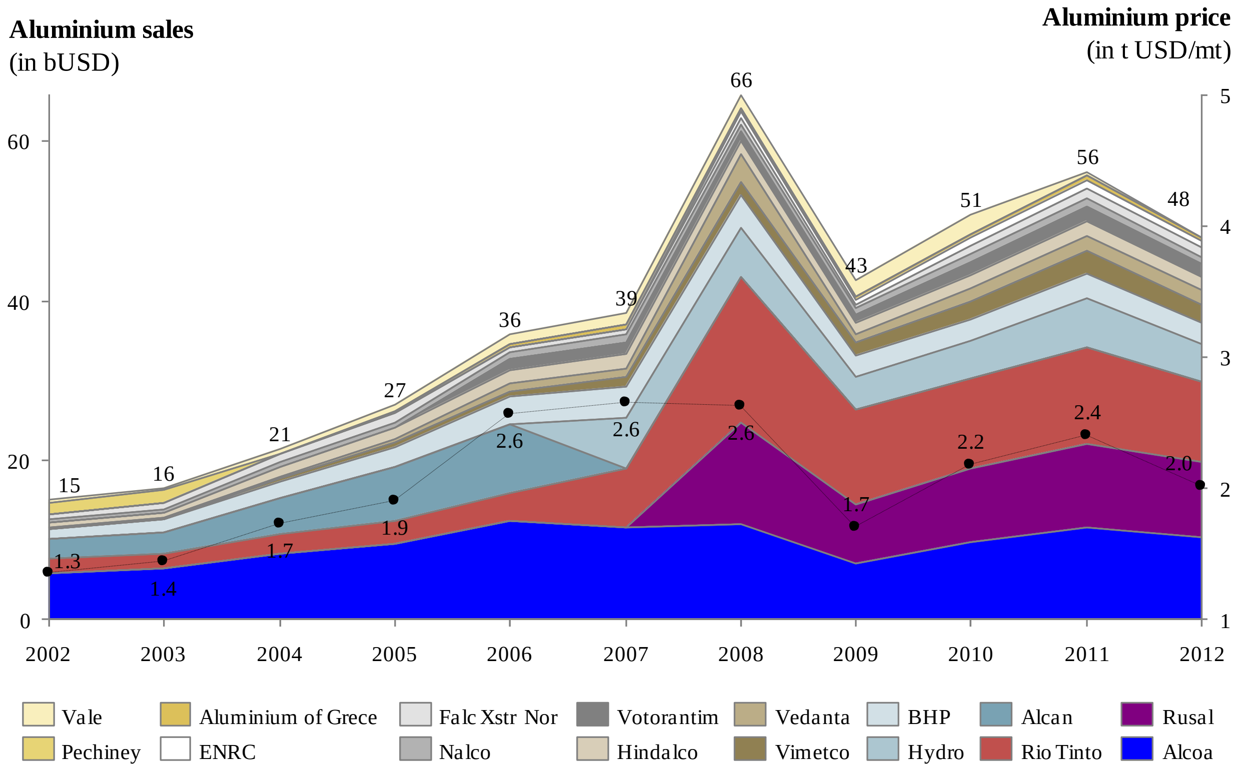

Figure 9 - Development of reported aluminium sales and prices from 2002 until 2012[69]

However, future supply and demand trends look promising for the aluminium industry since supply is not expected to increase further and need for lighter consumer goods are increasing. Automakers, for instance, are reportedly working with aluminum producers to develop lighter vehicles and hence increase fuel efficiency in response to increased Corporate Average Fuel Economy standards. Substituting steel with aluminum could increase the average amount of aluminum from 156kgs in 2012 per vehicle to 249kgs by 2025.[70]

2.2.2 Copper

Most copper is extracted from copper sulfide ores that contain only between 0.4% to 1.0% actual copper content at large open pit mines located in Chile, Peru, the United States and China. After the ore is mined the metal is extracted in three steps: First, the mined ore is concentrated via froth

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[69] Data were sourced from single company reports from 2002 to 2012 of mining companies that publish their production and sales volumes.

[70] See Kelly 2012.

flotation to copper sulfides that contain 10–15% copper. These sulfides are then converted to impure copper, also called blister copper, via leaching, roasting or a bacterial process. In a final step, the impure copper is purified by electrolysis.[71]

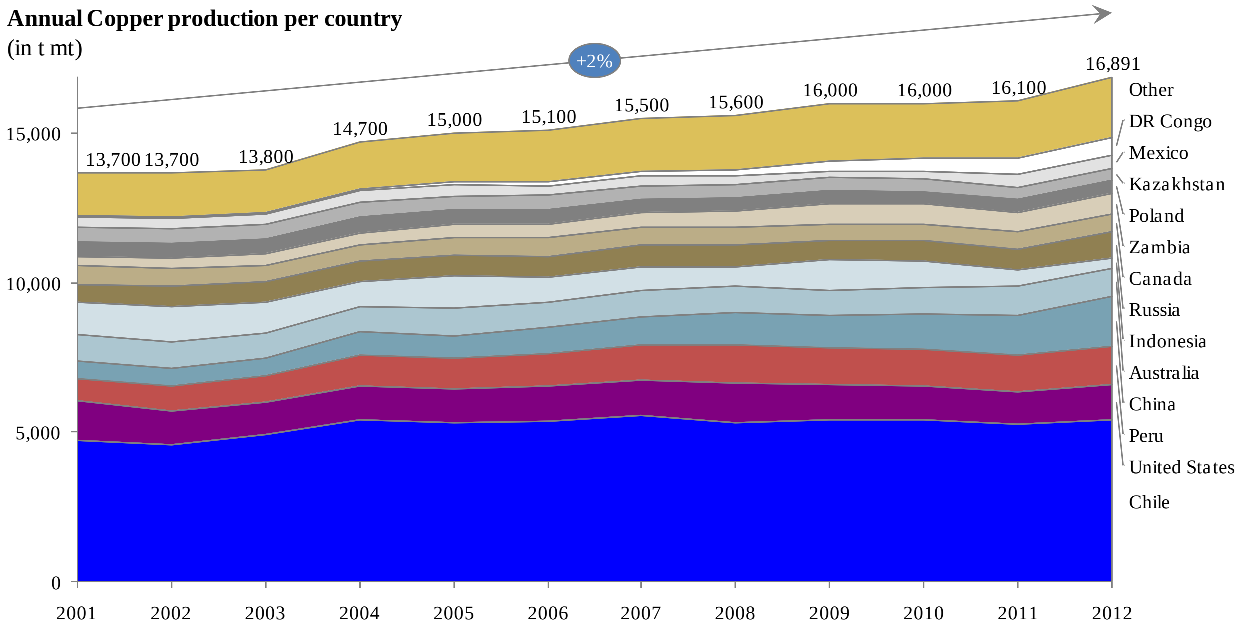

Figure 10 - Annual copper production per country from 2001 until 2012[72]

According to the USGS, Chile was by far the top copper producer with at least 30% market share of total primary copper production followed by the United States, China and Peru.[73]

With much of the copper being sourced in more developed countries, the transparency in the market is high compared to the other non-ferrous metal markets. Many producers are publicly traded companies that publish detailed information on production cost per produced metal and even per asset. Since copper is also one of the oldest industrial produced metals and it is the second largest non-ferrous metal market after aluminium the producer landscape is quite scattered with many mid-sized miners participating in the market.[74]

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[71] See Clements 2010.
[72] See U.S. Geological Survey 2002-2014.
[73] See Figure 10.
[74] See Figure 11.

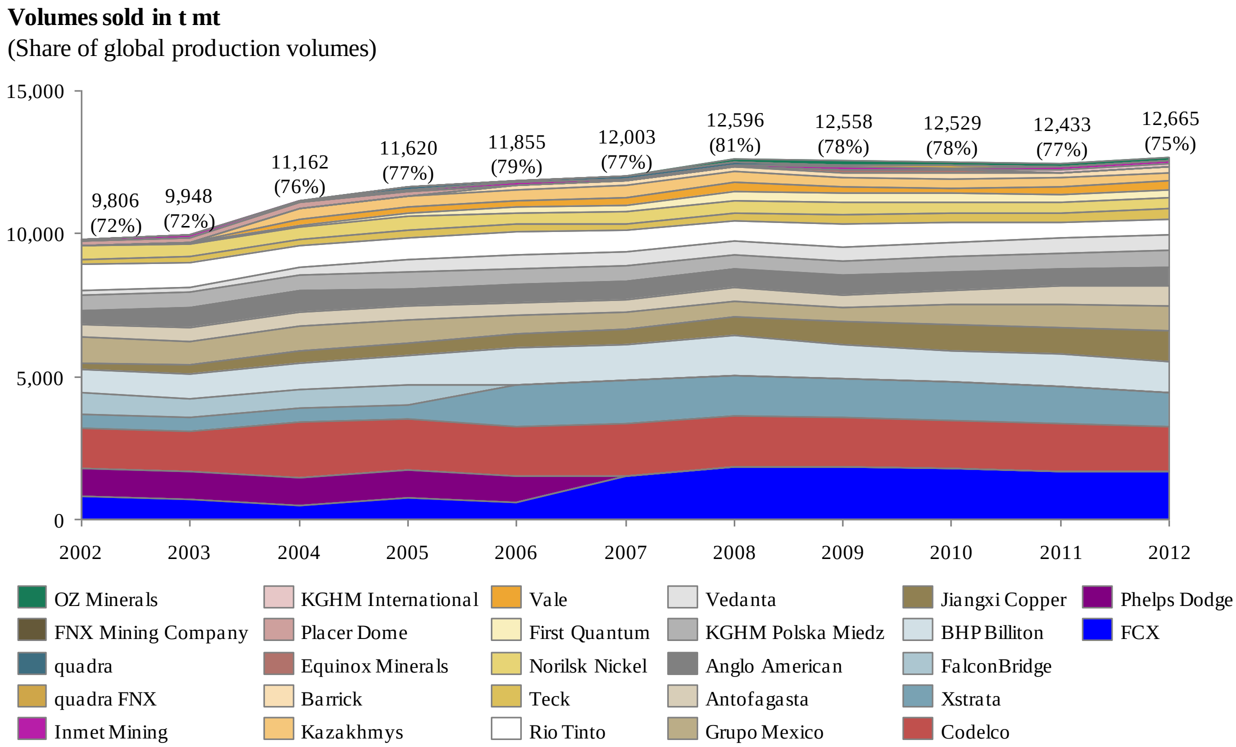

Figure 11 - Development of volume market share in the copper market[75]

From 2002 until 2012, there were various acquisitions:[76] Xstrata took over Falconbridge in 2006. In 2007, FCX drew equal by acquiring Phelps Dodge yielding two of the three largest copper producers worldwide from a current perspective. Further consolidations took place with Barrick acquiring first Placer Dome and subsequently Equinox Minerals. Quadra and quadra FNX merged with Inmet Mining in 2010 which again merged with KGHM International. Apart from these acquisitions, there were also some new global entrants to the market: driven by an ever increasing copper price[77], Kazakhmys, Vale and First Quantum pushed into the market in 2003. Given these new market participants the competition concentration in the market remained constant during the observation period albeit the initially described consolidations.

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75 Data were sourced from single company reports from 2002 to 2012 of mining companies that publish their production and sales volumes.

76 See Figure 11 and Figure 12.

77 From 1850 until 1950 the copper price stayed relatively stable below US$500/mt. From 1950 until 1990 copper has showed a constant CAGR of 4% leaving sufficient time to develop new assets, see U.S. Geological Survey 2013.

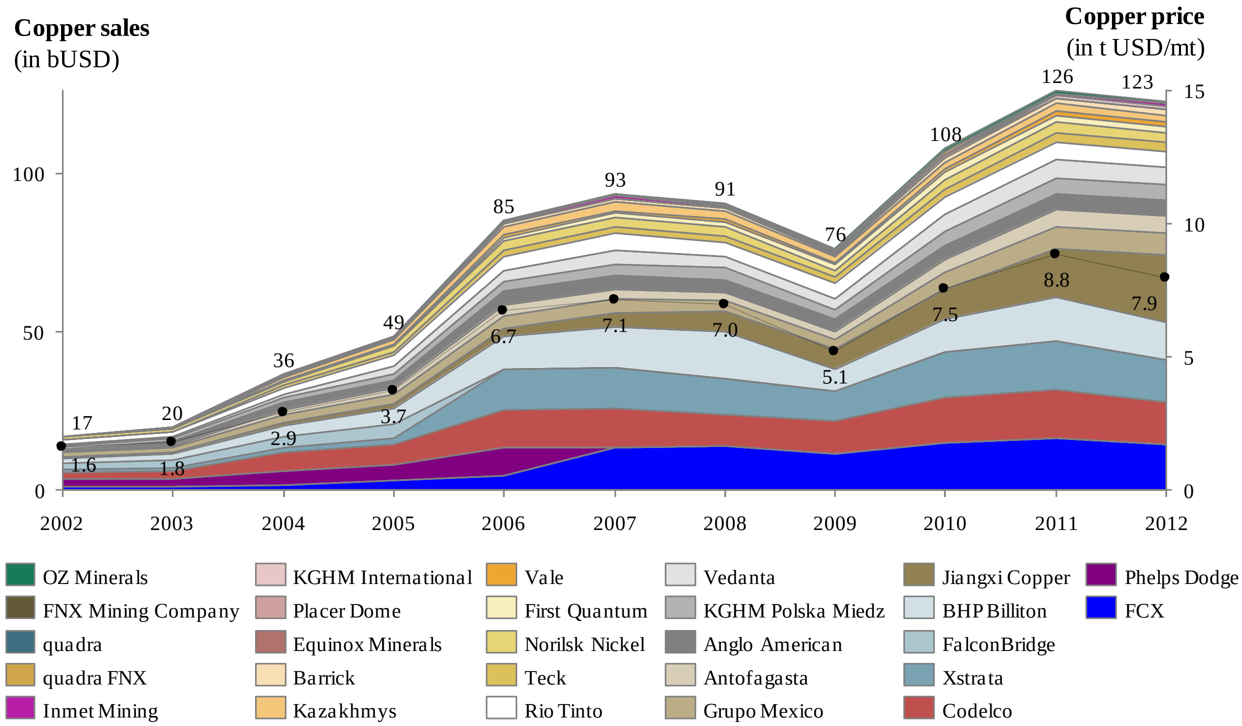

Figure 12 - Development of reported copper sales and prices from 2002 until 2012[78]

During the observation period the prospects of the copper market flourished: substitutes for copper in power cables and electrical equipment, its two biggest end markets were limited.[79] Taking into consideration the construction boom in Chinese infrastructure and housing, copper prices surged from 2002 until 2007 and even increased since the crisis in 2008.[80] Accordingly, sales in the copper market have increased 10-fold between 2002 and 2012. And even until the end of 2014, copper has been traded at prices between US$6500/mt and US$9000/mt: No surprise given that global refined copper consumption has exceeded refined copper production in every single year since 2010 according to The International Copper Study Group.[81] However, the slowdown in Chinese growth is leading to decreases in the metal's price which dropped to only US$5500/mt in the first quarter of 2015 and which will harm the sales and profitability of the spoiled market looking forward.

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78 Data were sourced from single company reports from 2002 to 2012 of mining companies that publish their production and sales volumes.

79 In high voltage cables aluminum currently constitutes the metal of choice, in other power cables the malleability and ductility of copper remains unbeaten.

80 See Figure 12.

81 See The International Copper Study Group 2015.

2.2.3 Manganese

Known land-based resources of manganese ore are large but irregularly distributed. About 80% of these resources are found in South Africa. However, most interestingly the worldwide oceans offer another rich source of manganese: 500 billion tons of manganese nodules are estimated to exist on the ocean floor. But attempts to find economically viable methods of harvesting these manganese nodules were abandoned in the 1970s.[82]

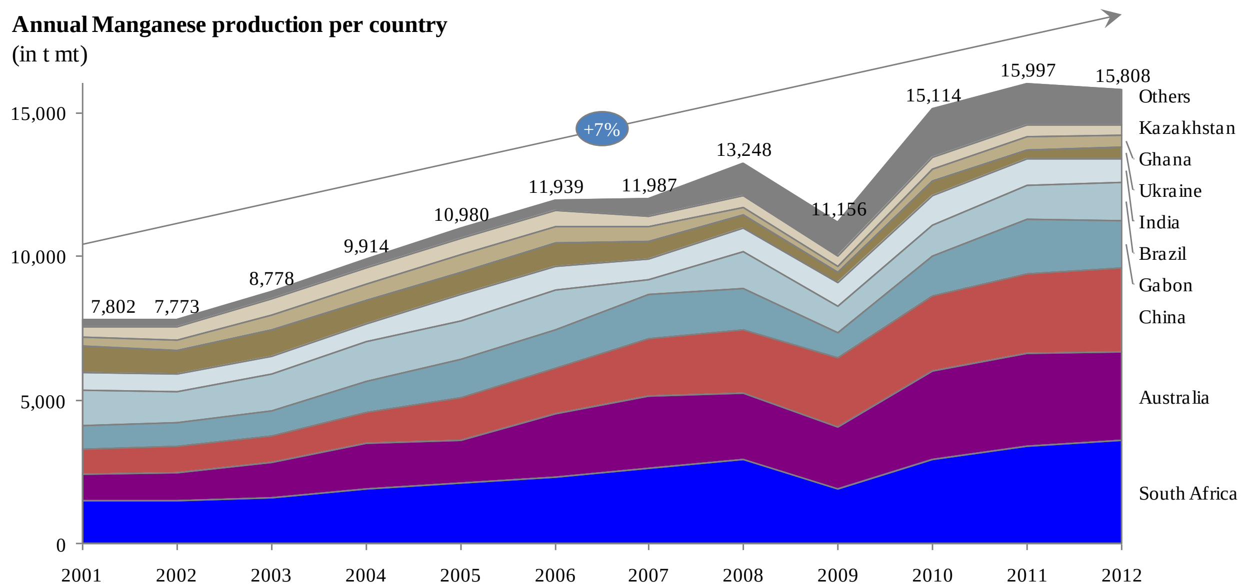

Figure 13 - Annual manganese production per country from 2001 until 2012[83]

The actual processing of manganese ore depends on the desired end product: Approximately 90% of manganese ore is processed to ferromanganese, as an essential ingredient for the steel production process by virtue of the manganese's sulfur-fixing, deoxidizing, and alloying properties. For this end product, the manganese ore is mixed with iron ore and carbon, and then reduced either in a blast furnace or in an electric arc furnace. The resulting ferromanganese then contains 60-80% manganese.[84] In its pure metal form however, manganese is primarily used for the production of

[82] See United Nations Ocean Economics and Technology Office 1979, pp.21.
[83] See U.S. Geological Survey 2002-2014.
[84] See Zhang, Cheng 2007, p.139.

iron-free alloys. The metal is obtained via leaching the manganese ore with sulfuric acid and subjecting it to an electro-winning process.[85]

As a key ingredient to steelmaking and hence essential to most construction, machinery, and transportation products manganese has no satisfactory substitute in its major end applications. In combination with China's ever growing thirst for exactly these products the manganese market has doubled with regards to its production volumes between 2001 and 2012.[86] Due to the low ore grade of available manganese reserves in China Chinese demand had to be satisfied from Australia and South Africa curbing the production in these countries.

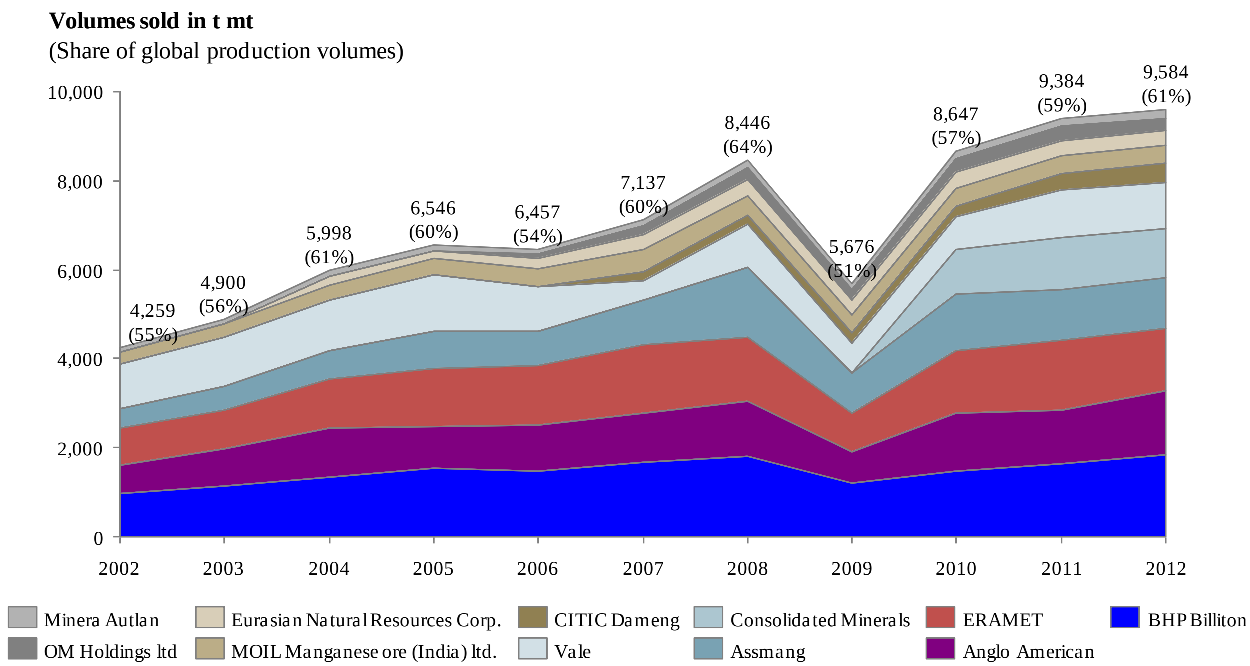

Figure 14 - Development of volume market share in the manganese market[87]

Unlike the mature and liquid copper market with index-priced contracts and transparency down to unit operating cost the manganese market is illiquid, much more concentrated and rather opaque.[88] Amongst the largest producers in this market are the Ukrainian Privat Group (approximately 12% market share in 2012 including its stake in OM Minerals) and the Russian Renova Group (7%),

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85 See Olsen et al. 2007, p.43.
86 See Figure 13.
87 Data were sourced from single company reports from 2002 to 2012 of mining companies that publish their production and sales volumes.
88 See 2.1.5.

which are both privately owned and thus do not publish any data. There are also several relevant state-owned or privately owned Chinese or Indian companies that exclusively supply the domestic market with low grade ore for steel production. Altogether, reporting in the manganese mining industry is still comparably scarce.

From the reported figures[89], we know that BHP Billiton and Anglo American control around 23% of the market with their joint venture Samancor that operates mines in Australia and South Africa. Assmang also operates in South Africa, whereas the French Eramet and the fast growing Chinese company Citic Dameng are based in Gabon.

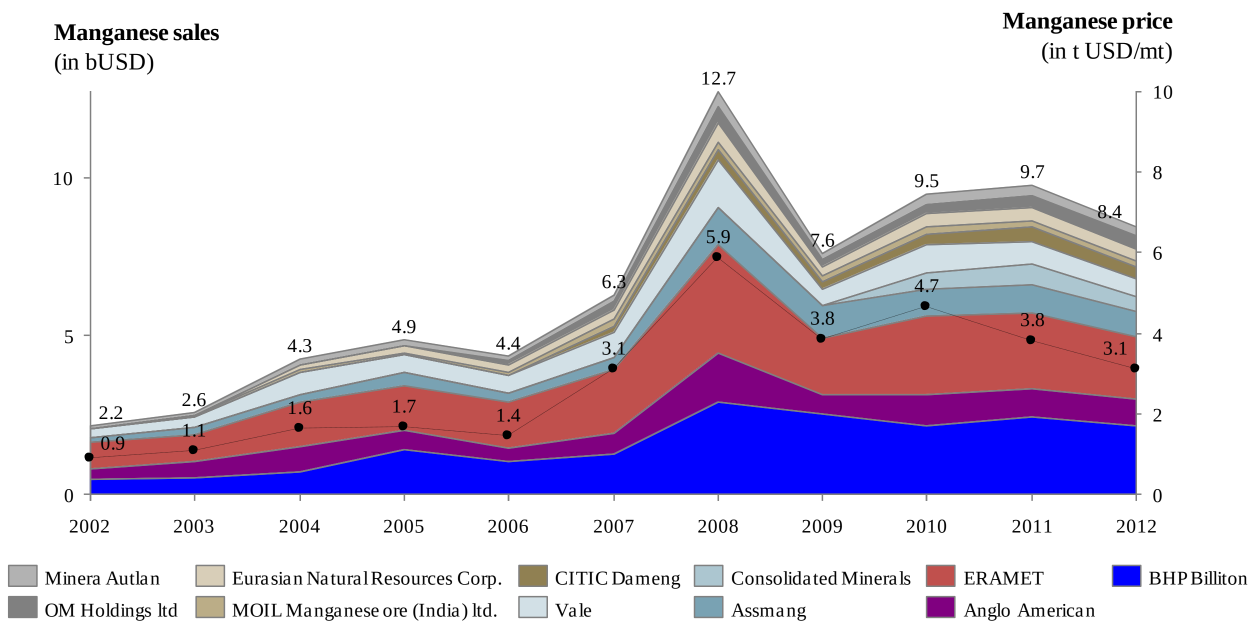

Figure 15 - Development of reported manganese sales and prices from 2002 until 2012[90]

With a lack for substitutes and this rather concentrated supply market structure manganese prices and its sales have more than tripled since 2002. And even as of 2015 US prices of Manganese vary around US$2900/mt similar to its pre-crisis levels in 2007.

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89 See Figure 14 and Figure 15.

90 Prices are average CIF prices in the United States and are published annually by the USGS. Sales data were sourced from single company reports from 2002 to 2012 of mining companies that publish their production and sales volumes.

2.2.4 Molybdenum

Unlike the other metals under research, molybdenum is mainly recovered as a byproduct of other metals, mainly copper: Due to the lack of a molybdenum price index before 2010[91] contracts could not be fixed to globally traded and accepted prices. Thus business cases for molybdenum assets contained a higher risk profile and were less often developed leading to nowadays 78% of molybdenum ore being extracted as a byproduct of copper production.[92] As a byproduct, mining company internal economics for the production differ substantially from the metals that are sourced as a principal metal: Whether or not the extraction of molybdenum is pursued or not depends on the opportunity cost of the mining company rather than the molybdenum's market price.

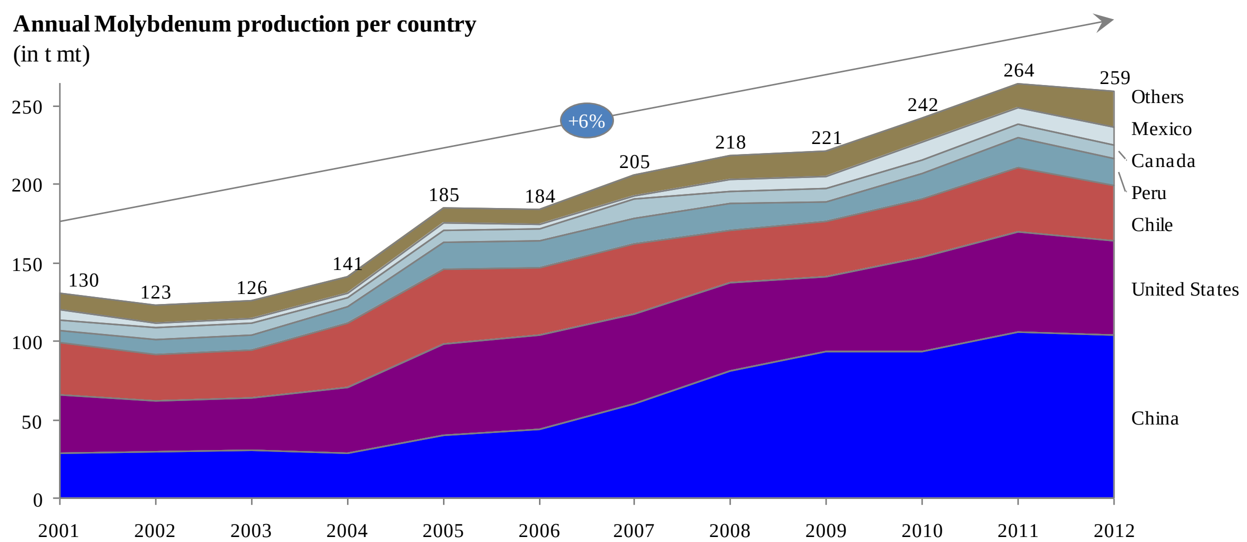

Figure 16 - Annual molybdenum production per country from 2001 until 2012[93]

With regards to the molybdenum production process it is similar to the copper production process: the crushed molybdenum ore is first concentrated by flotation and leaching to yield a molybdenum concentrate. The concentrate is then roasted to obtain molybdenum oxide. If the molybdenum is intended to serve as a compound of high strength low alloy steel the oxide is smelted with iron to yield ferromolybdenum. If preferred as a chemical compound the oxides are upgraded via

91 See 2.1.5.
92 See Table 44 - Share of molybdenum extracted as byproduct versus from dedicated assets.
93 See U.S. Geological Survey 2002-2014.

sublimation or wet chemical treatment and for metal usage even further processed by a two stage hydrogen reduction.[94]

Among the metal markets under research in this thesis, the molybdenum market is the smallest with regards to global production volumes.[95] In 2012, only 260kmt in metal content were produced in a very limited number of countries. Since molybdenum is an essential alloying agent in steel and is used as an important super-alloy with only few acceptable substitutes, the demand for molybdenum has surged in China between 2001 and 2012. This has led to an enormous boost in Chinese domestic molybdenum production from 28kmt in 2001 to more than 100kmt in 2012.[96] Since then, matters have not changed significantly: In 2014, global metal output was encore at 260kmt with China still contributing 40% of total metal content produced.[97]

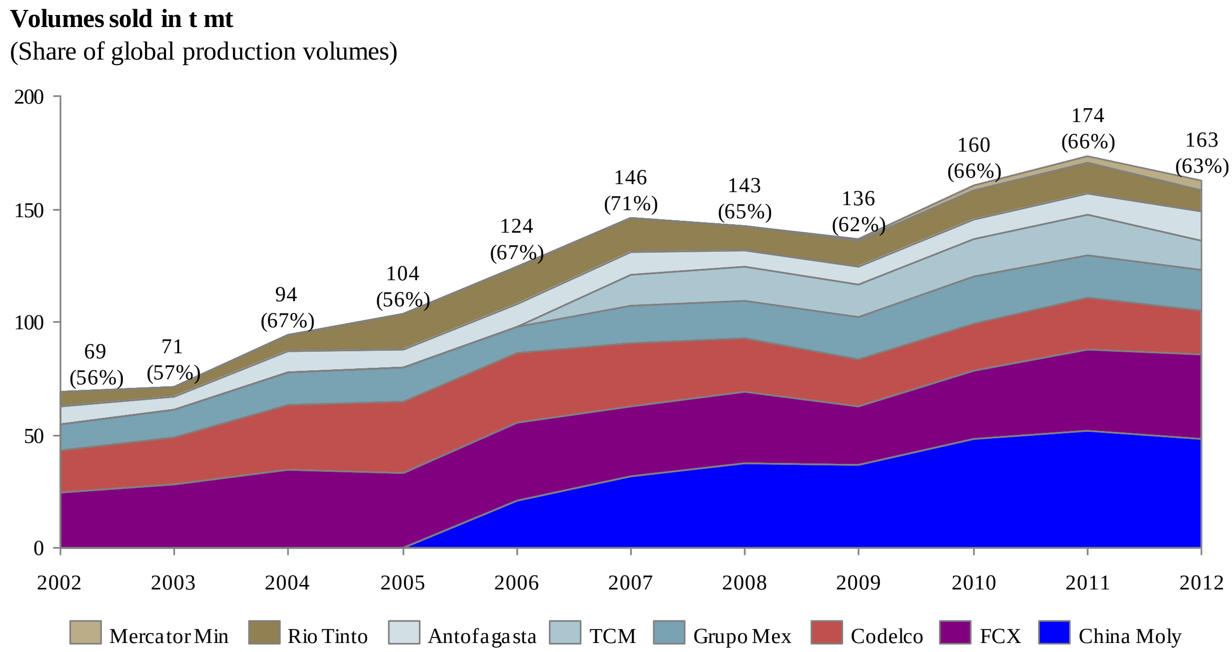

Figure 17 - Development of volume market share in the molybdenum market[98]

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[94] See Lide 1994, pp.721.
[95] Also see Table 1 - Global annual production volumes of most important non-ferrous metals.
[96] See Figure 16.
[97] See U.S. Geological Survey 2002-2014.
[98] Data were sourced from single company reports from 2002 to 2012 of mining companies that publish their production and sales volumes.

From all the traded metals at the London Metal Exchange[99] the molybdenum market is the most illiquid market. Transparency as well as the number of producers is still limited and embargos have hindered the establishment of global trade flows: In an attempt to foster the Chinese steel economy, Chinese export quotas were introduced that allowed a maximum export volume of 25kmt annually. These quotas encouraged Chinese producers to supply domestic steel mills instead of selling their products on the more liquid and lucrative global market[100] supporting the intransparency in the market.

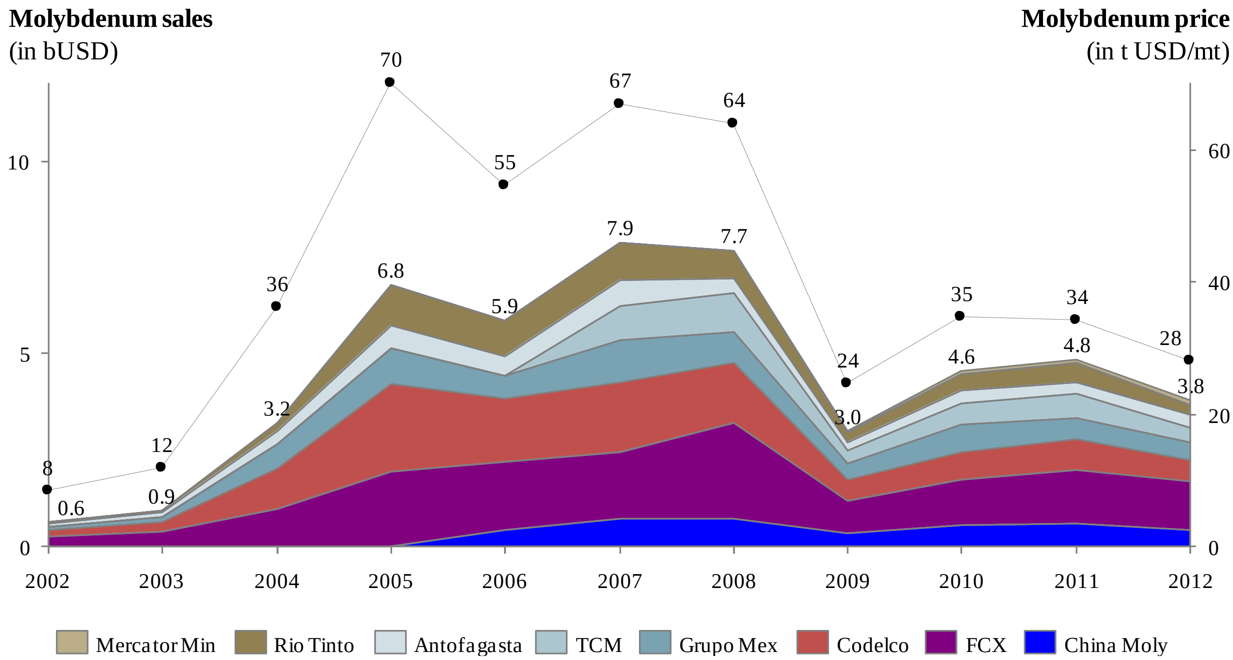

Figure 18 - Development of reported molybdenum sales and prices from 2002 until 2012[101]

Given this plus the already high concentration in the molybdenum supply market and its small size there were only three notable changes in the molybdenum production landscape:[102] Thompson Creek Metals (TCM) bought the junior miner Blue Pearl Mining Limited and thereby entered the market in 2007. In 2009, the Canadian miner Mercator Minerals entered the Molybdenum market

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99 In 2010 only, the London Metal Exchange (LME) started trading Molybdenum, see 2.1.5.
100 In 2015, these quotas have been cancelled due to a resolution of the World Trade Organization (WTO).
101 Prices are average CIF prices in the United States and are published annually by the USGS. Sales data were sourced from single company reports from 2002 to 2012 of mining companies that publish their production and sales volumes.
102 See Figure 17 and Figure 18.

extracting 5kmt as a byproduct of its copper mining operation. Last but not least, the biggest Chinese miner China Moly developed from being a domestic, privately owned company into a global player by going public in 2007 thus allowing insight into its financial and operational performance since 2006.

Unlike the price of the other metal markets under research, the molybdenum market did not peak in 2007 or 2008 but rather in 2005 due to short-term supply disruptions. Accordingly, sales of the different producers developed along with the price. What is worthwhile noticing are the differences in volume and value market shares indicating that achieved prices on the Chinese market were well below globally traded molybdenum prices.

Looking forward, the principal uses for molybdenum are expected to continue to be in chemicals and catalysts[103] and as an additive in steel manufacturing, most importantly alloy and stainless steel. With no practical alternatives to molybdenum in many of its catalytic applications, analysts expect global demand for catalysts to increase by more than 5% annually until 2016, resulting in demand for additional molybdenum of approximately 20kmt per year.[104] However, molybdenum consumption continues to be heavily dependent on the steel industry. With the lack of China's industrial growth, future demand will thus depend on rapid growth in other economies such as India.

2.2.5 Nickel

Nickel is produced either from oxidic (60%) or sulphidic (40%) ores. Dependent on the grade of the ore and on the other metals contained in the ore the production process varies. In general the nickel ore is first concentrated by flotation techniques then roasted to yield a Nickel matte which is further purified by chemical treatment or electro-winning.[105]

Since the beginning of the millennium the origin of nickel production has shifted from more expensive to less expensive countries with regards to operational expenditures. While in 2001, the three largest production countries were Russia (24%), Canada (15%) and Australia (15%), Russia

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[103] As a catalyst molybdenum will continue to play a vital role in the energy industry.
[104] See Duggan 2012.
[105] See Kerfoot 2000, pp.43.

nowadays only contributes 13%, Canada 10% and Australia 11%. Instead, Indonesia (15%) and the Philippines (16%) have caught up and are now the top two producers on a global scale.[106]

Although Nickel has been used for many industrial applications[107] and currencies since 1880 global nickel production volumes of 2000kmt are relatively small compared to production volumes of zinc (13,500kmt), copper (16,800kmt) or aluminium (45,900kmt). This can be explained by its high old scrap ratio of 70% and end of life recycle rate of 57% which allow many nickel consumers to utilize secondary instead of primary produced nickel.[108]

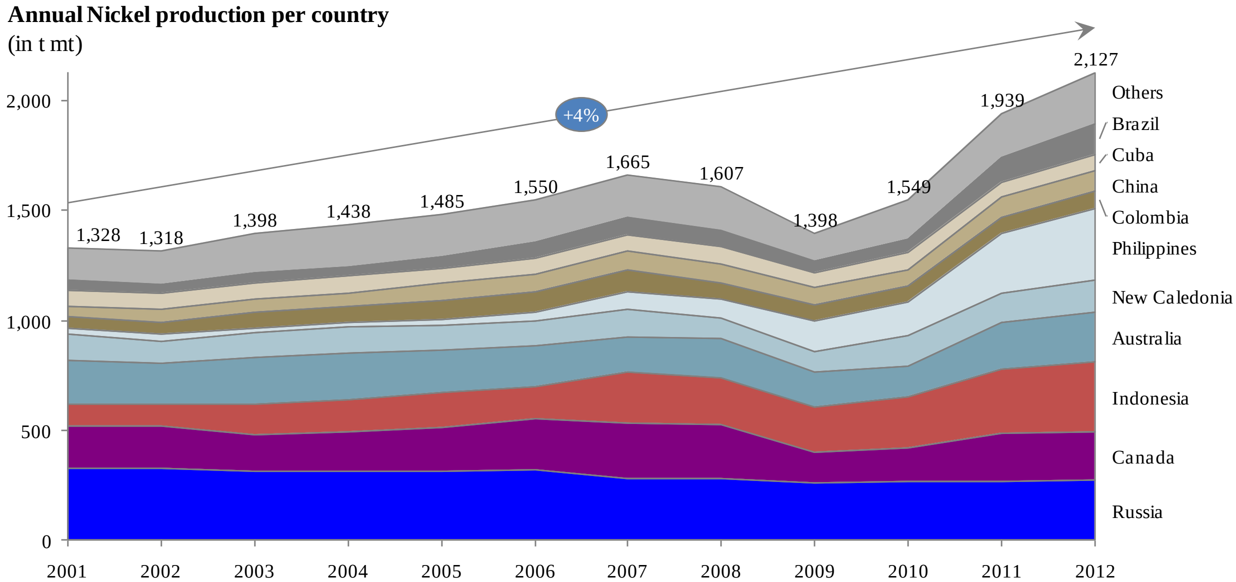

Figure 19 - Annual nickel production per country from 2001 until 2012[109]

Due to low growth in demand and the high availability of recycled Nickel metal and other substitutes in its main applications the growth of produced nickel volumes has been moderate in the observed period. As a result, competition was high which led to the takeover of Falcando by Xstrata in 2005 and Inco by Vale in 2006.[110] Both were mid-sized mining companies with focus

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106 See Figure 19.
107 The main property for which it is sought for is its corrosion resistance in stainless steel and superalloys. Stainless steel is required for all kinds of consumer products, in the construction industry and for infrastructure projects. Nevertheless, it is the aerospace industry in particular that consumes the majority of nickel-based superalloys.
108 Also see 2.1.2.
109 See U.S. Geological Survey 2002-2014.
110 See Figure 20 and Figure 21.

on one or two metals and saw little perspective in the competitive Nickel market without the backup and cash of a larger and more diversified mining company.

Just after the financial crisis in 2008 there were several new market entries of producers introducing additional capacity that was, as a consequence of the economic downturn, not met by large demand: Western Areas started to extract nickel in Western Australia. The Nickel Asia Corporation had developed its assets in the Philippines to refine the extracted nickel ore to nickel metal. Lastly, the Brazilian conglomerate Votorantim, which is just a minor nickel producer, started reporting dedicated nickel performance figure after internal restructuring in 2009.

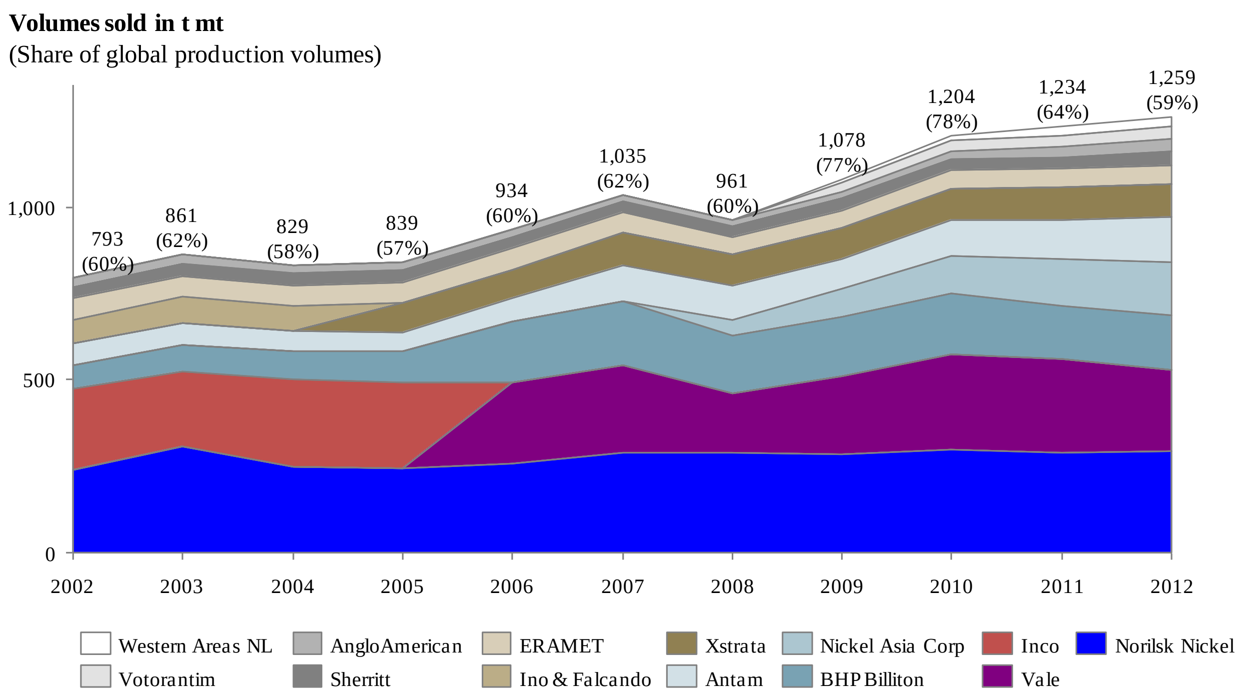

Figure 20 - Development of volume market share in the nickel market[111]

Similar to the other non-ferrous metals under research, nickel prices surged from 2002 to 2007.[112] The increase in value was of such an extent that it even endangered the currency of the US: in 2007, the metal contained in the US nickel coin was worth 180% of the actual face value making it an

[111] Data were sourced from single company reports from 2002 to 2012 of mining companies that publish their production and sales volumes.

[112] See Figure 21.

attractive target for melting. In anticipation of this practice, the United States Mint implemented a resolution in 2006 which criminalized the melting and export of cents and nickels.[113]

In 2009 however, nickel prices dropped to 2005 levels due to the global crisis and excess capacity online. Sales figures in the nickel market developed accordingly. Based on the difference between volume and sales market shares of Antam and Nickel Asia Corp which operate assets in Indonesia and the Philippines respectively[114] we can draw the conclusion that metal quality and prices achieved in Asia were most likely lower than world market prices.

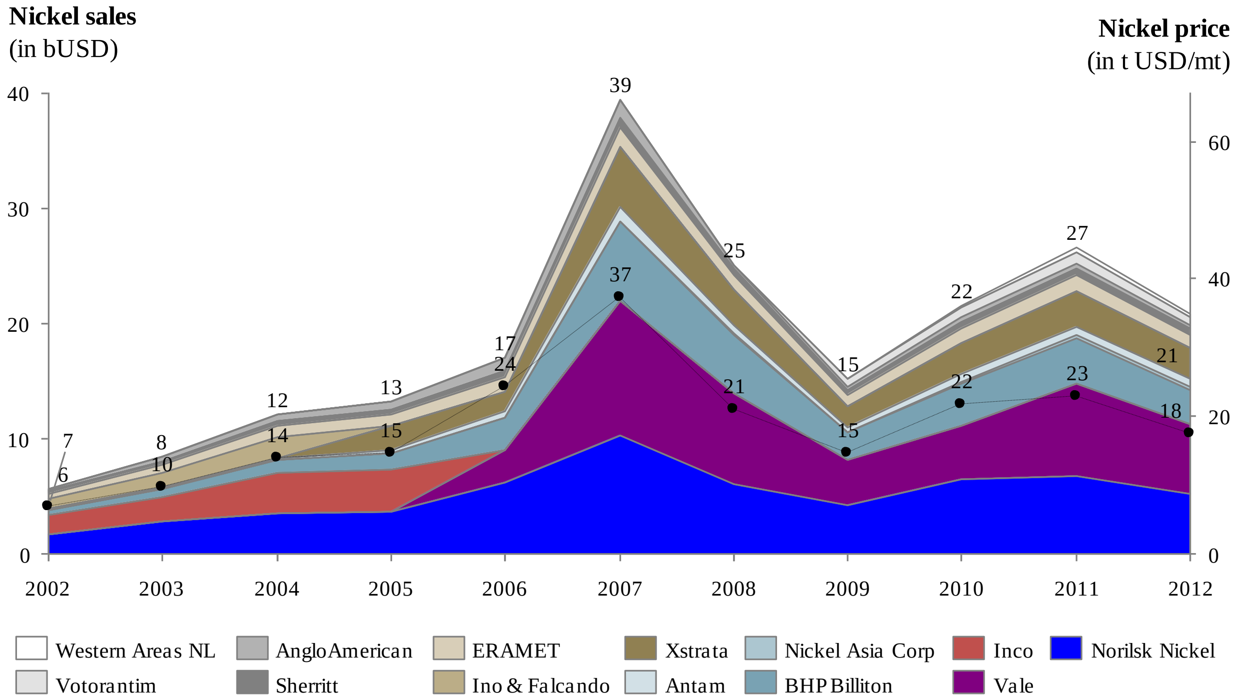

Figure 21 - Development of reported nickel sales and prices from 2002 until 2012[115]

In the beginning of 2015, global nickel prices have still not recovered, the metal is traded at around US$15,000/kmt on the LME. Despite these weak prices and an oversupply of the metal, mining companies continue to bring on new nickel projects in anticipation of further growth in the global

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113 See United States Mint 12/14/2006.
114 Comparing market shares in Figure 20 and Figure 21.
115 Prices are average CIF prices in the United States and are published annually by the USGS. Sales data were sourced from single company reports from 2002 to 2012 of mining companies that publish their production and sales volumes.

economy.[116] Given that global production of austenitic stainless steel continues to increase and demand for nickel-based super-alloys in the aerospace and power-generation sectors is also expected to escalate until 2020 this might be the right bet.[117]

2.2.6 Titanium dioxide

Titanium is mainly extracted from two types of minerals: ilmenite and rutile. Being the more abundant and cheaper source ilmenite is utilized for 90% of global titanium production. However, before ilmenite can be further processed it has to be converted to synthetic rutile by removing iron. Once obtained, the synthetic rutile as well as rutile itself is purified via the chloride process to give pure titanium dioxide.[118]

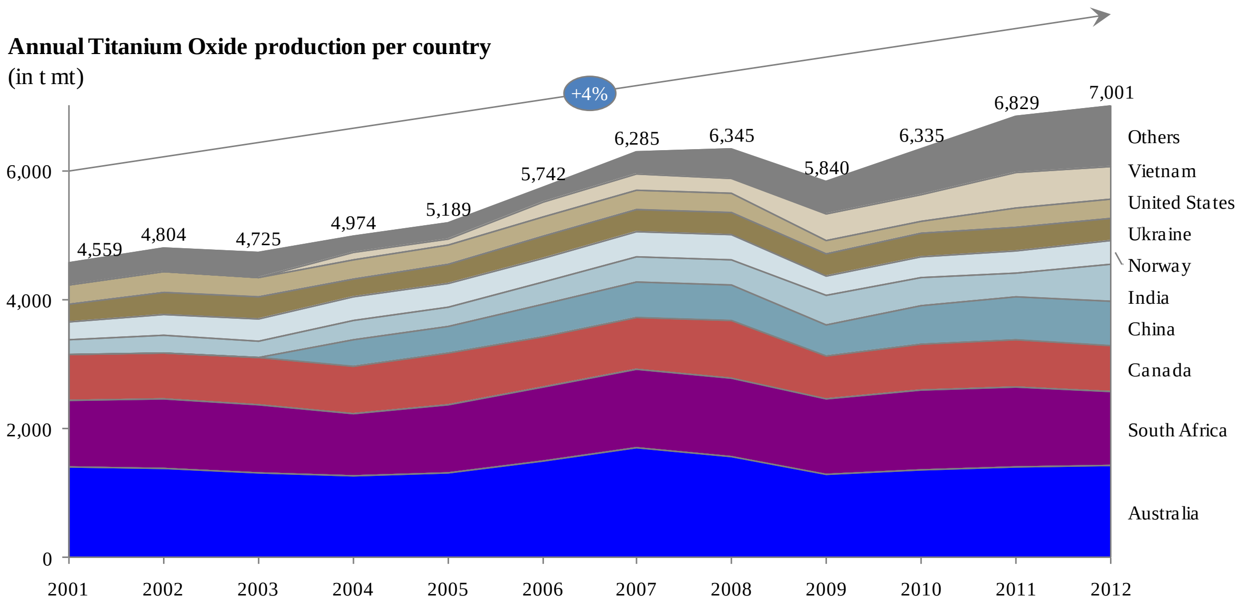

Figure 22 - Annual titanium oxide production per country from 2001 until 2012[119]

Pure titanium dioxide is of high economic use as an important compound for paints and consumer products such as toothpaste and sunscreen and represents already around 95% of global titanium

[116] See U.S. Geological Survey 2002-2014.
[117] This is largely driven by increasing demand for new aircrafts with more fuel efficient engines (The Boing Co. 2012).
[118] See Winkler 2003, pp.39.
[119] See U.S. Geological Survey 2002-2014.

demand. The remaining 5% are further processed to yield the high strength titanium metal in three major steps: first the reduction of titanium dioxide to titanium sponge, a porous form; then the melting of the sponge to form an ingot and finally the processing of the ingot to general mill products such as billets, bars, plates or sheets.[120]

Much of the titanium mined today is from heavy mineral deposits, e.g. ilmenite, rutile, or zircon deposits. These deposits are found along many continental margins including the eastern coasts of North and South America, the southern coast of Africa, the coasts of India, and along the east and west coasts of Australia. In 2012, about 20% of the world's production of titanium content in minerals came from Australia, 17% from South Africa and 10% from Canada.[121]

As mentioned in 2.1.3 approximately 95% of titanium is consumed in the form of titanium dioxide (TiO_2), a white pigment in paints, paper, and plastics. Since this dioxide is the main ingredient to produce titanium metal few titanium dioxide producers focus solely on one end market. Instead they sell the dioxide to the end use that offers the highest return on the sold volumes. Thus, we analyze the titanium dioxide market instead of trying to capture only the titanium metal smelters for the further analysis in this thesis.

In general, the titanium dioxide production landscape is comparably concentrated with only eight global players that report their production and performance figures. Heavily depending on the consumer products such as paint, toothpaste, sunscreen or flights demand for titanium dioxide decreased in 2007 due to the financial crisis. As a consequence, more domestic and cheaper producers pushed into the market in China, Vietnam and India as for example Kenmare.[122] Other changes in the titanium production landscape were scarce between 2002 and 2012. In 2007, AngloAmerican had to divest its titanium dioxide business to the black economic empowerment company Exxaro Resources as compensation action after the apartheid regime. Apart from AngloAmerican's titanium assets, Exxaro also took over Ticor a minor titanium dioxide producer in South Africa. However, with less demand for titanium dioxide and cheaper producers from China, Vietnam and India Exxaro did not succeed to increase its market share.

[120] See Donachie 1988, p.3.
[121] See Figure 22.
[122] This in turn also decreased data availability in the market, see Figure 23.

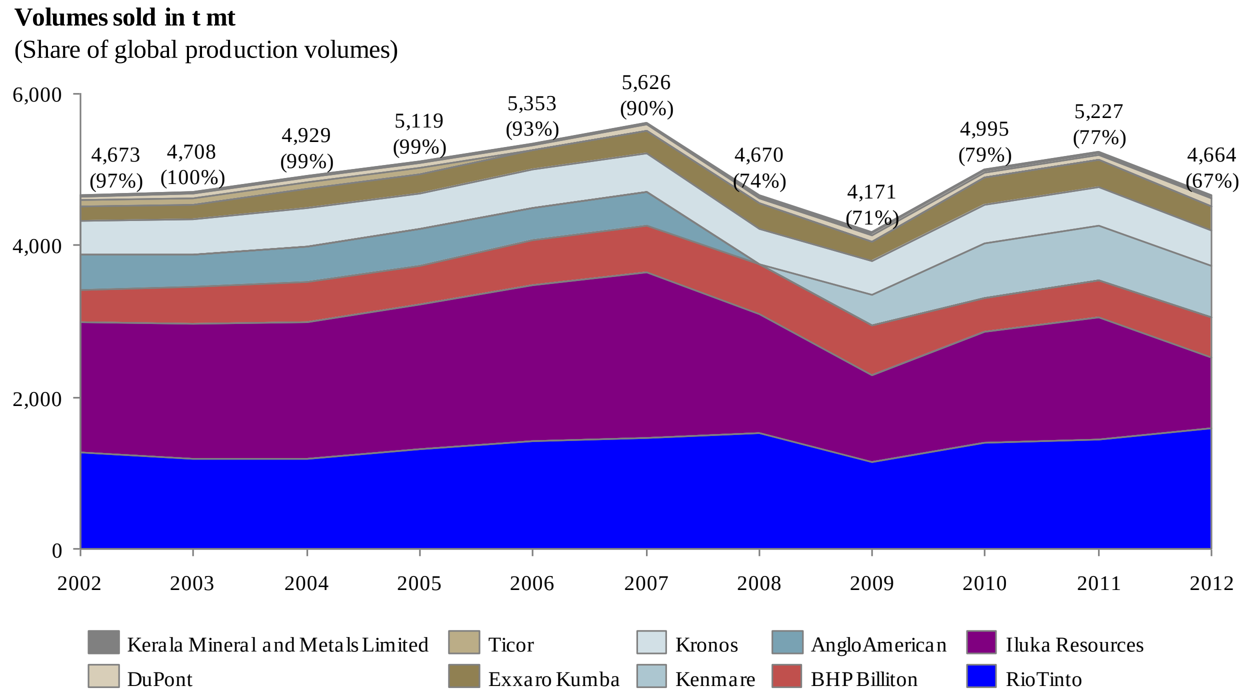

Figure 23 - Development of volume market share in the titanium oxide market[123]

When we consider the development of sales in the titanium dioxide industry we can observe a significant shift from volume market share to revenue market share.[124] This is due to the highly varying end markets observed in the titanium industry. Whereas producers such as DuPont and Kronos target titanium dioxide consumers that require highly refined titanium dioxide such as the chemical industry, Rio Tinto and BHP Billiton rather sell to consumers that are satisfied with more impure versions of the dioxide such as some of the steel producers.[125]

What is also remarkable in the titanium industry is the price development. Unlike the prices of the other metals under research the titanium price did not recover after the crisis. Again this can be explained by the growing titanium dioxide supply from cheaper producers from 2007 onwards.

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[123] Data were sourced from single company reports from 2002 to 2012 of mining companies that publish their production and sales volumes.

[124] See Figure 23 and Figure 24.

[125] The chemical specialist DuPont is a great example to demonstrate the differences in value versus volumes in the titanium dioxide market: While DuPont holds an average market share of 1% with regards to volumes; it maintains an average market share of 32% when measured in revenues during the observation period.

Nevertheless, many global players succeeded to increase their sales figures although the global sponge price declined: Since the end markets of the titanium dioxide and alongside the respective prices that can be achieved differ significantly, producers can optimize their revenues by shifting sales volumes from low priced end markets to more lucrative customers.

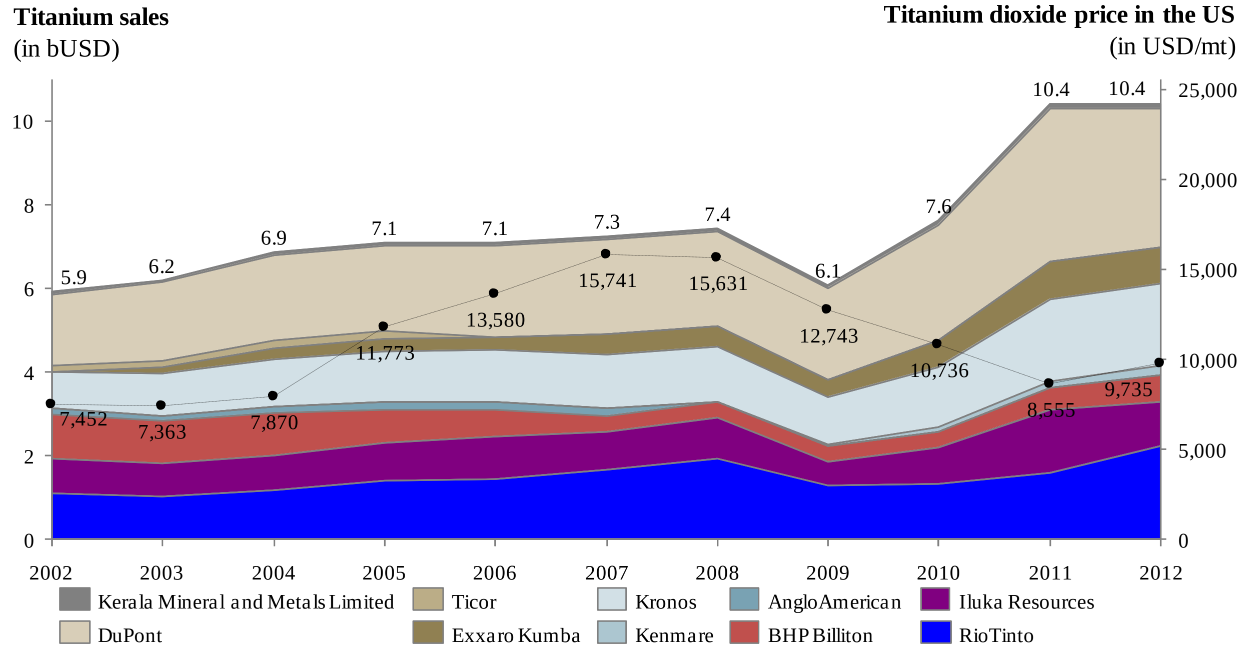

Figure 24 - Development of reported titanium oxide sales and prices from 2002 until 2012[126]

In 2014, global production of titanium sponge was estimated to have decreased by 8% owing to overcapacity and increased inventories compared to 2013.[127] Looking forward demand for titanium minerals is expected to trend with the production of paint, paper, plastics and the aerospace industry which yet again is heavily dependent on global economic growth.[128]

2.2.7 Zinc

Worldwide, 95% of the zinc is mined from sulfidic ore deposits in which the sulfides of copper, lead and iron are often mixed. As for copper and molybdenum zinc is produced in 3 major steps:

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[126] Prices are average CIF prices in the United States and are published annually by the USGS. Sales data were sourced from single company reports from 2002 to 2012 of mining companies that publish their production and sales volumes.

[127] See U.S. Geological Survey 2002-2014.

[128] See Hickton 2013, p.3.

After grinding the ore, the ore is concentrated to 50% zinc content by froth flotation. Then, roasting converts the zinc sulfide to zinc oxide. Finally the zinc oxide is purified to metal via electro-winning.[129] Regarding its origin of production, zinc is mined throughout the world, the main mining areas in 2012 being China (36%), Australia (11%) and Peru (9%).[130]

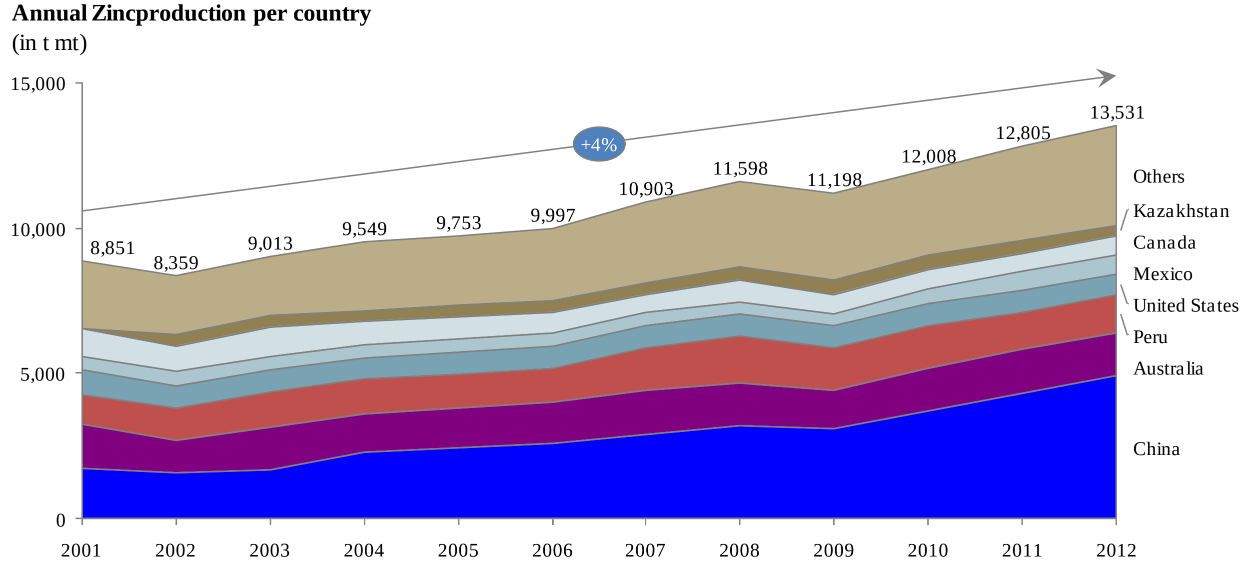

Figure 25 - Annual zinc production per country from 2001 until 2012[131]

In total, there were 14 reporting zinc producers for the period under research, however with many changes in the course of these 11 years:[132]

Noranda and Falconbridge merged during the course of 2005 and were subsequently acquired by Xstrata in 2006. In 2007, Oxiana and Zinifex merged to form OZ Minerals which again was taken over by Minerals and Metals Group in 2008.[133] Following the financial crisis 2007 AngloAmerican assessed all of its operations to identify its zinc assets as non-core business. It thus sold these assets to Vedanta in 2010. In the same year, Nyrstar took over Breakwater Resources and along with the necessary restructuring started reporting mining specific production statistics and performance indicators. Last but not least, the commodity trading giant Glencore decided to go public in 2011 and hence allowed insights in its production and financial statistics from 2011 onwards.

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129 See Schwab et al. 2015, pp.719.
130 See Figure 25.
131 See U.S. Geological Survey 2002-2014.
132 See Figure 26 and Figure 27.
133 As the Minerals and Metals Group is a private company no reported figures are available from 2009 onwards.

Zinc sales of the different producers developed according to the global zinc price which peaked during 2007 and dropped to US$1700/mt due to the economic downturn in 2008 and 2009.[134] The boost of total zinc market sales in 2011 primarily originates from Glencore reporting its commodity specific production and performance figures for the first time that year.

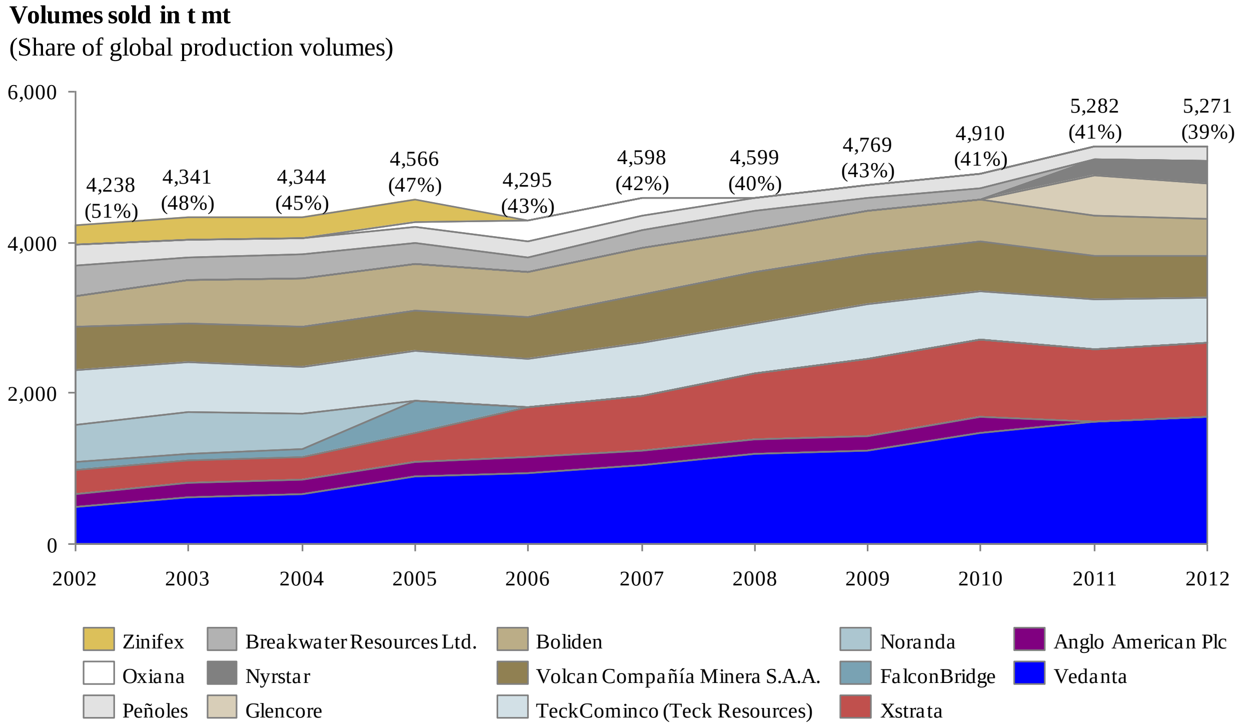

Figure 26 - Development of volume market share in the zinc market[135]

From 2012 to 2014, global zinc demand rose by 5% annually while supply remained constant according to the International Lead and Zinc Study Group. The increase in demand was primarily a consequence of a reported rise in Chinese apparent demand of 10.5%. Usage in the United States however only increased by 3.9% and declined in Europe by 1.6%.[136]

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134 See Figure 27.

135 Data were sourced from single company reports from 2002 to 2012 of mining companies that publish their production and sales volumes.

136 See International Lead & Zinc Study Group 2015.

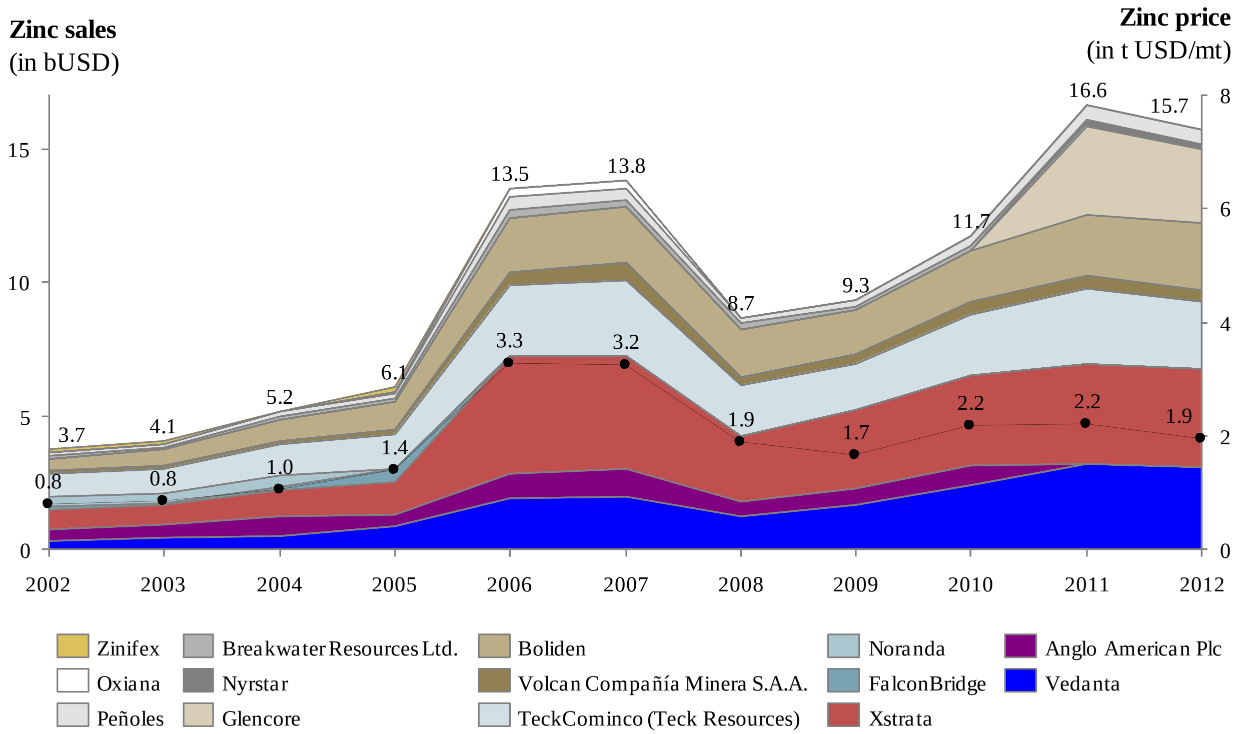

Figure 27 - Development of reported zinc sales and prices from 2002 until 2012[137]

Since China's growth is slowing and supply is not forecast to change drastically in the coming years, the future demand for zinc, its price and the performance of its producers will depend on how strongly India and other developing countries can take over China's role as a global growth driver.

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[137] Prices are average CIF prices in the United States and are published annually by the USGS. Sales data were sourced from single company reports from 2002 to 2012 of mining companies that publish their production and sales volumes.

3 Literature Review and deduction of hypotheses

In this chapter, we give an overview on the research that has so far been conducted on economics and company performance in the non-ferrous metal markets. Based on this, we deduct the hypotheses that lay the foundation for the quantitative analyses in this dissertation.

3.1 Overview on research

The overview on research is split in four parts: At first, we summarize the theories as well as analyses regarding the general economics of mining and metal markets. Then, we give an overview on the rather small corpus of research on profitability determinants in the mining industry. Following that, we discuss the deficits of company performance analyses in the mining industry. At last, we briefly review the most common findings in the broad field of company performance research to be able to leverage these more general findings to the mining market and mining company analyses for the formulation of our hypotheses in section 3.2.

3.1.1 Research on general economics in mining and metal markets

Due to the small amount of research that has been conducted on company performance in the mining and metal industry so far we widen the perspective to give a broader review on research regarding the economics in mining and metal markets: First, we elaborate how research evolved around mining and metals in the first place. These first analyses focus on the theoretical fundamentals of commodity price development and along with it the industry's profitability. Then, the current views on the basic dynamics which influence the metal price as one of the fundamental levers for profitability a summarized.

Theories regarding mining of non-renewable resources

Interest in commodity markets, especially in non-renewable natural resources was first raised during the conversation movement in the late nineteenth and early twentieth century. With rising resource prices the movement was concerned about the possible overexploitation of non-renewable natural resources and called for regulation and better understanding. Harold Hotelling responded to this call in 1931 by scrutinizing a miner's behavior and explaining the development of commodity prices by returns in economic markets.[138]

According to Hotelling's rule a mine owner's decision on his production volumes is determined by two factors, the market interest rates and the expected accretion of resources: If market interest rates are higher than the expected accretion of resources, output will be increased to invest the resulting earnings for the market interest rate. If the expected resource accretion is higher than market interest rates the resources will not be sold in anticipation of a future value increase higher than the market's interest rate. In consequence to obtain equilibrium and a steady production in a competitive market with a fixed and known stock of homogenous resources the rent per ton has to grow over time at a rate equal to the rate of interest. In the light of Hotelling's rule, the commodity's price and the miner's profitability is thus decided deterministically only by the change in market interest rates on an industry wide scale. [139]

However, despite its widespread and long-lasting influence empirical research has not been able to validate Hotelling's theory: The propagated relationship between price and interest rates, leading to exponentially increasing market prices over time, could be confirmed neither in time series testing[140] nor with more complex modeling[141]. So far, this has been explained by the lack of analysis on long time horizons in which those relations are said to evolve. In the short or medium term, other factors such as changes in mineral extraction techniques[142], in capital requirements and delineating ore bodies[143] plus market fluctuations and uncertainties[144] seem to disturb Hotelling's equilibrium depending on the study. These additional factors are largely environmental with less emphasis put on management decisions. Nevertheless, Hotelling's theory is still seen as valid because it "is a consequence of any model which assumes that mining companies think not just about the present but also about the future and that they wish to maximize the value of their assets".[145]

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[138] See Gaudet 2007, p.1034.
[139] See Hotelling 1931, p. 170.
[140] See Livernois 2009, p.37.
[141] See Halvorsen, Smith 1984.
[142] See Cairns 1986, p.97.
[143] See Livernois 2009, p.38.
[144] See Slade 1988, p.203.
[145] See Livernois 2009, p.38.

Although Hotelling's rule for non-renewable resources could not be confirmed empirically the dynamics of non-renewable resource markets remain in the center of public interest: The super-cycle in metal markets that caused metal prices and miners' profitability to dramatically increase from 2002 until 2008 followed by a drastic drop in both, prices and profitability, made consumers, producers, investors, managers and regulators worry and called for better understanding of the underlying fundamentals of the these markets.

Metal prices

In 2010, Humphreys published a review on the great metals boom explaining the development of metal prices during the supercycle from 2001 until 2010.[146] As with most price determinants these can be decomposed into supply and demand determinants that together lead to rising or falling metal prices:

- *Supply:* The shortage in metal supply until 2008 can be traced back to the dot-com bubble peaking in 2001. During the dot-com days investors were seeking assets in the software and service industries. No one was interested to fund the archaic and low profitability sector of mineral and metal production.[147] To put this in figures: By 2001, the combined value of all of the world's quoted mining and metals companies had fallen to around $300 billion, equivalent to only 1% of the value of global equity markets or around two-thirds the value of Microsoft. This lack of interest and investment led to long-term underinvestment in new mining capacity planned to come online.[148]
- *Demand:* This inadequate situation was hit by a sudden surge in demand driven by two major underlying factors: High overall growth in global demand, driven by the materials and metals intensive growth in an urbanizing and industrializing China and the new investors' euphoria pushing demand in metals to unexplainable heights.

  Between 2002 and 2007 the global economy enjoyed an average growth rate of 4.8% a year which was the longest sustained period of strong economic growth since 1970. With China's demand for steel growing at 16%, for aluminium at 20%, for copper at 13% and

[146] See Humphreys 2010.
[147] See Crowson 2001, p.34.
[148] See Humphreys 2010, p.2.

> for nickel at 23% a year global demand for metals was skyrocketing between 2002 and 2007. Investors wanted to benefit from this upward trend when observing the Chinese growth trajectory and ever more positive analyst reports. However, without involvement in physical trading the only possibility for investors to participate in these promising commodity markets were either dedicated commodity indices or newly developed Exchange Traded Funds (ETFs). But with these financial vehicles investors were only able to go long and were thus accelerating the upwards trend in demand.[149]

When the financial crisis hit the commodity markets in 2008 metal prices plummeted driven by the lack of demand in physical but also financial terms. Until today metal demand has not recovered to 2008 levels and in the light of metal price developments in the beginning of 2015 it remains rather low. However, Humphrey also notes that the supercycle has led to a structural shift of power from the manufacturing industries towards the mineral extracting industry. If this has led to a structural increase in profitability in the mining industry remains to be analyzed.

3.1.2 Research on company performance in non-ferrous metal markets

Based on the research on the general economics in the mining industry, we now give an overview on the limited amount of research on the mining industry's profitability determinants as of today. First, we summarize the research conducted on the overall non-ferrous metal market. Then, we conclude this section with a research summary on determinants in the single seven metal markets under research in order to subsequently allow for differentiated hypotheses for the single metal market analyses.

Determinants of profitability in the overall non-ferrous metal market

So far, the profitability across metal industries has only been subject to very few research papers and only one study aims to analyze profitability determinants in the mining industry specifically:

In 1972, Beasley and Pfleiderer discuss the profitability of a single mining venture based on a case study.[150] Then, Crowson's essay "Mining Industry Profitability?" from 2001 qualitatively observes

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[149] See Humphreys 2010, pp.6-7.
[150] See Beasley, Pfleider 1972.

the low profitability of the mining industry in the two decades before 2001 and promotes possible ways of remedying this.[151] On a different note, Slade quantitatively compares four different models of firm profitability based on aggregate mining company data.[152] In 2010, Humphreys qualitatively describes the great metals' boom in Resources Policy[153] and in 2011, Garcia and Camus discuss "Value creation in the Resource Business" by qualitatively comparing the non-ferrous metals with the oil industry.[154] At last, Ericsson analyzes the corporate actors in the global mining industry to identify the main global challenges relating to access to resources for the European Commission in 2012.[155]

All of these studies have scrutinized the impact of particular profitability determinants rather than holistically scrutinizing determinants of profitability in the non-ferrous metal industry. Summarizing these papers we find five so far analyzed and relevant determinants of profitability in the mining of non-ferrous metal markets:

1. *Prices:* As noted earlier, metal prices have fluctuated extremely in the first decade of the new millennium. Broadly accepted, they are said to be a major driver of the mining industry's profitability. However, Crowson appeals to the mining industry to consider low metal prices not as a market given external factor but rather as the consequence of poor planning by the metal suppliers themselves. Instead of complaining about decreases in demand and thus falling prices miners should utilize more sophisticated demand and supply models when investigating new capacity extensions.[156]
2. *Market concentration:* Given the above explained rise in metal prices many miners accumulated significant amounts of free cash flow which had to be re-invested. Hence, many miners were pursuing mergers or acquisitions, either to diversify their commodity portfolio or to gain greater market power in their existing commodity portfolio.[157] As a consequence, miners were growing tremendously in total size: Just to mention the

151 See Crowson 2001.
152 See Slade 2004.
153 See Humphreys 2010.
154 See Garcia, Camus 2011.
155 See Ericsson 2012.
156 See Crowson 2001, p.40.
157 See Ericsson 2012, p.3.

heavyweights in the industry: From 2002 until 2012, AngloAmerican grew its total assets by 240%, BHP by 330%, RioTinto by 430%, Xstrata by 1500% and Vale even by 1550%. When concluding his qualitative paper on the mining industry's profitability Crowson highlights though that "The experiences of some highly concentrated sectors suggests that their record is not much better than those of the more competitive markets".[158] The only empirical profitability analysis of the non-ferrous metals market was conducted by Slade in "Competing Models of Firm Profitability" in 2004. In this paper, Slade tests four different profitability models, namely Hotelling's rule, the Capital Asset Pricing Model (CAPM) and two models from Industrial Organization: one that utilizes market concentration as the only explanatory variable for a miner's profitability which she calls the Structure-Conduct-Performance-Model (SCP-Model), the other that utilizes market concentration and market share as the only two explanatory variables which she calls the Firm Efficiency Model.[159] Due to the lack of more detailed data, Slade utilizes The Raw Materials Group (RMG) database on integrated miners which contains a broad set of production data yet only limited information on the financial performance of the miner's single business units, i.e. on the single non-ferrous metals. Thus, Slade has to analyze non-ferrous metal producers on a corporate rather than a commodity specific level which puts the clear demarcation of market boundaries and thus the underlying calculations of producer profitability, market share and market concentration under question.[160] Nevertheless, Slade finds a positive correlation between market concentration and market profitability during 1994-1998.[161] For the period during the great metal boom at the beginning of this century it remains to be understood if the consolidation that has taken place has led to increased profitability.

3. *Operation and overhead cost:* Metals are commodities and as such have little to no differentiators when it comes to the sold end product. Thus, a low cost profile is an

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158 See Crowson 2001, p.41.

159 See Slade 2004, pp.3-9.

160 Depending on data availability Slade utilizes volume or revenue weighted averages to estimate producer profitability, market shares and market concentration on a non-ferrous metal level, see Slade 2004, p.13.

161 She does not find consistent evidence neither for the CAPM nor for Hoteling's rule nor for the Firm Efficiency Model. See Slade 2004, p. 18.

important competitive advantage of a metal producer[162] and cost cutting has to be a permanent discipline if miners are to survive under the harsh regime of weak market prices[163]. Yet, many potential cost drivers are often underestimated with regards to their ubiquity and diversity. Most mining companies compare their general cost competitiveness by comparing their cash cost position on commodity cost curves.[164] What they dismiss by doing so are externally determined cost such as transport or energy cost which can fundamentally decrease a miner's profitability.[165] Besides these externally determined cost drivers incurred overhead costs are also often neglected which again can be determined by corporation size, complexity and need for management.

4. *Geographic sources and stability:* Ericsson notes in his analyses of corporate actors in the global mining industry that the locus of control over mineral resources is shifting to the countries where production is taking place and that especially Chinese mining companies are gaining substantial market power.[166] Commodity analysts have hypothesized that political stability of production countries can affect the metal's price development and can thus influence the miner's profitability.[167]
5. *Management focus*: Garcia and Camus draw a profitability comparison between the oil/gas industry and the metal industry.[168] They conclude that the higher rates of returns of oil and gas producers can be explained by their focus on upstream value generation that the metal industry lacks. This management focus means fostering the increase in resources through exploration or acquisitions and preparing the ground for their successful transformation into economic reserves to replace those consumed.[169]

162 See Beasley, Pfleider 1972, p.109.
163 See Crowson 2001, p. 38.
164 See Bielitza 2012, p.131.
165 See Porter, Kramer 2011, p. 6.
166 See Ericsson 2012, p.1.
167 See Böhringer 2014.
168 See Garcia, Camus 2011.
169 See Garcia, Camus 2011, p.808.

Determinants of profitability in single non-ferrous metal markets

Rather than analyzing metal markets holistically, many economists and researchers have focused on single metal market analysis. For the single commodities, these can be summarized as followed:

1. *Aluminium:* As discussed in 2.2.1 the production of aluminium is highly energy intensive. Thus, research that has modeled the profitability or prices of the aluminium market, whether in its global entirety or restricted to certain geographies has always found a high negative impact of the cost of energy on the aluminium market's development and profitability.[170]
2. *Copper:* As the most mature market the copper market is extremely transparent and allows for analyses and data collection that other non-ferrous metals still lack. As early as 1987, Tan publishes "An econometric Analysis of the World Copper Market" which tries to model supply and demand on a country level based on the available data.[171] Since then the data granularity has improved to the point that almost all copper producers publish very detailed information on production volumes, grades and even operational cost per asset and ton of extracted copper. However, so far no one has utilized these data to empirically distill the determinants of profitability in the copper market.[172]
3. *Manganese:* After the discovery of near to pure manganese nodules on the oceans' floor Foders and Kim modeled the manganese demand and supply situation in order to draw conclusions on the potential impact of deep-sea mining on the manganese market.[173] Since the manganese market is small in size and compared to other non-ferrous metals illiquid, intransparent and rumored to be lucrative the discussions around the potential deep-sea reserves have not ceased.[174] Nonetheless, an analysis on potential performance drivers within this obscure market has not yet been conducted due to the lack of transparency and data.

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170 See La Fisher, Owen 1981, p.158 and Turton 2002, p.36.
171 See Tan 1987.
172 Nevertheless, other economic analyses have been conducted: Young for instance investigates if productivity in the extraction of minerals actually decreases over time under the assumption of depleting resources but finds no evidence (see Young 1991).
173 See Foders, Kim 1983.
174 See Jardine 2014.

4. *Molybdenum:* As mentioned in 2.2.4 molybdenum is often mined as a by-product of copper and mostly used as a compound in the production of stainless steel. Thus, Molybdenum prices, demand and profitability have been found to depend highly on copper production and demand for stainless steel driven by the Chinese growth boom.[175] The actual empirical proof of these relations has so far not been given.
5. *Nickel:* In his overall analysis of the metal boom, Humphreys states that Nickel is often the metal most sensitive to changes in the rhythm of economic growth.[176] Apart from this overall dependency on global economic or GDP growth, Ellis and Halvorsen also find empirical proof that the mark up between actual production cost and market price in the Nickel industry can be explained by market structure and market power executed by the Nickel industry from 1947 until 1992.[177]
6. *Titanium:* With its many differing end uses, the titanium market and in particular its future demand has been subject to many different analyses. All of the papers agree on titanium to have a bright future. They justify this by the many different applications and end markets that in case of a downturn in one of the single markets could easily be substituted (automobiles[178], aerospace[179], petrochemicals, metallurgy, nuclear power, medical surgery, sea water desalination, sports/ leisure products, and luxury gifts[180]). Nevertheless, studies that analyze the titanium, rutile or ilmenite markets and their profitability determinants do not exist so far.
7. *Zinc:* Although ranking number three among the biggest non-ferrous metals in volume the zinc market has been studied surprisingly little. In 1982, Gupta conducted an empirical analysis on the relations between demand, supply and zinc prices.[181] He finds that the industry exhibits a reasonably stable market environment to exogenous disturbances such

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175 See Cisse 2007, p.9.
176 See Humphreys 2010, p.2.
177 See Ellis, Halvorsen 2002, p.898.
178 See Faller, Froes 2001, p.28.
179 See Qinglan et al. 2011.
180 See Fang, Jing 2009.
181 See Gupta 1982.

as an increase in the activity levels of consumers and variations in the prices of substitutes. Other potential determinants such as indicators on market power were not considered.

Altogether, we can summarize that potential profitability determinants in metal markets as well as in single metal markets have been analyzed independently. Nevertheless, a holistic empirical analysis concerning the fundamental determinants of profitability in metal and non-ferrous metal markets has not been conducted so far.

3.1.3 Deficits of research on company performance in non-ferrous metal markets

What research on mining and metal markets so far has analyzed or explained theoretically as well as empirically is the price development of commodities, metals in general and non-ferrous metals in particular. However, despite mining and metals markets being in the center of public and political interest there has only been one study that has quantitatively analyzed the performance of companies in global mining or metal markets, namely the study by Slade on "Competing models of firm profitability".[182]

As explained above, Slade empirically analyzes different types of company performance models in non-ferrous metal markets in the years from 1994 until 1998. Nevertheless, her study can only analyze aggregate producer data since detailed financial data for each of the mining markets was not publicly available back then and until today can only be gathered in a time-intensive and manual procedure involving great effort.[183] Given Slade's aggregate data set structure, she cannot specifically differentiate between the different metal markets and has to utilize weighted averages to estimate profitability, market share and market concentration for the single metal markets. This limits the granularity and comparability of the different non-ferrous metals.[184]

Apart from the lack of detailed data in the single metal markets Slade also puts her research focus on identifying the best performance model for non-ferrous metal producers as mentioned in 3.1.3.

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182 See 3.1.2, 3.1.3 and Slade 2004.

183 See Crowson 2001, p.35.

184 Slade particularly focuses only on big miners as she argues that otherwise she would not be able to interpret a positive relationship between size and profitability, i.e. economies of scale and excessive overhead/ "too large to manage" would be two conflicting interpretations of the variable company size. Given the fact that most of the big miners have diversified portfolios and focus on 5-10 different types of metals the use of aggregate data additionally biases the results of potential structural profitability differences among the single metal markets.

Instead of utilizing an integrative approach with a variety of different explanatory variables[185] she analyzes the impact of two single variables *Market concentration* and *Company market share* on the company profitability without considering further company specific or market specific profitability determinants.

3.1.4 Company performance research in general

Given that the amount of research that has been conducted on company performance in the non-ferrous metals is rather limited we now give a brief overview on the broad field of research on company performance in general in order to leverage these general findings for the formulation of our hypotheses in 3.2.

In general, the analysis of organizational, corporate, company or firm performance and its drivers has long been in the interest of research and theories as well as empirical studies have ever since enjoyed a lot of research attention.[186]

While many famous economists have postulated theories regarding the different determinants of company performance, even more research has been conducted on empirically analyzing these different profitability drivers across various markets and time periods, either set out as a single effect analysis, a multi effect analysis or as a meta-analysis synthesizing different single and multi effect studies.[187]

Many of the most recent single company performance studies focus on fields in which data availability has just now allowed to conduct company performance analysis at all covering for example profitability drivers such as taxation[188], organizational capital[189], the “too-much-of-a-

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[185] See Capon et al. 1996, p.49.

[186] First theories regarding "organizational performance" and their drivers trace back to Mason in 1939 (Mason 1939). In 1985, Porter publishes his standard work "Competitive Advantage - Creating and Sustaining superior performance" which gives an extensive overview of theoretical corporate performance drivers. According to Porter, these drivers consist on the one side of idiosyncratic factors such as the company's production cost, product differentiation and its organizational structure. On the other side, he sees environmental factors such as competition, entry barriers to markets, product substitution risk and the respective market power of buyers and producers as influential drivers for company performance (Porter 2008, pp.4-8).

[187] See Miller et al. 2013, p.948.

[188] See Mironov 2013.

[189] See Eisfeldt, Papanikolaou 2013.

good-thing effect"[190], group influence activities,[191] innovation[192] or information management[193]. In these cases, the few existing studies on the respective profitability determinants do not require or allow for a meta-analysis that are normally conducted to synthesize the directional impact of a company performance determinant across time, markets and different performance measures.

On the contrary, the company performance meta-analyses that have been conducted lately focus on synthesizing specific effects or variables such as family control[194], human resource management[195], the Chinese Guanxi[196], ownership structure[197], the top management teams[198], high-performance work practices[199], market orientation[200], acquisitions[201], equity[202], quality management practices[203] or corporate social responsibility[204] and their impact on company performance.

However, the most holistic and general meta-analysis across different industries, time horizons and so far scrutinized profitability determinants has been conducted by Capon, Farley and Hoenig in their book "Toward an Integrative Explanation of Corporate Financial Performance".[205] As a standard work on company performance it is thus often cited regarding general performance determinants and their directional impact on company performance.[206] Since we aim at leveraging the most common profitability determinants from general company performance analysis to test these on the dataset of the non-ferrous metal markets we utilize the determinants identified by Capon et al. if not more recent research has found additional or contradictive evidence.

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190 See Pierce, Aguinis 2013.
191 See Lechner, Floyd 2012.
192 See Gunday et al. 2011.
193 See Mithas et al. 2011.
194 See Essen et al. 2015.
195 See Jiang et al. 2012.
196 See Luo et al. 2012.
197 See Sánchez-Ballesta, García-Meca 2007.
198 See Certo et al. 2006.
199 See Combs et al. 2006.
200 See Kirca et al. 2005 and Ellis 2006.
201 See King et al. 2004.
202 See Dalton et al. 2003.
203 See Nair 2006.
204 See Orlitzky et al. 2003.
205 Capon et al. cover 428 studies on company performance from 1926 until 1996 (Capon et al. 1996).
206 See for example: Pierce, Aguinis 2013, p.321; Mithas et al. 2011, p.242; Gunday et al. 2011, p.664.

In general, organizational research has always covered three different types or clusters of variables: the company-specific or *strategic* variables, the market-specific or *environment* variables and the *organizational* variables.[207] Thereby, the cluster *environment* comprises market factors facing a company, meaning any externally determined factors (e.g., demographic, economic, regulatory) but also internally influenced external factors (e.g., customers, competitors, suppliers and regulators). The cluster *strategy* covers drivers that are idiosyncratic to the analyzed company, i.e. the company's major objectives combined with the set of strategic decisions, so designed that these objectives can be achieved. Finally, the cluster *organization* comprises drivers related to the company structure and the climate as experienced by its employees.

Table 7 summarizes the performance determinants and their directional impact that have been studied sufficiently often to determine patterns of significance.

Table 7 - Factors used frequently enough to determine significant patterns on firm performance[208]

Direction of correlation	Environment	Strategy/ Company	Organization
Positive	Market concentration	Company market share	Capacity utilization
	Market growth	Company growth	
	Market capital intensity	Company R&D	
	Market advertising	Company advertising	
	Market geogr. dispersion	Quality of product	
	Market economies of scale	Diversification	
	Market size	Vertical integration	
	Market barriers to entry	Corporate social responsibility	
Negative	Market imports	Company capital intensity	Decision centralization
	Market exports	Marketing expense	
		New product sales	
No significant correlation	Market diversification	Company Size	Employee compensation
		Debt	Owner vs. Mgmt. control
		Relative price	Plant & equipment newness
		Sales force expense	

[207] Also see Figure 40 - An Integrative Framework for Viewing Firm Financial Performance.
[208] Based on Capon et al. 1996, p.57.

These variables and their directional impact are all in line with theoretical work which has been conducted beforehand. The ones for which data availability is given on a business unit level in the non-ferrous metal markets are detailed for the sake of our further analyses whereas we first summarize the environmental or market specific factors and later the strategic or company specific factors.[209]

Environmental or market specific factors

- *Market concentration:* Seller concentration explains profits. High rates of return are thought to be caused by monopoly power conferred by high degrees of seller concentration. With Bain's analysis of the relationship between seller concentration and profitability in the US manufacturing market he has inspired a vast proliferation of empirical studies on the relationship between various measures of market structure or firm characteristics and economic performance.[210] The impact of market concentration on an organization's performance is thus probably the most studied factor, developed in the industrial organization framework.[211] In their meta-analysis Capon et al. find 823 positive correlations in 116 analyzed studies out of 1,214 data points.[212] Due to limited data availability these studies base their analyses on listed companies in the US or UK market. Some of them further restrict their analysis on specific industries such as manufacturing or food companies within these geographically closed markets. Given the unavailability of global data, these analyses fail to analyze global markets and thus exclude relevant competition from global competitors.[213] Due to the lack of transparency and data availability commodity markets in particular have only been researched scarcely.[214]
- *Market growth:* As with market concentration, market growth has been found to impact company performance positively.[215] This is in line with Brozen‘s theoretical disequilibrium hypothesis that profitability originates not from monopoly power but from adjustments in

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[209] Unfortunately, data availability does not allow to obtain any of the variables from the organizational cluster.
[210] See Bain 1951, p.323.
[211] See Capon et al. 1996, p.32.
[212] See Capon et al. 1996, p.253.
[213] See Einav, Levin 2010, p.23.
[214] See 3.1.3.
[215] See Capon et al. 1996, pp.56-57.

capacity lagging behind changes in demand.[216] Firms in high-growth environments are less concerned about competing with rivals because they are able to enhance revenues simply by maintaining their share of the steadily increasing demand. Given such environments companies have to spend less on defending their market share which in turn helps to generate higher rates of return.[217]

- *Market capital intensity:* According to industrial organization theory high capital requirements to participate in a specific market constitute an entry barrier to a specific industry or market and thus influence company profitability positively.[218] Nevertheless, more recent research has often criticized this concept: If capital markets work properly and returns promise proportional margins raising capital should not deter new market entrants.[219] Quite the opposite, it can impact company performance negatively since it reduces the earning margin according to the impact of company specific capital intensity.
- *Market size:* Although the relation between profitability and size of companies has been studied in abundance the relation between a firm's profitability and the size of the industry within which it operates lacks empirical evidence. That industry matters has been stated by Schmalensee and Rumelt.[220] Porter argues that larger geographical markets provide environments that foster higher profitability through better transparency and access to liquidity.[221] However, niche markets generally are less transparent and more concentrated which again are correlated to higher profitability.[222] The lack of available and complete industry data has hindered further inter-industry comparisons and remains to be analyzed.

Strategic or company specific factors

- *Company capital intensity:* As mentioned above, required capital investment on a firm level is found to be correlated negatively with company performance. Again, this corresponds

[216] See Bothwell et al. 1984, p.401.
[217] See Derfus et al. 2008, p.66.
[218] See Capon et al. 1996, pp.56-57 and Bain 1968.
[219] See for example McAfee et al. 2003, pp.7-9 or Carlton 2004, p.2.
[220] See Rumelt 1991, p.182 and Schmalensee 1985, p.349.
[221] See Porter 2011, pp.67-68.
[222] See the discussion on Market concentration above.

with theories established with regards to rate of returns in excess of competitive levels.[223] If a company faces higher capital requirements than average within a competitive environment the company's cost advantage is diminished and reduces its profitability.

- *Company market share:* Similar to a high market concentration, a high market share as a possible indicator for market power is also found to correlate positively with profitability. Besides high market power, theoretical rationales include larger economies of scale in procurement, manufacturing, marketing, and other cost components and quality of management and other processes such as sales.[224] However, in empirical studies the impact of market share often also depends on the levels of other firm and industry characteristics, including total firm size and leverage, industry growth and concentration.[225]
- *Company size:* Unlike company market share, company size has been found to have no clear correlation with profitability.[226] Many studies have shown positive however weak correlations of firm size as a performance driver when analyzed in combination with other influencing factors.[227] Theoretically, this can be explained again either by scale economies and their propensity to serve as entry barriers or by the implied cost disadvantages imposed on smaller firms operating at sub-optimal scale. On the other hand larger firms have to cope with higher complexity, slow processes and cost of controlling the complexity that smaller companies do not have to bear (e.g. strategy, M&A, controlling functions or department).[228] Overall, the relationship still seeks further understanding, especially given the growth trajectory of the mining industry in the new millennium that has led to many mining companies developing into mining giants.
- *Company diversification:* In their meta-analysis, Capon, Farley and Hoenig find that a firm's diversification meaning the number of different industries in which the firm sells its products has a positive impact on company performance.[229] In theory, this is supported by

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[223] See Grant 1991, p.122.
[224] See Ravenscraft 1983, p.23.
[225] See Gale 1972, p.422.
[226] See Capon et al. 1996, p.57.
[227] See Hall, Weiss 1967, p.329 and Scherer, Ross 1990, p.126.
[228] See Amato, Wilder 1985, p.188 and Dhawan 2001, p.290.
[229] See Capon et al. 1996, p.57.

the idea of risk diversification and less dependency on a single end product market. However, Rumelt highlights the importance of a careful corporate diversification strategy[230] supported by empirical findings from Porter who finds that diversification through acquisition generally leads to poorer performance.[231]

All of the above mentioned single profitability determinants have shown to impact company performance in theory or when applied. When analyzing these single determinants and their impact on company performance we are however not only interested in their single impact but also aim to understand how these variables work together and interact when influencing company performance.[232] We thus utilize an integrative approach and combine the potential profitability determinants to analyze their combined impact on company performance as for example proposed by the White-Hamermesh Model that integrates Industrial Organization, Organization Theory & Strategy.[233]

In addition, empirical analyses on organizational performance nowadays normally include a set of control variables in order to test the robustness of the analyzed model. Typical control variables cover the asset structure, capital efficiency, company size, dividend payments of the analyzed company, or growth or volatility of any of the before mentioned variables.[234]

Given that data availability on the operating business unit or metal production level is limited especially with regards to accounting information such as asset structure or dividend payments we can only include a subset of control variables in our regression analyses, namely company size in revenues or overall assets, company capital efficiency, company market share and company capital intensity.[235]

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[230] See Rumelt 1982, p.368.
[231] See Porter 1987.
[232] Gale found, for example, that the impact how market share affects profitability depends on the levels of other firm and industry characteristics, including firm size and leverage, industry growth and concentration (Gale 1972, p.422).
[233] See Figure 41 - The White/Hamermesh model as an integrative model to explain performance as an example for an integrative approach to view company performance.
[234] See for example Mironov 2013, p.1457, Eisfeldt, Papanikolaou 2013, p. 1386.
[235] See 4.2 for further details.

3.2 Hypotheses on company performance in non-ferrous metals markets

Given the lack of profound research on profitability in commodity markets (3.1.3) we leverage findings from the vast corpus of research on general company performance (3.1.4) to derive the different hypotheses that build the basis for our empirical research on profitability of non-ferrous metal producers. First, we deduce the hypotheses for profitability in non-ferrous metal markets in general, i.e. across all non-ferrous metal markets (3.2.1), then for the single metal markets under research (14). Finally, we summarize all hypotheses that are to be tested in a final chapter (0).

3.2.1 Hypotheses for the overall non-ferrous metal market

In order to test drivers and sources of profitability we utilize an integrative approach to test determinants of company profitability.[236] Accordingly, we consider company specific or idiosyncratic factors as well as industry and thus metal market specific factors. For the formulation of our hypotheses we choose to formulate these conservatively and postulate causal hypotheses.

Market specific explanatory factors:

1. *Market metal price:*
   With few sudden changes in production cost and volumes as well as few possibilities to differentiate the sold end product the metal producers' profitability is highly driven by the achieved metal price.[237] Since most metal sales are nowadays indexed to market prices, market prices ought to be positively correlated to the profitability of miners. For the overall model across all non-ferrous metal markets we hence assume to find:[238]

   H1: Market prices of non-ferrous metals have a positive impact on the idiosyncratic profitability of non-ferrous metals producers.

[236] See 3.1.4.
[237] See Crowson 2001, p.38.
[238] Market prices may not play such an important role in less mature markets where contracts are not yet linked to commodity indices. This needs to be reviewed in the analyses of the less mature markets.

2. *Market production cost - Transport cost*

   Since a miner's production is geographically determined by the occurrence of the mineral miners are highly dependent on transport cost. And since few miners own their proprietary transportation fleet this external cost driver is hard to manage or optimize. Therefore, changes in this cost drivers have a direct impact on margins in the mining industry if metal prices do not adjust accordingly. We thus expect to detect a negative relation with the miners' profitability:

   H2: Transport cost has a negative impact on the idiosyncratic profitability of non-ferrous metals producers.

3. *Market production cost - Energy cost*

   Again, few miners have dedicated energy plants or energy supply this cost driver is hard to manage or optimize. Yet again, changes in this cost drivers have a direct impact on margins in the mining industry if metal prices do not adjust accordingly. We thus expect to detect a negative relation between energy cost and the miners' profitability:

   H3: Energy cost has a negative impact on the idiosyncratic profitability of non-ferrous metals producers.

4. *Market growth:*

   Market growth has been found to impact company performance positively.[239] Whether this causal relation originates from increasing demand, adjustments in production capacity lagging behind changes in demand or because firms in high-growth environments have to spend less to defend their market share, depends on the characteristics of the market and remains to be analyzed for the single markets. Yet, across all non-ferrous metal markets we assume:

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[239] See Capon et al. 1996, p.57.

H4: Market growth of non-ferrous metal markets has a positive impact on the idiosyncratic profitability of non-ferrous metals producers.

5. *Market concentration:*

   In the general research field of company performance analysis, seller concentration has been found to explain profits.[240] This assumption was confirmed by the only empirical profitability analysis of the metals market of the years 1994-1998.[241] Based on Slade's results we assume to find a similar causal relationship from 2002 until 2012:[242]

H5: Market concentration in non-ferrous metal markets has a positive impact on the idiosyncratic profitability of non-ferrous metals producers.

6. *Market capital intensity*

   Since the impact of *Market Capital Intensity* has been found to influence company performance either positively if serving as an entry barrier or negatively if increasing the cost margin without being justified by higher returns we postulate two hypotheses:[243]

H6a: The average capital intensity of a market has a positive impact on the idiosyncratic profitability of non-ferrous metals producers.

H6b: The average capital intensity of a market has a negative impact on the idiosyncratic profitability of non-ferrous metals producers.

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240 See Bain 1951, p.323.
241 See Slade 2004, p.18.
242 With the rise in metal demand, prices and available cash, mining giants were able to grow through mergers and acquisitions leading to more concentrated metal markets during the observation period and especially between 2002 and 2008 before the financial crisis hit the mining industry.
243 See 3.1.4.

7. *Market size*

   Although Porter has argued that larger markets provide environments that foster higher profitability through better transparency and access to liquidity he has postulated this for geographical markets, i.e. nations such as the United States, Japan or Germany.[244] When it comes to comparing the profitability levels of different product markets however no empirical evidence has yet been given on the impact of producers' profitability. This is mostly due to a lack of complete global market data to produce supporting evidence. We argue that metal producers in niche metal markets which are normally small and less transparent have more market power than producers in larger more liquid markets. Miners in smaller markets can thus generate higher rates of return:

   H7: The size of a non-ferrous metal market has a negative impact on the idiosyncratic profitability of its producers.

8. *Market stability of production countries*

   Following the argumentation of commodity analysts we assume that political instability of production countries will lead to higher risk for the producing miners and accordingly higher profitability.[245] Vice versa, this can be summarized by:

   H8: The stability of the production countries of a certain non-ferrous metal has a negative impact on the idiosyncratic profitability of non-ferrous metals producers.

Company specific explanatory factors:

9. *Company size*

   Regarding the impact of company size on a miner's profitability, there is supporting evidence for a positive relationship[246] or a negative relationship[247] depending of the

[244] See Porter 2011, pp.67-68.
[245] See Böhringer 2014.
[246] See Hall, Weiss 1967, p.329 and Scherer, Ross 1990, p.126.
[247] See Amato, Wilder 1985, p.188 and Dhawan 2001, p.290.

industry or the inclusion of other explanatory variables. We thus postulate two hypotheses for the two different directions:

H9a: The size of a metal producer has a positive impact on the idiosyncratic profitability of the non-ferrous metals producer.

H9b: The size of a metal producer has a negative impact on the idiosyncratic profitability of the non-ferrous metals producer.

10. Company Capital Efficiency

In addition to a miner's size its capital efficiency has been found to be a useful measure when analyzing company performance determinants.[248] A high sales-to-capital-employed ratio is an indication for an efficient use of capital and thus explains higher profitability. This may have two underlying drivers: on the one side a minimization of capital or assets that are required to generate the targeted turnover, on the other side a maximization of output or turnover given the available assets. In both cases, we expect a positive impact of company capital efficiency on company performance:

H10: The capital efficiency of a metal producer has a positive impact on the idiosyncratic profitability of the non-ferrous metals producer.

11. Company capital intensity

In analogy to the impact of other production cost such as energy or transport cost required capital investment on a firm level is found to be correlated negatively with company profitability.[249] We thus postulate:

[248] Also called capital turnover, i.e. generated sales in relation to employed capital. See Chen, Shimerda 1981, p.52.
[249] See Grant 1991, p.122.

H11: The company-specific capital intensity has a negative impact on the idiosyncratic profitability of the non-ferrous metal producer.

12. Company market power

Market power mostly measured as a company's market share has been found to have a positive impact on company performance. Nevertheless, many researchers have often highlighted that the importance of market power highly depends on other firm and industry characteristics, including firm size and leverage, industry growth and concentration.[250]

H12: The market power of a company has a positive impact on the idiosyncratic profitability of the non-ferrous metal producer.

13. Company diversification / Company focus

During the observation period many non-ferrous metal mining companies have sought mergers or acquisitions to diversify their commodity portfolio. As explained in 3.1.4 a company's diversification can either have a positive or negative impact on its profitability. We thus assume:

H13a: The focus of non-ferrous metal producers on a single metal has a positive impact on the idiosyncratic profitability of the producer.

H13b: The focus of non-ferrous metal producers on a single metal has a negative impact on the idiosyncratic profitability of the producer.

14. Company Sales Capabilities

In general miners fix their sales contracts to global price indices. In less mature markets these price indices do not exist. Thus achieved metal prices can differ substantially across miners. In this case the miners' performances depend on the capabilities of their sales

[250] See Gale 1972, p.422.

departments to quickly mark up prices in times of metal shortages and to lock in high prices when metal oversupply is expected to persist. Since the majority of the markets under research are sufficiently mature and thus offer metal price indices we do not expect the sales capabilities to have a significant impact on company performance when analyzing the overall non-ferrous metal market. Nevertheless, we will scrutinize this variable in the single metal markets and include it in the overall market analysis for comparison with the results from the single markets.

3.2.2 Hypotheses for the single non-ferrous metal markets

As elaborated in 2.2 and 3.1.1 the non-ferrous metal markets under research all differ substantially. Thus, in addition to our hypotheses on profitability drivers across all non-ferrous metal markets we also postulate to find specific profitability drivers when testing profitability determinants in the single non-ferrous metal markets:

1. *Aluminium*

   Due to the high energy intensity of aluminium production and based on the existing research we assume energy cost as a substantial share of production cost to have a significant negative impact on the profitability of aluminium producers.

   A1: Average energy cost has a negative impact on the idiosyncratic profitability of aluminium producers.

2. *Copper*

   As outlined in 2.2.2 the copper market is one of the oldest, most mature and most transparent metal markets worldwide. Given the high maturity and transparency of the market, many copper assets have been operated for many decades. These assets along with their underlying production processes have continuously been streamlined with little room for further improvement. Any change in external transport or energy cost can often not be absorbed by further asset or process optimization and is thus expected to specifically impact the miner's margin:

C1: Energy cost has a negative impact on the profitability of copper producers.

C2: Transport cost has a negative impact on the profitability of copper producers.

3. *Manganese*

Since the manganese market is small in size and compared to other non-ferrous metals so far rather immature and illiquid there are not sufficient publicly traded manganese volumes to form a global and trustworthy manganese price index. Due to the lack of an appropriate price index the majority of sold manganese contracts are negotiated bilaterally. Achieved prices can thus differ substantially and depend on the sales capabilities of manganese producers to quickly mark up prices in times of manganese shortages and to lock in high prices when manganese oversupply is expected to persist. We thus assume:

Mn1: The sales capabilities of manganese producers have a positive impact on their profitability.

4. *Molybdenum*

As elaborated in 3.1.1 commodity analysts have found a positive relation between the political instability of countries of origin and metal prices and thus metal market profitability.[251] Given that the share of molybdenum production that originates from China has increased from 21% in 2001 to 40% in 2012 production volumes along with mining capabilities have shifted from politically more stable countries like the United States or Chile to the less politically stable China.[252] We thus assume:

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[251] See Böhringer 2014

[252] See 2.2.4.

Mo1: The stability of countries in which molybdenum is sourced has a negative impact on the profitability of molybdenum producers.

In addition, we assume that high prices of copper have a negative impact on the profitability of molybdenum producers since high copper prices lead to increased production volumes of copper and thus its byproduct molybdenum.[253] This in turn can create a molybdenum oversupply because molybdenum demand is not the determining variable for its production volume:

Mo2: High copper prices have a negative impact on the profitability of molybdenum producers.

On top of that byproducts are generally priced at their value in use against their alternatives, i.e. depending on demand rather than cost curves and their "production cost" can be described as the opportunity cost of foregoing use in the next best application. According to this logic we thus expect the miners' quality of assets or capital intensity to have an insignificant impact on their profitability.

5. *Nickel*

Since the nickel market is similar to the copper market and thus exhibits similar traits when it comes to its maturity and optimized assets we assume similar underlying performance drivers.

N1: Energy cost has a negative impact on the profitability of nickel producers.

N2: Transport cost has a negative impact on the profitability of nickel producers.

[253] See 2.2.4.

In addition and based on Humphreys findings that Nickel is often the metal most sensitive to changes in the rhythm of economic growth[254] we also postulate a positive impact of global GDP growth on the profitability of nickel producers.

N3: Growth of global GDP has a positive impact on the profitability of nickel producers.

6. *Titanium dioxide*

As mentioned in 2.2.6, 95% of titanium is produced and consumed as titanium dioxide and thus possesses a comparably low value-to-volume ratio compared to other non-ferrous metals. On top of that, countries of origin and country of demand differ substantially: the majority of production originates from Australia, South Africa and Canada whereas most consumption takes place in China, the United States and Europe. Combining these two facts we expect transport cost to be of high relevance for the profitability of titanium dioxide producers:

T1: Transport cost has a negative impact on the profitability of titanium dioxide producers.

Titanium and titanium dioxide are utilized in a broad variety of end markets ranging from aerospace, petrochemicals, metallurgy, nuclear power, medical surgery, sea water desalination, sports or leisure products, and luxury gifts. Depending on the end market, achieved prices differ substantially and strategic adjustment to global market prices can offer a significant competitive advantage. We thus hypothesize:

T2: The sales capabilities of titanium dioxide producers have a positive impact on the profitability of titanium dioxide producers.

[254] See Humphreys 2010, p.2.

7. *Zinc*

Since the zinc market is similar to the copper and the nickel market and thus exhibits similar traits with regards to its maturity and asset optimization we assume similar underlying performance drivers.

Z1: Energy cost has a negative impact on the profitability of zinc producers.

Z2: Transport cost has a negative impact on the profitability of zinc producers.

3.3 Overview on research question and hypotheses

Based on the existing research on mining and metal markets combined with the general findings of company performance analyses we have postulated hypotheses on profitability drivers in non-ferrous metal markets.[255] These hypotheses shall serve as the basis for the empirical tests first across all non-ferrous metal markets and subsequently for the single non-ferrous metal markets.[256]

Table 8 - Hypotheses on profitability drivers across non-ferrous metal markets

Hypothesis	**Explanatory variable of *producer profitability***	**Direction of impact**
Market specific explanatory variables		
H1	Market price	+
H2	Market production cost: Transport cost	-
H3	Market production cost: Energy cost	-
H4	Market growth	+
H5	Market concentration	+
H6a	Market capital intensity	+
H6b	Market capital intensity	-
H7	Market size	-
H8	Market stability of production countries	-
Company specific explanatory variables		
H9a	Company size	+
H9b	Company size	-
H10	Company capital efficiency	+
H11	Company capital intensity	-
H12	Company market power	+
H13a	Company focus	+
H13b	Company focus	-

(+ positive impact, - negative impact)

The hypotheses on profitability drivers across non-ferrous metal markets deducted in 3.2.1 are shown in Table 8 while the hypotheses regarding the profitability drivers in the single non-ferrous metal markets deducted in 3.2.2 are shown in Table 9.

[255] See 3.2.1 and 3.2.2.

[256] For the selection of commodity markets please refer to 2.1.6.

Table 9 - Hypotheses on profitability drivers within single non-ferrous metal markets

Hypothesis	Explanatory variable of *producer profitability*	Direction of impact
Aluminium market specific explanatory variables		
A1	Market production cost: Energy cost	-
Copper market specific explanatory variables		
C1	Market production cost: Energy cost	-
C2	Market production cost: Transport cost	-
Manganese market specific explanatory variables		
Mn1	Company sales capabilities	+
Molybdenum market specific explanatory variables		
Mo1	Market stability of production countries	-
Mo2	Copper market price	-
Nickel market specific explanatory variables		
N1	Market production cost: Energy cost	-
N2	Market production cost: Transport cost	-
N3	Growth of global GDP	+
Titanium dioxide market specific explanatory variables		
T1	Market production cost: Transport cost	-
T2	Company sales capabilities	+
Zinc market specific explanatory variables		
Z1	Market production cost: Energy cost	-
Z2	Market production cost: Transport cost	-

(+ positive impact, - negative impact)

4 Data and model

This chapter is structured in three sections: First, we describe the underlying data that constitute the analyzed dataset. Subsequently, the explanatory variables as well as the explained variable are described and lastly the choice and specification of the statistical model is explained.

4.1 Observations constituting the panel data

4.1.1 Data sources and completeness

In order to test the hypotheses deducted in chapter 3.2 we analyze the impact of miner specific indicators as well as more general metal market data on the miner’s performance. While market specific data can be sourced from global data providers such as the OECD, the USGS and the World Bank, the required idiosyncratic data cannot be sourced from a publicly available or purchasable database. Thus, we created a unique dataset containing operational and financial information based on annual business segment reporting by single mining companies. To conduct analyses on the miner’s performance in the metal specific commodity markets we combine the miner-specific data with metal market data from the above mentioned global data providers.

The generated database contains 826 observations, each generated from a single business segment reporting of a mining company active in one of the seven non-ferrous metal markets under research.[257] These observations cover the eleven year period from 2002 until 2012, thus scrutinizing the highly dynamic period in which commodity prices are undergoing their fourth super-cycle since the introduction of global commodity trades 150 years ago.[258]

While many companies are involved in the metal production value chain we restrict this analysis to miners.[259] Most mining companies however are vertically integrated, i.e. they are involved in exploring, mining, refining and smelting of the final metal. All of these value chain steps hold a different risk and return profile and are thus hard to cluster or compare. Thus, in the case of vertically integrated companies we have only included the mineral extraction and if combined with

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[257] Please refer to 2.1.6 for the selection of the markets.
[258] See Cuddington, Jerrett 2008, p.555.
[259] See 2.1.1.

the mineral extraction also the refining business segments in the data base in order to obtain comparable data. That means that we exclude dedicated metal refineries or metal smelters as well as exploring companies.

During the eleven year period under research many structural changes took place in the mineral and metal industry: Mergers, acquisitions, divestments, IPOs and new market entrants have changed the production landscape in each of the seven metal markets under research. These changes are covered in the dataset and have been checked for consistency across the different years based on publicly available market data and reports. To access data of miners no longer active in the market regulators such as the U.S. Securities and Exchange Commission (SEC) as well as data providers such as waybackmachine.com have played an important role for gathering sufficient data.[260] With regards to comparability of the gathered information, the filings included in the database are reported according to the International Financial Reporting Standards (IFRS).[261]

Table 10 - Data coverage of generated database compared to USGS market volumes

Commodity	**Aggregate production volumes from 2002-2012** (in kmt metal content)		**Data coverage**
	Volumes in generated database	Volumes according to USGS	
Aluminium	179,486	396,044	45%
Copper	129,175	168,391	77%
Manganese	77,034	132,694	58%
Molybdenum	1,384	2,169	64%
Nickel	11,027	17,474	63%
Titanium dioxide	57,721	64,069	90%
Zinc	52,380	118,714	44%
Sum	**508,207**	**899,555**	**56%**

Since this thesis focuses on companies competing freely without state subsidies the generated database does not cover state-owned companies. Markets such as aluminium, manganese, nickel or zinc in which Chinese or Russian state-owned companies constitute a large share of world metal production show thus less data coverage than more transparent markets such as copper or titanium.

260 See 9.1 for an overview on companies included in the dataset per observation year.
261 Research has shown that markets reporting under IFRS facilitate and increase the comparability of financial results, see for example Palacios Manzano, Martinez Conesa 2014, p.37.

Since state-owned companies are subsidized in order to foster national growth or economic independence, these miners are not comparable to other market participants and are thus excluded from the database.

Also excluded from the database are secondary metal production volumes that are produced via recycling. With 95% of titanium dioxide being utilized in consumer products such as paint, toothpaste or sunscreen it is recycled less intensely. Data coverage is thus significantly higher than compared to the other markets.

Last but not least we have excluded very small miners in their first operating year from the database. When junior miners develop and subsequently ramp up an operating asset operational as well as financial figures of the first year of production are normally distorted compared to their financial performance in consecutive years.

Table 11 gives an overview of the general sources for the different types of data.

Table 11 - Overview on data sources and data points for the different types of data

Data type	Data	Source	Data points
Company specific data			
Production data	Production volumes in metal content	More than 1000 filings and annual reports from company homepages, the U.S. Security and Exchange commission and Waybackmachine[262]	826
Sales data	Sold volumes		826
	Achieved price		826
	Total turnover		826
	Commodity-specific turnover		826
Capital intensity	Total depreciation & amortization		826
	Commodity specific depreciation & amortization		826
Financial performance	Total operating profit		826
	Commodity specific operating profit		826
Asset structure	Total assets		826
	Total debt		826
Market specific data			
Market production volume	Production volumes in metal content	USGS[263]	84
Political stability	Political stability rating of production countries	World Bank[264]	2,079
Traded metal volume	Seaborne metal volumes	OECD[265]	168
Metal market price	Global metal market price index	Westmetall[266]	48
	US metal price	USGS[267]	36
Transport cost	Ad valorem metal transport cost	OECD[268]	77
Energy cost	Cushing WTI oil price	US Energy Information Administration[269]	12
Summary			
Number of observations			826
Total data points			11,590

262 See 9.1 for included company filings, U.S. Securities and Exchange Commission 2002-2013 and Wayback Machine 2002-2013.
263 See U.S. Geological Survey 2002-2014.
264 See The World Bank 2015.
265 See OECD 2015.
266 See Westmetall 2015.
267 See U.S. Geological Survey 2013.
268 See OECD 2015.
269 See US Energy Information Administration 2015.

4.1.2 Data set structure

Given the time dimension as well as the company specific dimension of the single observations the data set is structured as a panel data set covering eleven years from 2002 until 2012 and exactly 100 different business units across seven commodities. During the course of the observation period the number of observations varies per year. These variations result from new market entrants pushing into the booming non-ferrous metal markets until the financial crisis hits the metal markets in 2009 and leads to consolidations and divestments afterwards. Since this variation and its impact on market concentration forms part of the research question we do not observe panel attrition as a problem rather than an enrichment of the underlying dataset.

Due to the differing amounts of market participants of each commodity market the data set is also unbalanced with regards to its commodity dimension: The copper market is the most transparent and largest commodity market whereas the molybdenum market shows the lowest number of market participants as can be seen in Figure 28: there are 221 observations for the copper market whereas the molybdenum market includes 72 single observations.[270]

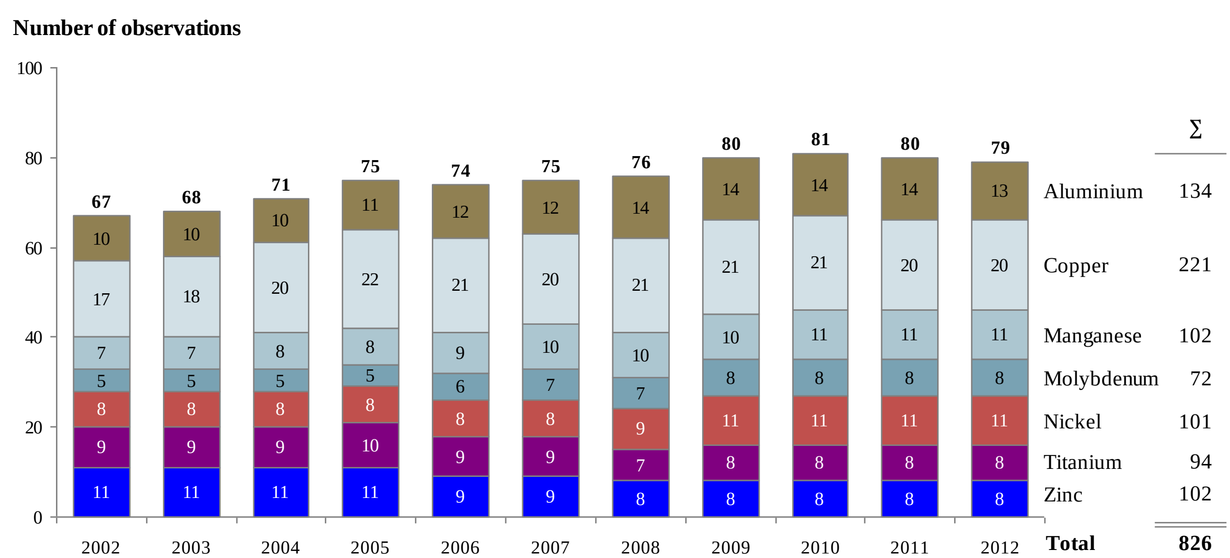

Figure 28 - Number of observations across time and commodity market dimension

[270] See Figure 28 - Number of observations across time and commodity market dimension and Table 29.

Altogether, the data set comprises 100 time series of miners' business unit performance and production data in total. However, many miners produce more than one commodity or metal. Thus the 100 different time series do not originate from 100 different miners. In fact, they originate from 73 different underlying companies.

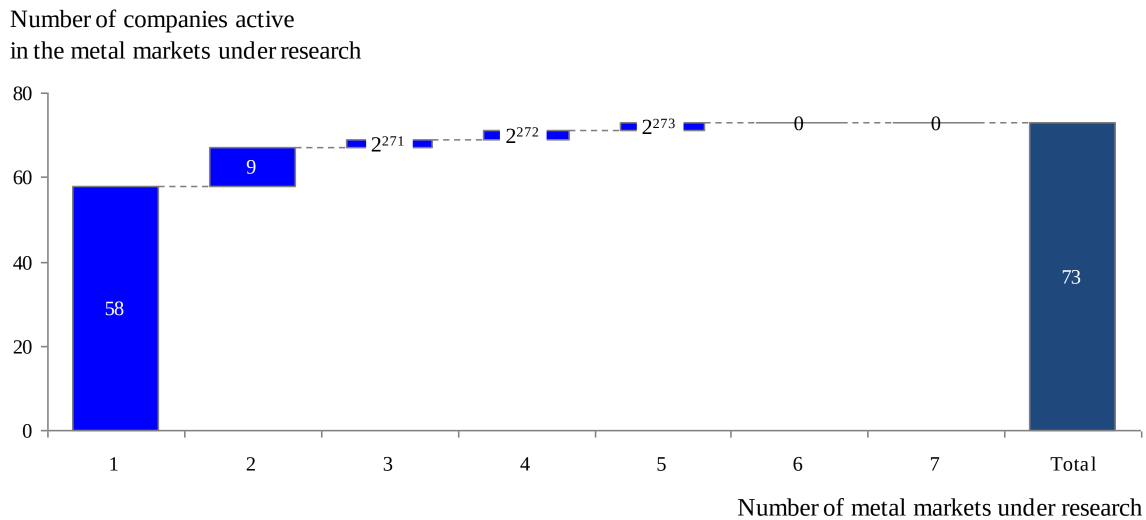

Figure 29 - Number of companies that participate in number of metal markets under research

As can be seen in Figure 29 there are two companies, namely BHP Billiton and Anglo American that operate in five of the seven markets under research. However, there are no companies that operate in six or even all seven markets under research.[274]

4.2 Model operationalization with variables

In the following section we explain the operationalization of the model with variables that represent the different performance measures and determinants. We first introduce the endogenous variable,

[271] Xstrata participates in the Copper, Nickel as well as Zinc market and Vedanta in the Aluminium, Copper as well as Zinc market.

[272] Vale participates in the Aluminium, Copper, Manganese as well as Nickel market and Rio Tinto in the Aluminium, Copper, Molybdenum and Titanium market.

[273] BHP Biliton participates in the Aluminium, Copper, Manganese, Nickel as well as Titanium market and Anglo American in the Copper, Manganese, Nickel, Titanium and Zinc market.

[274] Note that although 58 out of 73 companies are only active in one of the markets under research this does not imply that these miners do not produce any other metal or commodity.

then the different exogenous variables and conclude by summarizing the properties of the utilized variables.

4.2.1 The endogenous variable: Producer Profitability

The ultimate objective of this dissertation is the analysis of potential profitability determinants of non-ferrous metal miners' business units. Since few miners have dedicated financial departments per business unit we neglect the financial performance of miners and focus entirely on the operating profitability to ensure comparability of results across different miners.[275] There are many propositions on how to measure operating profitability and much has been discussed about the relative merits of these various measures.[276] In analogy to former studies on company performance we utilize the operating profit per business unit before interest payments, taxes, impairment charges and other exceptional items.[277] More generally, however, it has to be noted that the use of any accounting data has its limitations which are no more or less troubling here than in other applications.[278]

Since we compare companies of varying size the operating profit is normalized. Most commonly this is achieved by dividing earnings by either revenues or assets. Again, we stick to the most frequently utilized method in former research and normalize by utilizing revenues as a denominator since this most effectively reflects the price/cost margin of a business unit and is undetached from restructuring of financial assets.[279]

We deliberately utilize nominal figures since price level changes differ across regions and affect different commodity markets to varying extents which in turn can also be used to explain different profitability levels.[280]

All in all, we calculate the endogenous variable under research as follows:

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[275] Most commonly, there exists one consolidated finance department whose revenues, cost and earnings cannot be allocated to the different operating units.
[276] For a qualitative overview on advantages and disadvantages see Venkatraman, Ramanujam 1986, p.808.
[277] See Capon et al. 1996, pp.53-54.
[278] See Venkatraman, Ramanujam 1986, p.802.
[279] See Slade 2004, p.12.
[280] See Slade 2004, p.13.

$$Company\ Performance \cong Company\ EBIT\ margin_{i,t} = \frac{Operating\ Profit_{i,t}}{Revenues_{i,t}},$$

with *i* denominating the producing business unit and *t* denominating the year of an observation.

4.2.2 The exogenous variables: Company-specific

As summarized in 3.3 we have postulated various hypotheses on potential profitability determinants. These refer either to company specific or market specific variables. In the following section we explain the various company specific measures that can serve as exogenous variables. Subsequently, we introduce the market specific measures that partially build upon the idiosyncratic variables.

Company Size

The common way to measure a company's size are via the company's total assets or revenues. We prefer to utilize a company's total assets as assets are less correlated to other exogenous variables such as market prices.[281] Nonetheless, we have included total revenues as an alternative company size measure, also in order to test the model and its results for robustness. In addition, it is also possible to include logarithms of total assets or revenues in order to obtain more normally distributed variables. We have also tested for this option, but do not achieve statistically significant results.[282] Since the different measures for company sizes are highly correlated we only include one of these measures at a time.

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[281] A miner's revenues depend on sales prices which again are highly correlated to market metal prices, see 3.1.1.
[282] See Table 34 - Comparing different measures of company size.

Table 12 - Descriptive statistics of company total assets across the markets under research

Commodity	Company Total Assets (in mUS$)			
	Minimum	Maximum	Mean	Standard deviation
Aluminium	469	129,273	27,039	31,767
Copper	162	131,478	23,096	29,536
Manganese	93	131,478	22,978	34,933
Molybdenum	381	119,545	19,430	28,308
Nickel	272	131,478	29,900	34,504
Titanium	69	129,273	24,032	33,577
Zinc	128	86,165	16,229	22,626
Total	**69**	**131,478**	**23,494**	**31,015**

As mentioned in 4.1.2 most mining companies are active in more than one metal market. The companies' sizes are thus not dependent on the market in which they operate.[283]

Overall, we define company size either by:

$$Company\ Size^{Assets}{}_{i,t} = Company\ Total\ Assets_{i,t},$$

or alternatively by:

$$Company\ Size^{Revenues}{}_{i,t} = Company\ Total\ Revenues_{i,t},$$

with *i* denominating the producing business unit and *t* denominating the year of an observation.

Company Capital Efficiency

The capital turnover or capital efficiency is in general calculated by sales divided by capital employed. Since data on capital employed[284] are not available for the single business units we approximate capital employed by total assets and thus calculate company capital efficiency by:

$$Company\ Capital\ Efficiency_{i,t} = \frac{Company\ Total\ Revenues_{i,t}}{Company\ Total\ Assets_{i,t}},$$

with *i* denominating the producing company and *t* denominating the year of an observation.

[283] See Table 12 - Descriptive statistics of company total assets across the markets under research.
[284] Note that *Capital employed = Total assets + Working Capital – Current liabilities*.

Company Capital Intensity

In mining, a company's capital intensity can be deducted from the annually stated depreciation and amortization[285] denominated by the generated revenues of an operating unit.[286] The proxy chosen in this study represents the average commitment to capital over the observation period. As such, the capital intensity measure also represents capital maintenance and not only capital investment.[287] We thus calculate a business unit's capital intensity by:

$$Company\ Capital\ Intensity_i = \sum_{t=1}^{T} \frac{Company\ EBITDA_{i,t} - Company\ EBIT_{i,t}}{Company\ Revenues_{i,t}},$$

with *Company EBITDA* representing a business unit's earnings before interest payments, taxes, depreciation and amortization, *Company EBIT* characterizing a business unit's operating earnings, *Company Revenues* denominating a business unit's generated revenues, *i* denominating the producing business unit and T denominating the years in which a business unit participates in a specific market.

Company Market Power

Again, there are many different ways to measure market power. On a company level, market share has served as the most common measure although quality of product, achieved sales prices or more complex variables have served as alternatives.[288] In line with former research we utilize market share as the indicator for market power for the further empirical analysis although market power also depends on many other factors such as rivalry among the different producers and substitutability of the end product.[289]

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[285] Depreciation and amortization are normally aggregated in most of the business segment reports that serve as sources for the data basis. While depreciation refers to tangible assets, amortization refers to intangible assets. Since most mining business units do not own intangible assets the aggregated figure can be utilized as good proxy.

[286] See Lev 1983, p.33. Traditionally, the capital intensity ratio uses the sum of depreciation expense and net interest expense in the numerator. The interest expense results from the financing decisions of the firm and should not be considered when analyzing operational performance. For that reason, only depreciation expense is used in the numerator.

[287] See Dickinson, Sommers 2008, p.7.

[288] See Capon et al. 1996, p.61.

[289] See Porter 2008. Although metals are commodities and as such in general easily replaceable by one another some metals are used in very specific end markets and in formats that offer only few alternatives. In the titanium market for example, DuPont focuses on the production of high purity titanium specialty products that achieve

Market share can be calculated in terms of production volumes or generated revenues. Revenue market share reflects the combination of sold production volumes and achieved prices which are generally higher for higher quality commodities or purer metals. Since we analyze non-ferrous metals which can highly differ in quality or purity we utilize revenue market share:

$$Company\ Market\ Share_{i,t} = \frac{Revenues_{i,t}}{\sum_{n=1,\ldots,N} Revenues_{n,t}},$$

with i denominating the producing business unit, t denominating the year of an observation and N denominating the total number of producing business units in a given year.

Company Focus

As mentioned in 4.1.2 most miners extract more than one type of mineral and produce more than just one type of metal. Natural diversification thus forms the reality for most miners. Research on the impact of diversification and related measures is manifold.[290] In their evaluation of various measures Robins and Wiersema recommend to utilize a continuous instead of a categorical measure. One of the most widespread continuous measures for company diversification is a concentric index adapted from the original Herfindahl-Index and applied to company business segment sales.[291] For the calculation of this measure data on sales figures of all business segments of the analyzed company are required. Since the collection of these data would exponentially increase the required data volume we propose to utilize a simplified form of this measure to express a company's product diversification: the business segment sales normalized by total company sales. We thus calculate a company's focus as the opposite of company diversification as:

$$Company\ Focus_{i,t} = \frac{Business\ Unit\ Revenues_{i,t}}{Total\ Company\ Revenues_{i,t}},$$

with *Business Unit Revenues* representing a single business unit's revenues, while *Total Company Revenues* characterizes the revenues of the total mining company, i denominating the producing business unit and t denominating the year of an observation.

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exceedingly high sales prices. Few other miners produce suitable substitutes which could raise the question whether the total market in which DuPont competes is constituted by DuPont's volumes or revenues only.

290 See Robins, Margarethe F. Wiersema 1995.

291 See Robins, Margarethe F. Wiersema 1995, p.280.

Company Sales Capabilities

In order to measure the capabilities of miners' sales departments we consider the speed with which miners adjust to market prices: Good sales departments manage to adjust the achieved sales prices very quickly to new market prices when prices are rising. In times of economic downturn and falling metal prices though, these departments act smartly by slowly adjusting the fixed prices in their sales contracts to market prices. We thus propose the following indicator in order to measure a miner's sales capabilities:[292]

$$Company\ Sales\ Capabilities_{i,t} = Achieved\ Price\ Growth_{i,t} - \ Market\ Price\ Growth_t$$

with *Achieved Price Growth* representing the growth of a business unit's achieved metal prices from *t-1* to *t*, *Market Price Growth* characterizing the growth of the markets average metal price from *t-1* to *t*, *i* denominating the producing business unit and *t* denominating the year of an observation.

4.2.3 The exogenous variables: Market-specific

After having defined the company specific variables in 4.2.2 we now introduce the market specific indicators that partially build upon these company specific variables.

Market Price

The Market Metal Price is obtained by averaging daily index prices published by Westmetall. For the metals under research that are not sufficiently liquid to generate a global index, namely manganese, molybdenum and titanium, we utilize annual metal prices for CIF landed volumes in the United States published by the USGS. For the more liquid markets, namely the aluminium, the copper, the nickel and the zinc market we thus consider:

$$Market\ Metal\ Price_{j,t} = \sum_{d=1}^{D} \frac{Daily\ Metal\ Price_{j,d}}{D},$$

[292] This indicator is positive when a miner's achieved prices grow faster than market prices and when achieved prices decline more slowly than market prices. Vice versa, we obtain a negative indicator when achieved prices grow less than market prices and when achieved prices decline faster than market prices.

with *Daily Metal Price* representing the average daily metal index price per ton of metal, *j* characterizing the non-ferrous metal market, *t* denominating the year of an observation and *D* the number of trading days for this specific year.

Market Transport Cost

For the market transport cost variable we utilize the data published by the OECD which measure maritime transport cost[293] as a percentage share of the import value of the landed volumes[294].

$$Market\ Ad\ Valorem\ Transport\ Cost_{j,t} = \frac{Metal\ Maritime\ Transport\ Cost_{j,t}}{Metal\ Import\ Value_{j,t}},$$

with *Metal Maritime Transport Cost* representing the maritime transport cost of metal that has been traded between different countries via vessels and are thus recorded in the World Trade Organization's maritime transport data bases, *Metal Import Value* representing the imported value of the transported metal recorded by the World Trade Organization, *j* characterizing the non-ferrous metal market and *t* denominating the year of an observation.

Global Energy Cost

For the global energy cost we cannot refer to a public source to obtain ad valorem values. However, in order to include energy price levels and their potential impact on company performance in the different metal markets we include the annual average cost per barrel of Cushing OK WTI price. Since none of the metal production processes has changed substantially with regards to required energy input during the observation period this measure can serve as a good proxy to express energy cost development as an input cost factor to the metal production process. We thus consider:

$$Global\ Energy\ Cost_t = Oil\ Price_t$$

with *Oil Price* representing the annual averaged Cushing OK WTI Spot Price FOB in dollars per barrel published by the US Energy Administration and *t* denominating the year of an observation.

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[293] The cost in US$ that is required to transport one kilogram of merchandise.

[294] When input cost increases are immediately passed through to the end customer via higher metal sales prices the impact on the profitability of the miner should be negligible.

Market Growth in Demand or Supply

The growth of the market volume can be defined based on different volume figures: As a base, we can either utilize the metal production volume which represents the supply situation, or we can utilize the seaborne metal volume which represents the demand situation since metal is only shipped once the metal is required elsewhere than in the production country. We thus define market demand growth by:

$$Market\ Demand\ Growth_{j,t} = \frac{Seaborne\ Metal\ Volume_{j,t} - Seaborne\ Metal\ Volume_{j,t-1}}{Seaborne\ Metal\ Volume_{j,t-1}},$$

and market supply growth by:

$$Market\ Supply\ Growth_{j,t} = \frac{Production\ Volume_{j,t} - Production\ Volume_{j,t-1}}{Production\ Volume_{j,t-1}},$$

with *Seaborne Metal Volume* representing the metal volume that has been traded between different countries via vessels and are thus recorded in the World Trade Organization's maritime transport data bases, *Production Volume* representing the production volume in metal content published by the USGS, *j* characterizing the non-ferrous metal market and *t* denominating the year of an observation.

Market Concentration

Since the US Department of Justice and the Federal Reserve's decision to utilize the Herfindahl Hirschman Index (HHI) in the analysis of competitive effects of mergers the measure has achieved an unusual high visibility for a statistical index.[295] It is by far the most commonly used measure to express market concentration.[296] We stick to the common grounds and measure market concentration by:

$$Market\ HHI_{j,t} = \sum_{n=1}^{N} Company\ Market\ Share_{n,j,t}{}^{2}$$

[295] See Rhoades 1993.

[296] The biggest alternative to the Herfindahl Hirschman Index is the Concentration Ratio (CR) which gives an equal weight to companies independent of their size and thus relevance within a competitive environment.

with *Company Market Share* representing a business unit's market share[297], N representing the total number of companies active in a specific market during the observation period, j characterizing the market in which the companies are participating and t denominating the year of an observation.

Market Size

For the variable *Market Size*, we have two options to measure it: either by utilizing aggregated data based upon the collected operational figures of single market participants or by utilizing published data from one single source, e.g. the USGS or the Organization for Economic Co-operation and Development (OECD). Since we want to utilize market size as a level figure that expresses market size independent of data availability[298] across the markets under research independent on data availability and changes in demand we prefer to utilize production volume data published by the USGS. We thus obtain market size as:

$$Market\ Size_{j,t} = Production\ Volume_{j,t}.$$

with j characterizing the non-ferrous metal market and t denominating the year of an observation.

Market Capital Intensity

Based on similar rationales as for the development of the variable *Company Capital Intensity*[299] we utilize the reported depreciation and amortization ratios of single miners active within a certain metal market to deduct a market wide index on capital intensity. Based upon the reported ratios in a given year we calculate a revenue weighted market capital intensity by:

$$Market\ Capital\ Intensity_{j,t} = \frac{\sum_{n=1}^{N} \left(EBITDA_{n,j,t} - EBIT_{n,j,t} \right) * Revenues_{n,j,t}}{\sum_{n=1}^{N} Revenues_{n,j,t}}$$

with *EBITDA* representing a single business unit's earnings before interest payments, taxes, depreciation and amortization, *EBIT* characterizing a single business unit's operating earnings, N representing the total number of business units active in a specific market during the observation

[297] See 4.2.12.
[298] Utilizing market size figure that are generated by aggregating production or financial figures from single market participants would lead to incomparable data across the markets under research as data availability differs per market, see 4.1.1.
[299] See 4.2.2 The exogenous variables.

period, *j* characterizing the market in which the companies are participating and *t* denominating the year of an observation.

Market Stability of Production Countries

In order to measure the political stability that could foster or affect the production of a specific metal we combine an index on political stability of single countries with the metal production volumes of single countries to obtain a weighted average of the index per year as:

$$Political\ Stability_{j,t} = \frac{\sum_{k=1}^{K} Political\ Stability_{k,t} * Production\ Volume_{k,j,t}}{\sum_{k=1}^{K} Production\ Volume_{k,j,t}}$$

with *Political Stability* representing the political stability index per single country which is published by the World Bank,[300] *Production Volume* representing the production volumes in metal content per production country published by the USGS, *K* symbolizing the total number of metal production countries active during the observation period, *j* characterizing the market in which the companies are participating and *t* denominating the year of an observation.

[300] The index measures political stability yearly on a continuous scale from -2.5 to +2.5, with low political stability expressed by -2.5 and high political stability expressed by +2.5.

4.2.4 Summary and descriptive statistics of endogenous and exogenous variables

Table 13 summarizes the different utilized endogenous and exogenous variables and enables a quick overview on the calculation methodology for the single variables.

Table 13 - Overview on utilized variables and their calculation methodology

Variable	**Calculation methodology**
Endogenous variable	
Company EBIT Margin	$\frac{Operating\ Profit_{i,t}}{Revenues_{i,t}}$
Exogenous variables - Company specific	
Company Size - Assets	$Company\ Total\ Assets_{i,t}$
Company Size - Revenues	$Company\ Total\ Revenues_{i,t}$
Company Capital Efficiency	$\frac{Company\ Total\ Revenues_{i,t}}{Company\ Total\ Assets_{i,t}},$
Company Capital Intensity	$\sum_{t=1}^{T} \frac{Company\ EBITDA_{i,t} - Company\ EBIT_{i,t}}{Company\ Revenues_{i,t}}$
Company Market Share	$\frac{Revenues_{i,t}}{\sum_{n=1,\ldots,N} Revenues_{n,t}}$
Company Focus	$\frac{Business\ Unit\ Revenues_{i,t}}{Total\ Company\ Revenues_{i,t}}$
Company Sales Capabilities	$Achieved\ Price\ Growth_{i,t} - Market\ Price\ Growth_{t}$
Exogenous variables - Market specific	
Market Metal Price	$\sum_{d=1}^{D} \frac{Daily\ Metal\ Price_{j,d}}{D}$
Market Transport Cost	$\frac{Metal\ Maritime\ Transport\ Cost_{j,t}}{Metal\ Import\ Value_{j,t}}$
Global Energy Cost	$Oil\ Price_{t}$
Market Demand Growth	$\frac{Seaborne\ Metal\ Volume_{j,t} - Seaborne\ Metal\ Volume_{j,t-1}}{Seaborne\ Metal\ Volume_{j,t-1}}$
Market Supply Growth	$\frac{Production\ Volume_{j,t} - Production\ Volume_{j,t-1}}{Production\ Volume_{j,t-1}}$
Market HHI	$\sum_{n=1}^{N} Company\ Market\ Share_{n,j,t}{}^{2}$
Market Size	$Production\ Volume_{j,t}$
Market Capital Intensity	$\frac{\sum_{n=1}^{N} (EBITDA_{n,j,t} - EBIT_{n,j,t}) * Revenues_{n,j,t}}{\sum_{n=1}^{N} Revenues_{n,j,t}}$
Market Instability of Production Countries	$\frac{\sum_{k=1}^{K} Political\ Stability_{k,t} * Production\ Volume_{k,j,t}}{\sum_{k=1}^{K} Production\ Volume_{k,j,t}}$

Note that *i* denominates the producing business unit, *t* the year of an observation, *T* the years in which a business unit participates in a specific market, *N* the total number of producing business units in a given year, *j* the non-ferrous metal market, *D* the number of trading days for this specific year and *K* the total number of metal production countries active during the observation period

For these variables, Table 14 summarizes their most important distribution properties, namely their arithmetic mean, standard deviation, minimum and maximum.

In order to facilitate comparison of coefficients and optimize results of statistical tests that might run less efficiently when handling variables that are very differently scaled, we standardize all exogenous variables for the regression analysis to obtain variables with an arithmetic mean of 0 and a standard deviation of 1 before we run the single regressions.[301]

Table 14 - Descriptive statistics of the endogenous and exogenous variables[302]

Variable	Mean	Standard deviation	Minimum	Maximum
Endogenous variable				
Company EBIT Margin	0.2576	0.2147	- 0.7224	0.8608
Exogenous variables - Company specific				
Company Size – Assets	23,494	31,015	69	131,478
Company Size – Revenues	12,616	16,336	27	72,226
Company Capital Efficiency	0.5964	0.2677	0.0450	3.2437
Company Capital Intensity	0.0748	0.0395	0.0140	0.2432
Company Market Share	0.0932	0.0891	0.0002	0.4301
Company Focus	0.4139	0.3381	0.0046	1.0000
Company Sales Capabilities	0.0005	0.4387	- 2.4692	5.9199
Exogenous variables - Market specific				
Market Metal Price	8,205	12,803	380	69,953
Market Ad Valorem Transport Cost	0.0564	0.0678	0.0032	0.4135
Global Energy Cost	66.96	23.92	26.12	99.57
Market Demand Growth	0.0916	0.1945	- 0.3823	0.7504
Market Supply Growth	0.0453	0.0721	- 0.1579	0.3548
Market HHI	0.1612	0.0517	0.0738	0.2812
Market Size	13,786	11,700	123	45,894
Market Capital Intensity	0.081	0.034	0.019	0.201
Market Stability of Production Countries	0.017	0.185	- 0.440	0.480

301 See for example Backhaus 2011, p.338.
302 Variables are not yet standardized.

4.3 Statistical model specification

In the following section we explain the specification of the empirical model given the available data set structure and variables[303] in order to test the postulated hypotheses most consistently and efficiently. In order to do so, we first give a short overview on available options for model specifications with their respective advantages and disadvantages given the data set, the data structure and the defined variables that have been developed so far as a presumption. Based on these advantages or disadvantages we subsequently elucidate the selection of the chosen model specifications to achieve the results explained in chapter 5 and 6.

4.3.1 Overview of potential statistical models and estimators

There are various options to test relations between variables. The simplest form assumes a linear relationship between the endogenous and the different exogenous variables[304] and introduces a constant and an error term to allow for unexplained but relevant drivers and measurement errors:

$$E(y|x) = y_{it} = \alpha_i + x_{it}'\beta + u_{it},$$

with x_{it} representing a k-dimensional vector of exogenous variables, β representing a k-dimensional vector of unknown coefficients belonging to the different exogenous variables, α_i representing the constant[305], and u_{it} the idiosyncratic error term. The index i denotes the cluster dimension of an observation, in this case the varying company clusters, to which an observation belongs, while t denotes the year of an observation.

Based on the available data along with its structure and properties, the proposed relation is validated by approximating the values of the constant and the coefficients with the help of an appropriate estimator. The utilized estimator and its properties[306] highly impact the estimated values of the constant, the coefficients and the thereupon resulting statistics of the error term or residuum.

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303 See 4.2.4.

304 We stick to this simple form since introduction of more complex relations such as hyperbola etc. should be avoided if data allow for it, see Crawley 2002, p.211.

305 In case of panel models, the constant can depend on the cluster that it belongs to. It then represents a random idiosyncratic effect instead of a constant, see Cameron, Trivedi 2010, p.231.

306 Properties refer to the distribution of the estimator and especially the variance-covariance matrix of the estimator (VCE). More efficient estimators have smaller VCEs.

Therefore, we have to ensure to utilize the Best Linear Unbiased Estimator (BLUE)[307] given the data structure to ensure validity and robustness of the coefficient estimations in order to enable the interpretation of these estimations.

There are many different estimators that can be utilized. The most relevant options are summarized in Table 15 - Comparison of different estimators, their requirements and usability. For further mathematical background please refer to Izenman's book on Modern Multivariate Statistical Techniques.[308]

While the Ordinary Least Squares (OLS) estimator without cluster robust standard errors is the simplest solution for estimating the coefficients and its statistics for the regression model, it can only serve as a starting point: since for the default OLS estimator to work consistently regression errors have to be independently and identically distributed (i.i.d.) it normally only serves to summarize the data, generate conditional predictions, or test and evaluate the role of specific regressors.[309] In a dataset with clusters as for example a panel dataset comprising differing company clusters across a time span this prerequisite is not given.

The assumption of independence can be relaxed to independence at a more aggregated level by utilizing cluster robust standard errors (CRSE), provided that the number of clusters is still large and the clusters nest the individual.[310] As possible clusters we could utilize different dimensional variables of the dataset: we could either cluster by company, commodity type or year. Since we assume errors in the dataset to mostly originate from company specific manners or methodologies to measure performance indicators we choose to cluster by company.[311] When utilizing these company robust standard errors we consider the company affiliation of an observation when

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307 An estimator is called a Best Linear Unbiased Estimators if its generated estimates of the constant and the coefficients lead to (i) the mean of the error terms to equal zero (exogeneity of regressors), (ii) the variance of the error terms to be constant (conditional homoscedasticity) and (iii) the error terms to be uncorrelated (conditionally uncorrelated observations), see Crawley 2002, p.696 or Backhaus 2011, p.86.

308 See Izenman 2008.

309 See Cameron, Trivedi 2010, p.71.

310 Another option to obtain i.i.d. standard errors provides the introduction of a single regression model for each company under research, yielding 100 regression models for the given dataset, each with its own coefficient estimation. However, in order to generalize results across companies and industries this approach is not helpful. See Cameron, Trivedi 2010, p.233.

311 In order to allow for errors per commodity market or year we have included time and commodity dummies in the overall model.

estimating the unknown variance-covariance-matrix of the estimator that in turn determines the distribution of the standard errors. Thus, we correct the estimation of standard errors.

Nevertheless, the utilization of cluster robust standard errors does not yet allow for a company specific error component. In order to do so and thus to benefit from the knowledge on the underlying structure of the panel data, more specific estimators can be utilized, whereby the most common are the fixed effects (FE) and random effects (RE) models and estimators.

The FE estimator computes the model solution by performing the OLS minimization on the mean-differenced data. Thereby, the FE estimator allows for a company specific error term α_i that is correlated to the other regressors but independent of time t. Because all the observations of the mean-difference of a time-invariant variable are zero, we cannot estimate the coefficient on a time-invariant variable[312]. Thus, FE estimators omit regressors that do not vary over time if included in the model.

In this case, the RE estimator which is a generalized least squares (GLS) estimator might serve as an alternative since it does not only consider the "within"-variation but also the "between"-variation of different companies. However, to include time-invariant regressors it requires the company specific error term α_i to be completely exogenous and independent of all regressors x_{it}, thus "random".

Therefore, if effects are fixed and hence not random, the RE estimator is inconsistent, and instead the FE estimator needs to be utilized. The FE estimator is otherwise less desirable because of three major advantages: first of all, it is impossible to test the statistical significance of time-invariant regressors. Secondly, using only within variation withdraws the ability to analyze the impact of a regressor on the entire market. Last but not least, if variables do not vary much over time and thus show little variation across the dataset the coefficient estimation is less efficient.[313]

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[312] See Crawley 2002, p.670.
[313] See Cameron, Trivedi 2010, p.259.

Table 15 - Comparison of different estimators, their requirements and usability[314]

Estimator	OLS without CRSE	OLS with CRSE	OLS Fixed Effects with CRSE	GLS Random Effects with CRSE
Criteria				
Requirements for Standard Errors	1. $E(u_{it}\|x_{it}) = 0$ 2. $E(u_{it}^2\|x_{it}) = \sigma^2$ 3. $E(u_{k,it}u_{l,jt}\|x_{it}x_{jt}) = 0, \quad k \neq l, \forall i,j \in I$	1. $E(u_{it}\|x_{it}) = 0$ 2. $E(u_{k,it}u_{l,jt}\|x_{it}x_{jt}) = 0, \quad k \neq l, i \neq j$	1. $E(u_{it}\|\alpha_i, x_{it}) = 0$, with α_i correlated to x_{it} 2. $E(u_{k,it}u_{l,jt}\|x_{it}x_{jt}) = 0, \quad k \neq l, i \neq j$	1. $E(u_{it}\|\alpha_i, x_{it}) = 0$, with α_i uncorrelated to x_{it} 2. $E(u_{k,it}u_{l,jt}\|x_{it}x_{jt}) = 0, \quad k \neq l, i \neq j$
	1. Exogeneity of regressors 2. Homoscedasticity 3. Uncorrelated standard errors	1. Exogeneity of regressors 2. Allowed heteroscedasticity 3. Correlated standard errors within cluster	1. Endogeneity of regressors with one time invariant constant 2. Allowed heteroscedasticity 3. Correlated standard errors within cluster	1. Exogeneity of regressors, introduction of cluster specific error term 2. Allowed heteroscedasticity 3. Correlated standard errors within cluster
Appropriate for	– Pooled data sets without (w/o) cluster	– Clustered data sets w/o expected cluster specific errors	– Clustered data sets with time-invariant cluster specific error term (data in which effects are fixed)	– Clustered data sets with cluster specific error term – Regression with time invariant regressors
Inappropriate for	– Datasets with clusters	– Datasets with cluster specific error term	– Short panels – Time-invariant regressors – Predictions	– Inconsistent when cluster specific error term α_{it} is correlated to u_{it}

[314] Based on Cameron, Trivedi 2010.

4.3.2 Selection of statistical model and estimator

As mentioned in chapter 4.1.2 the dataset comprises 826 observations originating from 100 clusters, i.e. companies (*N*) across 11 years (*T*). The estimators utilized to solve the empirical regression analysis thus have to be particularly specified to generate cluster robust standard errors.[315]

Since the number of companies surpasses the number of years (N>T) the dataset is described as a short panel. This is important since the Fixed Effects estimator has to compute the correlation of each of the company specific error terms α_i with the exogenous variables x_{it} and thus does not operate as efficiently in shorter panels as the RE estimator does.[316] In addition, we would like to include time-invariant regressors in the analyses of this dissertation which is normally not possible with the FE estimator.[317] We therefore prefer to utilize the RE estimator if company specific effects are random and thus the RE estimator is consistent.

To test if this is the case we utilize the Hausman Test which compares the estimable coefficients of time-varying regressors and their robustness. Under the null hypothesis that company specific effects are indeed random, the FE and RE estimator should be similar because both are consistent. Under the alternative, these estimators diverge[318] which is a natural setting for a Hausman test. Results of the Hausman test depend on the model that we want to utilize. Table 43 summarizes the outcome of the Hausman Test on the different models[319] which shows that the null hypothesis of consistent coefficient estimates for both the FE and RE model does not have to be refuted. We therefore prefer to utilize the more efficient Random Effects Estimator with Cluster Robust Standard Errors for the multivariate regression analysis displayed in chapter 5.

[315] See 4.3.1.
[316] A short panel has few time periods but many individuals, see Hair 2006, p.204.
[317] In order to include time-invariant variables we could clean or fix the endogenous variable for the time-invariant effect. For the time-invariant regressor "Company Capital Intensity" we could utilize the measure EBITDA instead of EBIT as a performance measure. By doing so we would lose the opportunity to test the impact of capital intensity on the performance. In addition, we would like to include time-invariant commodity market dummies as regressors to allow for variations across commodity markets that cannot be explained by the other regressors.
[318] See Table 15 - Comparison of different estimators, their requirements and usability.
[319] See 5.2 for the different model specifications.

The issue of potential multicollinearity among the regressors is addressed for each of the regression analyses by considering the variance inflation factors of each regressor. Results of these multicollinearity tests can be found in section 5.2.3 and 6.1.2.

5 Findings and discussion of the overall metal market analysis

In the following chapter the hypotheses that have been postulated in chapter 3.2 will be analyzed based on the dataset of all seven non-ferrous metal markets under research. This analysis is conducted first qualitatively and then quantitatively. Following the qualitative and quantitative results we will discuss and evaluate the findings.

5.1 Descriptive analysis of variables

Since the analyzed dataset has been generated uniquely for the purpose of this dissertation we will present some of the most insightful data descriptively before diving into the results of the statistical analysis.

Endogenous variable: Company EBIT margin

Just after the burst of the IT bubble and the following global crisis in 2001, profitability of metal miners was very low at an average 14% which also represents the lowest value across the entire observation period.[320] Molybdenum and copper represented the metal markets with the highest returns whereas Aluminium and Titanium producers performed comparably badly. Worthwhile noticing is the decrease of average profitability in the aluminium market during the observation period which started off at the same average profitability as the copper market of 17% on average in 2002 but finishes at -2% in 2012.

[320] See Figure 30 - Average EBIT margin development per non-ferrous metal market from 2002 until 2012.

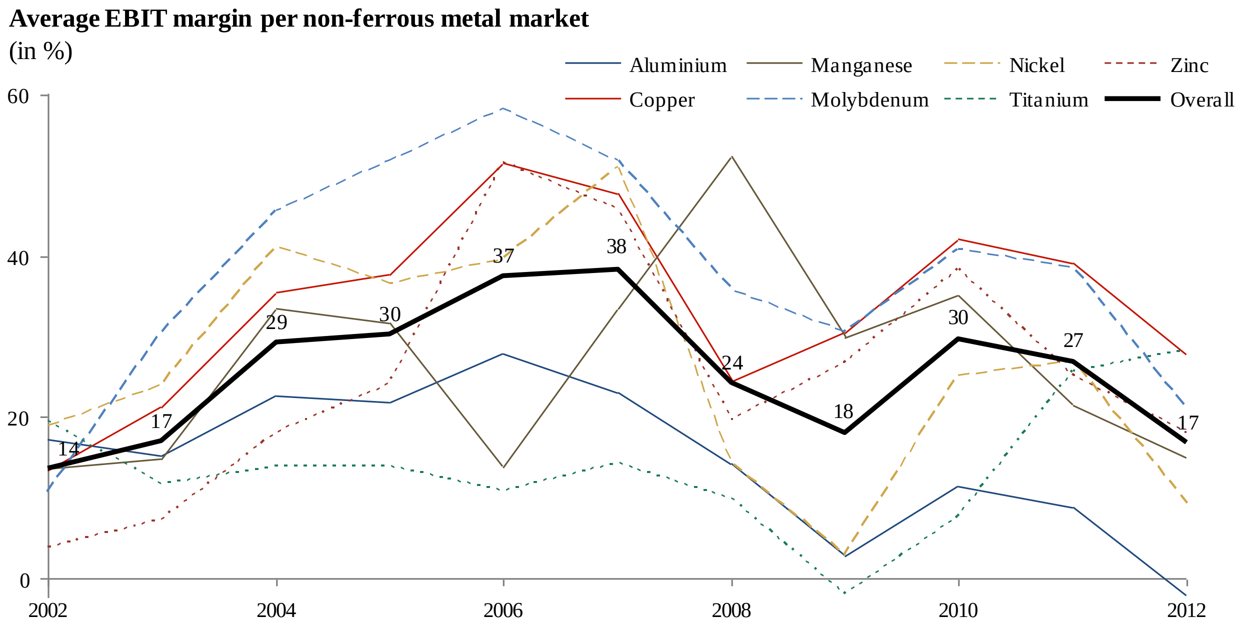

Figure 30 - Average EBIT margin development per non-ferrous metal market from 2002 until 2012[321]

Exogenous market variables

Even though not all metal volumes are sold via indexed contracts market metal prices are important profitability indicators in commoditized markets. As shown in Figure 31 average metal prices have almost quadrupled from 2002 until 2012. However, the price development between 2002 and 2007 is the most remarkable where prices grew by ~480% to US$13,400 in 2007. Due to the dip in metal demand and existing oversupply the prices subsequently dropped to US$6,800 in 2009.

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321 Note that the average is unweighted.

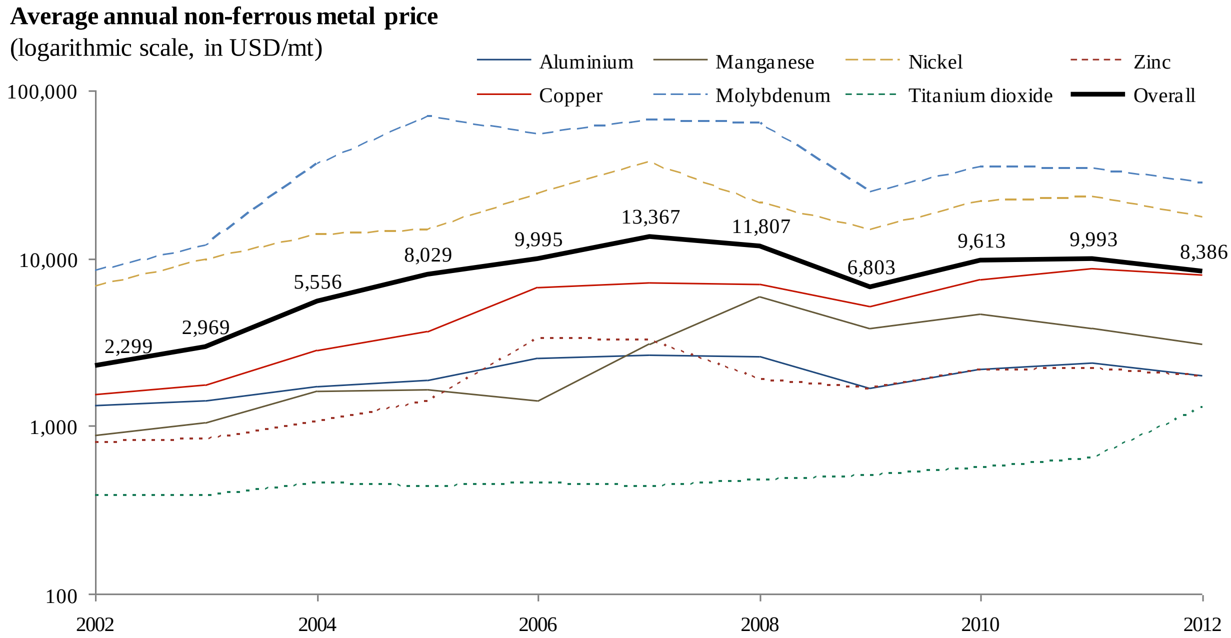

Figure 31 - Metal market price development per non-ferrous metal from 2002 until 2012[322]

Other possible profitability determinants such as energy and transport cost are depicted in Figure 32. The transport cost as a share of total metal prices remained relatively stable until 2008 since demand for maritime transport was growing but at the same time high capacity in vessel volume was being built up. After the crisis in 2008, this newly installed capacity did not meet sufficient demand and thus ad valorem transport cost remained low. In contrast to freight rates, oil prices measured as the average oil price per barrel dipped during 2009 but quickly recovered to pre-crisis levels and hence put pressure on the profitability of energy-intensive industries.

[322] Note that the metal prices are presented on a logarithmic scale to display the highly varying price structures in one figure. Please refer to Figure 422 in the appendix for a non logarithmic view on the highly volatile price development.

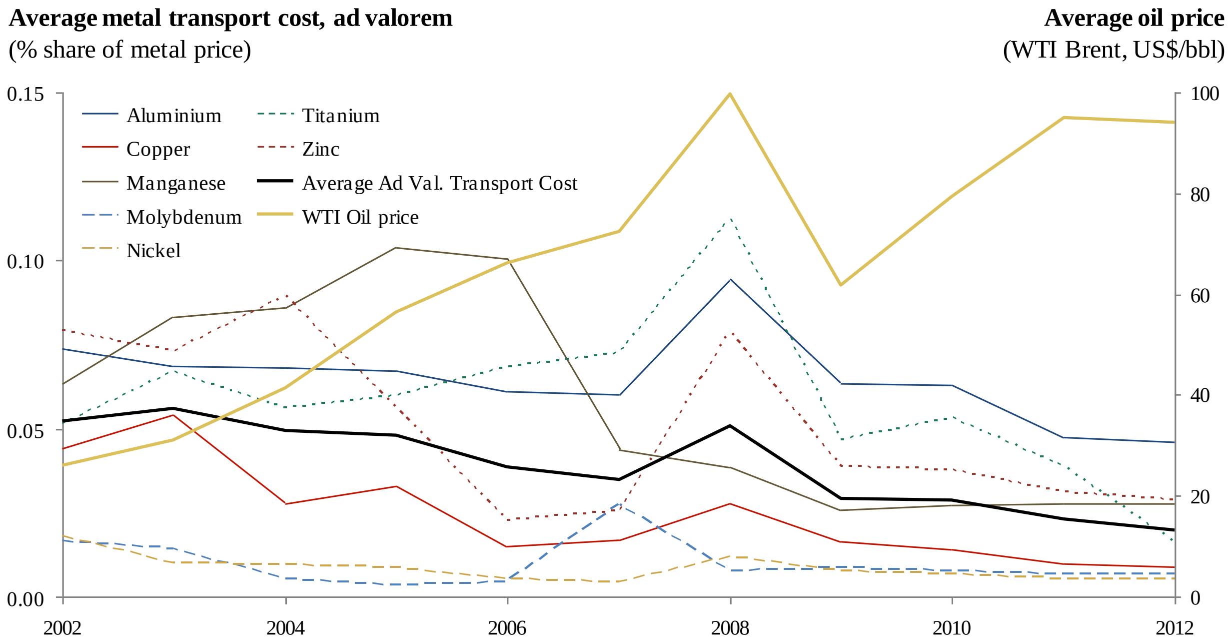

Figure 32 - Development of input cost factors for metal producers from 2002 until 2012

Whereas transport cost declined and energy cost increased the producer concentration in metal markets remained relatively constant but differed highly across the different markets under research.[323]

The copper market showed the lowest competition concentration while the molybdenum market started off as the most concentrated market. Nevertheless, the tables turned when producers pushed into the high margin molybdenum market. Unlike in the molybdenum market, the concentration in the zinc market increased due to consolidations during the observation period.

Nevertheless, we can deduct from Figure 33 that albeit the many mergers and acquisitions the competitor concentrations in the different markets slightly decreased during the observation period. This can be explained by the steep increase of metal prices and thereof generated cash flow in the beginning of the millennium. While the high metal prices lured many companies into developing new assets, the generated cash flow only made the development possible. Given a minimum lead

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[323] See Figure 32 - Development of input cost factors for metal producers from 2002 until 2012.

time of seven years to ramp up an operational asset this explains the many markets entries versus the end of the observation period.

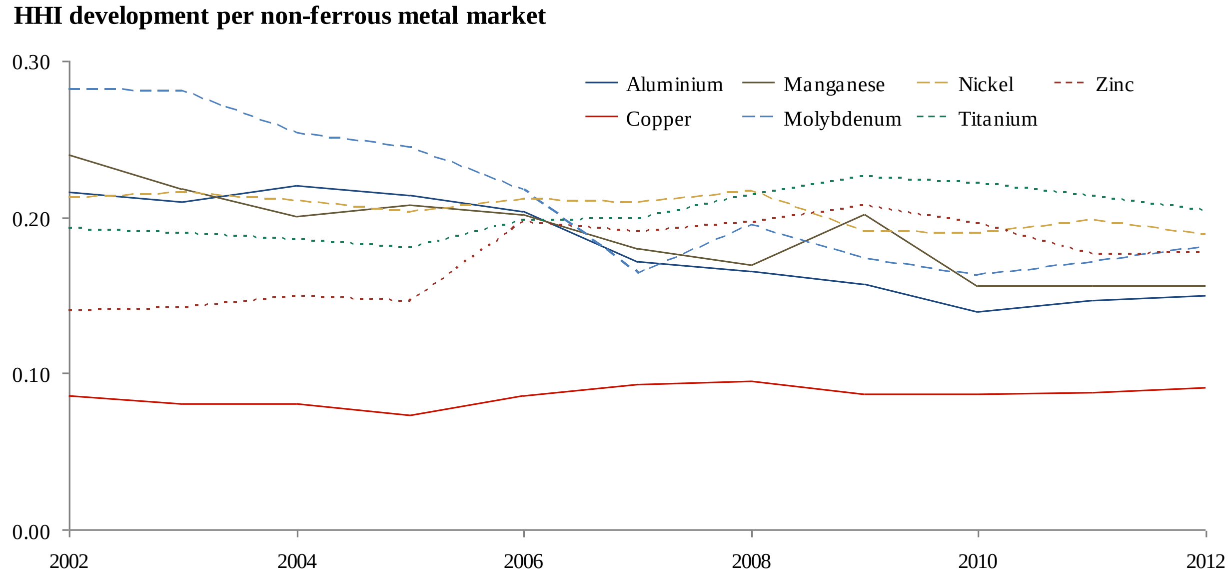

Figure 33 - Development of producer concentration in metal markets from 2002 until 2012

Unlike the relatively stable competitor concentration, demand and supply of non-ferrous metals varied greatly from 2002 until 2012. Demand dropped in 2003 and 2009, both times most probably as late consequences of economic downturns but also since the utilized indicator, namely seaborne metal volumes highly depend on stock levels and geographic relocation of metal customers. Metal supply increased every year with the exception of 2008. Nevertheless, until 2008 growth rates of metal supply were lower than growth rates of global GDP which can serve as an indicator for shortages in metal supply.[324] This again is one of the underlying reasons for the high growth in metal prices until 2008.[325]

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[324] As anticipated by Crowson in 2001, see Crowson 2001, p.41.
[325] See 3.1.1 for more details.

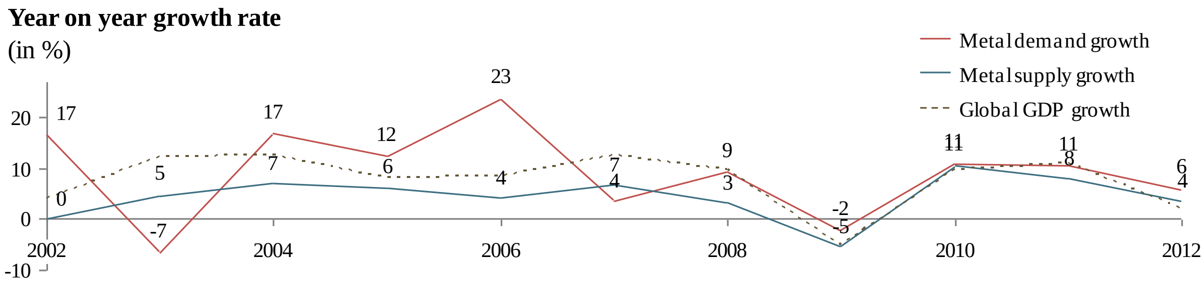

Figure 34 - Growth of metal supply and demand from 2002 until 2012

As explained in Table 1 the markets under research differ greatly in size: in 2012, almost 46 million metric tons of aluminium were produced whereas – although growing quickly – only 260 metric tons of molybdenum were produced.

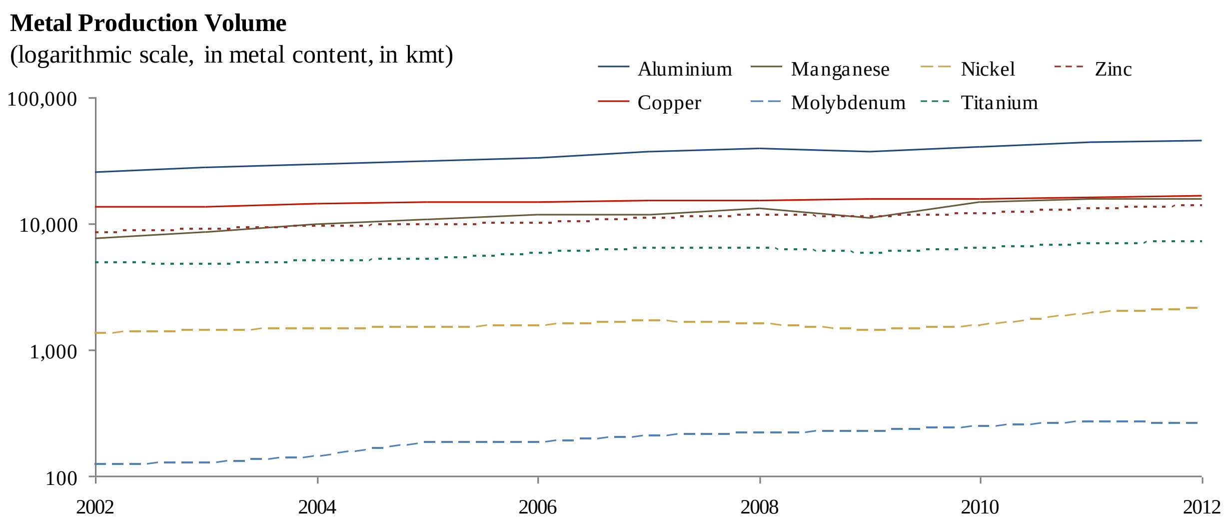

Figure 35 - Metal production volume per non-ferrous metal from 2002 until 2012

In addition, the markets also differ greatly with regards to the capital intensity as a share of revenues. While titanium dioxide producers publish depreciation figures on capital expenditure of up to 20% of their generated sales, manganese and molybdenum producers report figures between 5-10%. For manganese producers this can be explained by low production cost per ton of metal, for molybdenum producers the low capital intensity rates are due to the very high sales price of molybdenum.

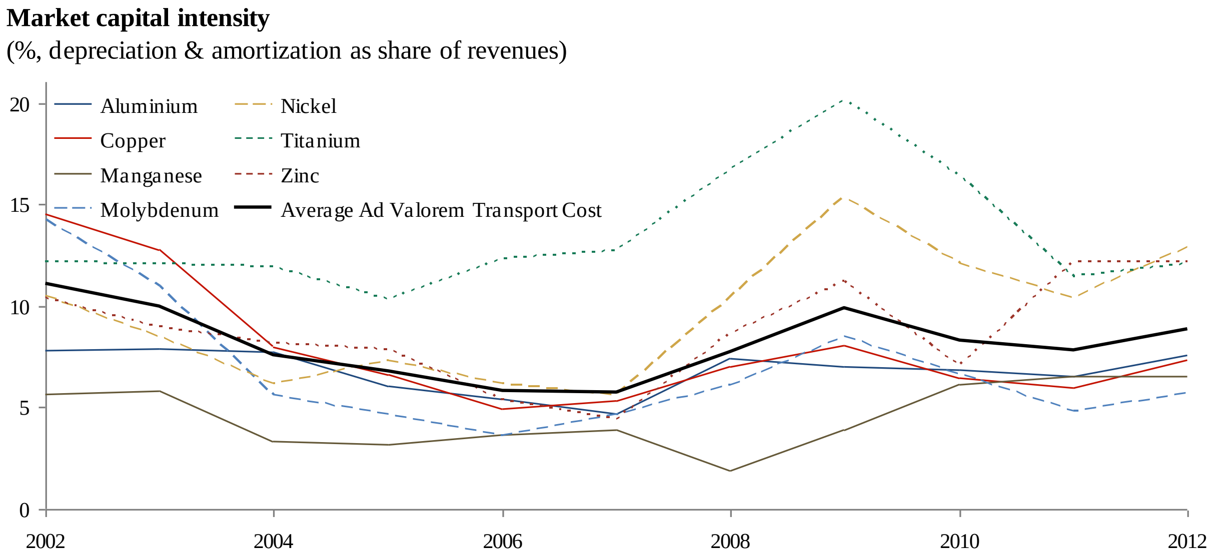

Figure 36 - Metal market capital intensity development from 2002 until 2012

Exogenous company variables

While the company performance is clearly dependent on many environmental, i.e. market factors, idiosyncratic factors also play an important role. To cover two of the most influential idiosyncratic factors we briefly discuss the two variables *Company Size* and *Company Capital Efficiency*:

In research, *Company Size* has been found to have either a positive or a negative impact on company profitability.[326] In some industries, implied cost disadvantages imposed on smaller firms operating at sub-optimal scale has led to lower profitability of smaller companies when compared to their larger competitors.[327] In other industries mostly more mature industries, exorbitant company size has led to inefficiency due to complex processes and hierarchical structures. In these industries, being smaller and more focused, has contributed to superior company performance.

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[326] See 3.2.1.
[327] See Hall, Weiss 1967, p.329 and Scherer, Ross 1990, p.126.

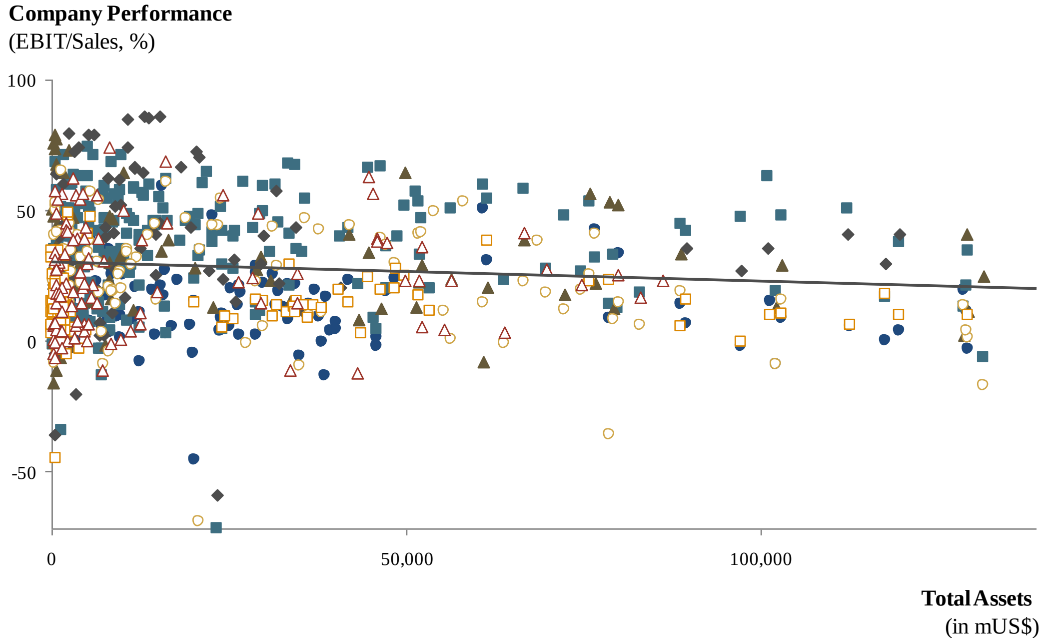

Figure 37 - Scatter plot between Company performance and Company Total Assets

Figure 37 shows the scatter plot of *Company Performance* explained by the variable *Company Total Assets* in which a negative relation between the two variables can be observed. This finding supports the latter notion of smaller miners being more profitable than larger ones and will be analyzed in more depth in the following regression analyses.

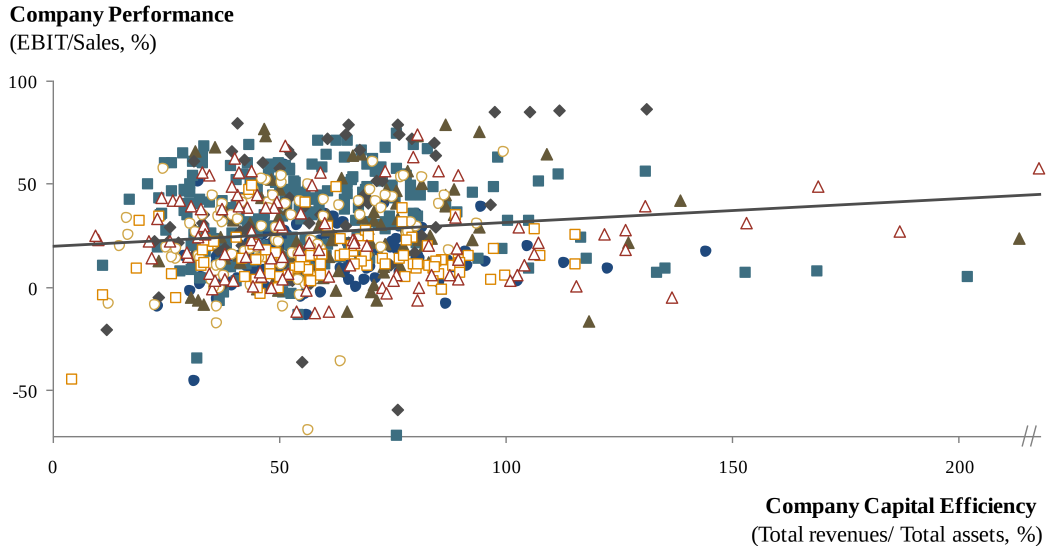

Figure 38 - Scatter plot between Company Performance and Company Capital Efficiency

In line with findings in research,[328] the scatter plot in Figure 38 shows that *Company Capital Efficiency* measured as the *Total Revenues* divided by *Total Assets* of a company has a positive relation to *Company Performance*.

In combination with the negative significance of *Company Size* this is an interesting finding: If only company size measured in *Total Assets* would have been considered its negative impact on *Company Performance* could also have been interpreted as optimized asset allocation of companies with fewer assets. Further analysis of this relation will be conducted in the following regression analyses.

5.2 Validation of hypotheses for the overall non-ferrous metal market

Following the descriptive analysis of the utilized measures and indicators we now statistically analyze the relation between the potential profitability determinants, i.e. the exogenous variables and the performance of metal producers, i.e. the endogenous variable. In a first step, we explain the process of the statistical analysis. Then, we analyze the singular correlations between all exogenous variables and the endogenous variable. Subsequently, we gradually analyze the exogenous variables in statistical models proceeding step by step in order to understand the impact of a combination of regressors on company performance. Last but not least, we discuss the robustness of the findings by addressing the potential in-exhaustiveness of the model, the challenge of multicollinearity among the regressors and the danger of utilizing an inconsistent estimator.

5.2.1 Process of the statistical analysis

In order to gather a first impression on the uni-variate relations among all exogenous and the endogenous variable we start the statistical analysis by scrutinizing the singular correlation coefficients among all the utilized variables.[329]

Based on this first impression we start the regression analyses by introducing different statistical control variables, first the *Market Metal Price* and then the main company-specific variables

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328 See 3.2.1.

329 The pair-wise Pearson correlation coefficient ρ ranges from $\rho = -1$ – absolute negative linear correlation to $\rho = 1$ – absolute positive linear correlation, see Backhaus 2011, p.336.

Company Size, *Company Capital Efficiency*, *Company Capital Intensity* and *Company Market Share* to obtain model (1)-(5).

Once we have tested the significance of the control variables we add the main market specific exogenous variables, namely *Market Ad Valorem Transport Cost*, *Global Energy Cost*, *Market Demand Growth*, *Market Concentration* and *Market Capital Intensity* to build the basic models (6)-(10). Model (10) then covers all key hypotheses for the overall dataset analysis and can thus be utilized to validate these.[330]

In a final step, we scrutinize additional company-specific and market-specific variables that we add to the basic model (10), namely *Company Size* measured in revenues, *Company Focus*, *Company Sales Capabilities* as well as *Market Size*, *Market Supply Growth* and *Market Stability of Producing Countries*. The coefficient estimations and p-values for these additional factors are summarized in the models (11)-(16).

As explained in 4.3.2 we utilize the Random Effects estimator to compute the underlying variance-covariance matrix, the variable coefficients and the residua of the model since industry dummies cannot be included in the regression with the fixed effects estimator.[331] For all presented regression analysis we have utilized estimators which compute cluster robust standard errors in the case of presumed heteroskedasticity within company clusters.[332]

The regression results are represented in tables which contain the coefficient estimates and their respective p-values. Coefficients that exhibit statistically significant estimations are marked with the symbols * ($0.05<p\leq0.1$), ** ($0.01<p\leq0.05$) and *** ($p\leq0.01$) depending on their level of significance.

For reasons of visualization coefficient estimations for commodity market dummies and time dummies are not included in the tables. Nevertheless, we test the relevance of time as well as commodity market dummies by conducting a Wald Test after each regression. The Wald Test tests

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330 See 3.2.1.
331 Estimation results of the Fixed Effects estimator are presented in the appendix, see 9.6.
332 Also see 4.3.2.

the null hypothesis of time and commodity market dummies equaling zero. High values of the χ^2 statistic lead to a rejection of this null hypothesis.[333]

All regression analyses are computed with the statistics software STATA, version 12.0 which covers all required functions.

5.2.2 Results for the overall non-ferrous metal market

Although the detailed analyses of profitability determinants is conducted via multivariate regressions the consideration of the linear correlation coefficients according to Pearson can help to detect linear relations between the endogenous variable and its potential regressors but also between the exogenous variables themselves. This can indicate issues of multicollinearity among regressors that need to be considered when structuring regressions and analyzing regression results Table 16 contains all correlation coefficients according to Pearson that measure the linear relation between two variables. The index ranges from -1 absolute negative linear correlation to +1 absolute positive linear correlation.[334]

In line with findings in research and our postulated hypotheses we find a positive correlation between *Company Performance* and *Market Metal Price* as well as *Market Demand Growth*. The negative relations that have been detected between *Company Performance* and *Ad Valorem Transport Cost*, *Market Capital Intensity* as well as *Market Size* are also in line with our hypotheses. What is striking, however, are the negative linear correlation coefficients between *Company Performance* and *Market Concentration/ Market HHI* as well as *Company Size* which will be closely analyzed in the following multivariate regression analyses.

333 See Cameron, Trivedi 2010, pp.389-394.
334 See Backhaus 2011, p.336.

Table 16 - Correlation matrix of the endogenous and the utilized exogenous variables

	Variables	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*	*(16)*	*(17)*
(1)	*Company EBIT margin*	*1.00*																
(2)	*Market Metal Price*	**0.27**	*1.00*															
(3)	*Company Size - Assets*	**-0.12**	0.03	*1.00*														
(4)	*Company Capital Efficiency*	0.06	-0.02	**-0.18**	*1.00*													
(5)	*Company Capital Intensity*	-0.10	-0.06	0.09	**-0.25**	*1.00*												
(6)	*Company Market Share*	-0.10	**0.17**	**0.25**	**0.12**	-0.05	*1.00*											
(7)	*Ad Valorem Transport Cost*	**-0.32**	**-0.38**	-0.04	0.09	**0.12**	0.09	*1.00*										
(8)	*Global Energy Cost*	0.00	**0.16**	**0.24**	0.01	0.03	-0.06	**-0.15**	*1.00*									
(9)	*Market Demand Growth*	**0.12**	0.01	0.02	0.10	-0.04	-0.01	0.07	0.09	*1.00*								
(10)	*Market concentration/ HHI*	**-0.16**	**0.21**	-0.02	0.08	0.05	**0.35**	**0.30**	-0.08	0.00	*1.00*							
(11)	*Market Capital Intensity*	**-0.38**	**-0.19**	0.05	**-0.13**	**0.28**	0.06	**0.49**	-0.07	**-0.14**	**0.20**	*1.00*						
(12)	*Company Size - Revenues*	-0.08	0.02	**0.93**	-0.01	0.02	**0.31**	0.01	**0.22**	0.05	0.01	0.03	*1.00*					
(13)	*Company Focus*	0.00	**-0.13**	**-0.58**	**0.15**	**-0.11**	**-0.23**	0.06	0.07	0.03	**-0.17**	0.01	**-0.58**	*1.00*				
(14)	*Company Sales Capabilities*	-0.04	0.00	-0.02	-0.02	**0.14**	-0.01	0.08	-0.06	-0.09	-0.01	0.07	-0.04	0.02	*1.00*			
(15)	*Market Size*	**-0.21**	**-0.45**	0.07	-0.01	-0.06	**-0.20**	0.00	**0.14**	**0.14**	**-0.26**	**-0.26**	0.06	0.05	0.01	*1.00*		
(16)	*Market Supply Growth*	0.08	**0.20**	0.00	0.06	-0.02	0.08	-0.01	0.07	**0.24**	**0.19**	**-0.14**	0.02	-0.05	-0.03	-0.02	*1.00*	
(17)	*Market instability of producing countries*	-0.04	**-0.35**	-0.04	**0.12**	-0.02	-0.09	**0.60**	-0.04	0.07	**-0.27**	**0.13**	0.02	**0.16**	-0.02	**0.16**	**-0.12**	*1.00*

The table shows the pair-wise Pearson correlation coefficients measure ρ ranging from ρ= -1 – absolute negative linear correlation to ρ= 1 – absolute positive linear correlation. Bold figures show correlations coefficients above 0.10 or below -0.10.

Introduction of control variables

We now introduce the different control variables that build the basis for the basic model and are all company specific variables apart from the metal market price that is constant per year for all producers of the same metal. As elaborated in 3.1.1 the metal price is expected to have a straight forward positive relation with company performance and is thus introduced first. Subsequently, all main company specific variables are introduced and tested for significance.[335]

As postulated in (H1), the *Market Metal Price* and *Company Performance* are positively related. This relation remains stably significant throughout the introduction of the company specific regressors. Among the company specific regressors the regression analyses confirm the relations as indicated by the Pearson correlation coefficients. *Company Size* seems to have a significant negative impact on *Company Performance* which is striking and will be further scrutinized in 5.3.2. In order to ensure that *Company Size* in Assets is not mis-specified to express the efficiency with which assets are utilized the variable *Capital Efficiency*[336] is introduced simultaneously. When introduced to the model *Company Capital Efficiency* proves to have a highly significant positive impact on *Company Performance* in line with (H10) while the negative impact of *Company Size* remains. Nonetheless, the additional other company specific variables, namely *Company Capital Intensity* and *Company Market Share* do not exhibit a statistically significant relation with *Company Performance* in the overall market analysis. This contradicts (H11) and (H12) and will be further tested in the single metal market analyses in chapter 6.

For the dummy variables that indicate the affiliation of an observation to a commodity market or a specific year we have included the Wald test statistic χ^2 that tests the null hypothesis of the dummy variables having no significant relation to *Company Performance*. All statistics are highly significant and lead to a rejection of this null hypothesis.

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[335] Note that the respective Variance Inflation Factors for the single regression models are summarized in Table 21 and discussed in more detail in chapter 5.2.3.

[336] Capital Efficiency measures the sales generated by the asset volume.

Table 17 - Overall dataset: Random Effects Models (1)-(5) - Introduction of Control Variables

Endogenous variable:	Random Effects				
Company EBIT margin	1	2	3	4	5
Market Metal Price	0.219**	0.231**	0.212**	0.213**	0.211**
(H1, +)	(0.021)	(0.015)	(0.018)	(0.018)	(0.022)
Company Size - Assets		-0.106***	-0.083**	-0.083**	-0.078*
(H9,+ or -)		(0.006)	(0.040)	(0.038)	(0.055)
Company Capital Efficiency			0.127***	0.122***	0.125***
(H10, +)			(0.001)	(0.002)	(0.001)
Company Capital Intensity				-0.059	-0.061
(H11, -)				(0.329)	(0.313)
Company Market Share					-0.030
(H12, +)					(0.616)
Wald test: Commodity χ^2	18***	15**	16***	16***	16***
Wald test: Year χ^2	112***	108***	96***	97***	97***
Wald test: Model χ^2	207	216	254	263	263
p-value	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations (N)	826	823	823	823	823
R^2 overall	0.235	0.236	0.219	0.221	0.226
R^2 between	0.186	0.163	0.133	0.143	0.145
R^2 within	0.263	0.270	0.289	0.289	0.289

The p-values in brackets are estimated based on cluster robust standard errors (cluster = business unit) / * 0.05<p≤0.1, ** 0.01<p≤0.05, *** p≤0.01 / All exogenous variables have been standardized before the analyses / (H, +/-) Hypotheses including postulated direction / Constant and dummy variables for commodity markets and year are not shown

Development of the basic model

Based on model (5) we now introduce the main market variables which are constant across different business units but vary over time. Given that the *Market Metal Price* causes elevated levels of multicollinearity if kept within the list of regressors[337] the variable is dropped in the models (7)-(16). For reasons of completeness, regression results for models (7)-(16) including *Metal Market Price* can be found in the appendix in 9.5.

As presented in Table 18 all hypothesized relations are strongly supported apart from the one on *Global Energy Cost*. Reflecting on this we can find a plausible explanation: *Global Energy Cost*, i.e. the price of oil does neither exhibit a stable nor a statistically significant relation to *Company*

[337] The Variance Inflation Factors (VIFs) that indicate the elevated multicollinearity between Market Metal Price and the other variables are presented in Table 37 in the appendix.

Performance when included in the regression analysis. This indicates that the price of oil as a metal unspecific variable is too generic to reflect the impact of energy cost on the different metal markets.

Table 18 - Overall dataset: Random Effects Models (6)-(10) - Development of the basic model

Endogenous variable: *Company EBIT margin*	Random Effects									
	6		7		8		9		10	
Market Metal Price	0.162	*								
(H1, +)	(0.060)									
Company Size - Assets	-0.106	***	-0.103	**	-0.104	**	-0.096	**	-0.106	**
(H9,+ or -)	(0.007)		(0.017)		(0.016)		(0.025)		(0.022)	
Company Capital Efficiency	0.117	***	0.127	***	0.122	***	0.118	***	0.093	**
(H10, +)	(0.002)		(0.002)		(0.003)		(0.005)		(0.033)	
Company Capital Intensity	-0.026		-0.023		-0.025		-0.033		-0.021	
(H11, -)	(0.655)		(0.695)		(0.675)		(0.571)		(0.705)	
Company Market Share	0.004		-0.001		-0.004		-0.024		-0.026	
(H12, +)	(0.943)		(0.986)		(0.952)		(0.707)		(0.704)	
Ad Val. Transport Cost	-0.336	***	-0.349	***	-0.364	***	-0.376	***	-0.239	***
(H2, -)	(0.000)		(0.000)		(0.000)		(0.000)		(0.000)	
Global Energy Cost			0.021		0.036		0.042		0.001	
(H3, -)			(0.662)		(0.461)		(0.374)		(0.973)	
Market Demand Growth					0.082	***	0.081	***	0.072	***
(H4, +)					(0.004)		(0.004)		(0.003)	
Market HHI							0.084		0.150	**
(H5, +)							(0.205)		(0.016)	
Market Capital Intensity									-0.373	***
(H6, + or -)									(0.000)	
Wald test: Commodity χ^2	21	***	22	***	24	***	32	***	52	***
Wald test: Year χ^2	123	***	171	***	198	***	199	***	90	***
Wald test: Model χ^2	329		304		406		434		513	
p-value	(0.000)		(0.000)		(0.000)		(0.000)		(0.000)	
Observations (N)	823		823		823		823		823	
R^2 overall	0.305		0.298		0.305		0.311		0.353	
R^2 between	0.222		0.217		0.224		0.235		0.246	
R^2 within	0.335		0.326		0.335		0.335		0.403	

The p-values in brackets are estimated based on cluster robust standard errors (cluster = business unit) / * 0.05<p≤0.1, ** 0.01<p≤0.05, *** p≤0.01 / All exogenous variables have been standardized before the analyses / (H, +/-) Hypotheses including postulated direction / Constant and dummy variables for commodity markets and year are not shown

What remains noteworthy is that the impact of *Market Concentration* on *Company Performance* is significantly positive unlike indicated by the linear correlation coefficient of Pearson. Nevertheless, *Market Concentration* only becomes statistically significant if *Market Capital Intensity* is added to the list of regressors in model (10). This can be explained by the positive correlation between the two variables:[338] Markets with higher capital requirements tend to be more concentrated. Removing this negative relation between the variables *Market Concentration* to *Company Performance* by adding the root causing variable *Market Capital Intensity* thus leads to the increase in statistical significance of *Market Concentration* from model (10) onwards.

Analysis of additional factors

To test further hypotheses and the robustness of the model we now enrich model (10) by adding new variables to analyze their singular impact combined with the variables of the basic model on company performance in the models (11)-(16). Thereby, we refrain from combining these single variables altogether in one combined model in order to avoid creating elevated levels of multicollinearity.[339]

First, we introduce the miner specific variables *Company Size* measured in Total Revenues, *Company Focus* and *Company Sales Capabilities*. Similar to the coefficient estimation for the variable *Company Size – Assets* the coefficient for the variable *Company Size – Revenues* also exhibits a negative relation to *Company Performance* although its significance level is not as strong.[340] The variable *Company Focus* which is measured as the revenues generated by the metal under research divided by the total revenues of the company is negatively related to Company Performance which supports the notion that diversified companies perform better and validates our hypothesis (H13). The last company specific variable, namely *Company Sales Capabilities*, exhibits no significant relation with *Company Performance*. When analyzing the single metal markets in chapter 6 we will further scrutinize this variable.

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[338] See Table 16 - Correlation matrix of the endogenous and the utilized exogenous variables.

[339] See Table 21 - Overview on Variance Inflation Factors of the Random Effects Models (6)-(16).

[340] When introducing the variable *Company Size – Revenues* to the model we have to drop *Company Size – Assets* since both variables are highly correlated, see Table 16.

Table 19 - Overall dataset: Random Effects Models (11)-(16) - Additional performance drivers

Endogenous variable:	Random Effects					
Company EBIT margin	11	12	13	14	15	16
Market Metal Price						
(H1, +)						
Company Size - Assets		-0.136 **	-0.092 **	-0.108 **	-0.105 **	-0.106 **
(H9,+ or -)		(0.010)	(0.039)	(0.015)	(0.023)	(0.021)
Company Capital Efficiency	0.107 **	0.090 **	0.073 *	0.089 **	0.092 **	0.093 **
(H10, +)	(0.015)	(0.037)	(0.059)	(0.039)	(0.033)	(0.033)
Company Capital Intensity	-0.022	-0.023	-0.021	-0.026	-0.023	-0.022
(H11, -)	(0.686)	(0.678)	(0.716)	(0.632)	(0.671)	(0.686)
Company Market Share	-0.035	-0.022	-0.030	-0.018	-0.027	-0.026
(H12, +)	(0.604)	(0.744)	(0.649)	(0.796)	(0.685)	(0.703)
Ad Valorem Transport Cost	-0.238 ***	-0.235 ***	-0.260 ***	-0.255 ***	-0.238 ***	-0.245 ***
(H2, -)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Global Energy Cost	-0.015	0.014	11.597 ***	0.048	-0.008	0.015
(H3, -)	(0.726)	(0.748)	(0.000)	(0.325)	(0.854)	(0.759)
Market Demand Growth	0.070 ***	0.072 ***	0.106 ***	0.074 ***	0.064 ***	0.072 ***
(H4, +)	(0.003)	(0.003)	(0.000)	(0.002)	(0.009)	(0.003)
Market HHI	0.154 **	0.146 **	0.180 ***	0.079	0.150 **	0.150 **
(H5, +)	(0.015)	(0.017)	(0.003)	(0.279)	(0.015)	(0.016)
Market Capital Intensity	-0.372 ***	-0.383 ***	-0.333 ***	-0.363 ***	-0.374 ***	-0.374 ***
(H6, + or -)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Company Size - Revenues	-0.071					
(H9,+ or -)	(0.114)					
Company Focus		-0.103 *				
(H13,+ or -)		(0.095)				
Company Sales Capabilities			0.009			
			(0.740)			
Market Size				-0.323 **		
(H7, -)				(0.015)		
Market Supply Growth					0.050 **	
(H4, +)					(0.046)	
Market stability of prod.						0.035
countries (H8, +)						(0.647)
Wald test: Commodity χ^2	54 ***	61 ***	66 ***	16 ***	54 ***	51 ***
Wald test: Year χ^2	90 ***	91 ***	92 ***	94 ***	72 ***	85 ***
Wald test: Model χ^2	509	526	491	523	515	510
p-value	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations (N)	823	823	724	823	823	823
R^2 overall	0.353	0.366	0.368	0.354	0.355	0.353
R^2 between	0.257	0.263	0.338	0.243	0.247	0.245
R^2 within	0.398	0.403	0.371	0.408	0.406	0.403

The p-values in brackets are estimated based on cluster robust standard errors (cluster = business unit) / * $0.05<p\leq0.1$, ** $0.01<p\leq0.05$, *** $p\leq0.01$ / All exogenous variables have been standardized before the analyses / (H, +/-) Hypotheses including postulated direction / Constant and dummy variables for commodity markets and year are not shown

After having assessed the company specific variables we gradually test the market variables *Market Size*, *Market Supply Growth* and *Market Stability of Producing Countries*. As can be seen in Table 21 the level of multicollinearity is relatively high when adding the variables *Market Size* and *Market Stability of Producing Countries*. Thus, findings of the models (14) and (16) have to be interpreted with more care and will be further discussed in 5.2.3. Nonetheless, the level variable *Market Size* exhibits a negative impact on *Company Performance* as postulated in (H7). This supports the finding in the descriptive analysis of the dataset that niche markets such as the molybdenum market exhibit higher returns than larger markets such as the Aluminium market.[341] When adding the variable *Market Supply Growth* to the regression model we detect a positive impact on *Company Performance* (H4) although the variable's coefficient estimation is statistically not as significant as the one for *Market Demand Growth*. Last but not least, we test the relevance of the stability of the metal production countries with the variable *Market Stability of Producing Countries* on the miners' profitability to find no statistically significant impact when analyzing the overall non-ferrous metal market. Again, this will be scrutinized further in the single metal markets in chapter 6.

5.2.3 Robustness of results

The above described regression results all base upon statistical assumptions whose violation can generate inconsistent or inefficient estimations of the coefficients, the respective standard errors and its p-values. In the following, we thus address the validity of the major assumptions given the scrutinized dataset and introduced model.

There are three major areas for potential concern that should be considered in order to validate the utilized models:[342]

1. *Exhaustiveness of the model:* Potential lack of relevant explanatory variables?
2. *Multicollinearity:* Potential linear dependency of exogenous variables?
3. *Utilization of inconsistent estimators:* Endogenous, heteroscedastic or correlated errors?

[341] See 5.1.
[342] See for example Gelman, Hill 2006, pp.513-515, Tabachnick, Fidell 2013, pp.122-128 or Backhaus 2011, p.84-85.

Exhaustiveness of the model

In their meta-study, Capon et al. publish a list of causal factors which, in research, have thus far proved to exhibit statistically significant relations to the profitability of companies.[343] These causal factors have been split in three clusters: the market or environmental factors, the strategy or company-specific factors and the organizational or company internal factors. With our database we have covered the environmental and company specific cluster, however we have not included the organizational factors since data are not available from the secondary data sources such as company filings and annual reports.[344] For the first two clusters of influential factors, namely the strategic and the environmental cluster Table 20 gives an overview of the identified drivers by Capon et al. and the according variables in our dataset and models in which we have included these drivers.

With regards to company specific variables, we have included as many variables as we could generate from the available data and have excluded a few since they were either too highly correlated to other variables in the dataset or irrelevant for the mining industry: *Company Debt* has been tested but excluded for reasons of multicollinearity with the variables indicating *Company Size*.[345] Since we only analyze the performance of the first value chain step, namely the performance of mining business units the variable *Vertical Integration* is not in the focus of our analysis.[346] The profitability determinant *Research and Development* will play a much more significant role in the future when more and more mines will be operated autonomously requiring only limited human labor input.[347] During the observation period though this did not yet play an important role. Concerning *Marketing* as a profitability determinant this determinant plays a rather minor role in the mining industry when compared to other industries since branded products for which marketing or sales expenses would be necessary do not exist in the commoditized non-ferrous metal markets. Last but not least, data on *Corporate Social Responsibility*, on the *Quality of Product or Service* and on *Inventory levels* were not available across the scrutinized business units and thus have been excluded from the analysis.

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343 See Capon et al. 1996, p.57.
344 As soon as these data are available it would be interesting to understand their impact on Company Performance.
345 See Table 39 - Correlation coefficients for Company Performance with Company Size & Debt.
346 If miners are vertically integrated their mining business unit have to sell production volumes at transfer prices to metal processing business units in order to ensure accountability within the respective company.
347 See Shaffer, Stentz 1992, p.638.

Table 20 - Overview of Performance Drivers[348]

Performance driver	Utilized variable to express performance driver	Included in Model
Company specific/ strategic variable		
Company Size	Company Size	(2)-(16)
Market Share	Market Share	(5)-(16)
Capital Investment	Company Capital Intensity	(10)-(16)
Diversification	Company Focus	(12)
Relative Price	Company Sales Capabilities	(13)
Debt	Debt	*dropped*[349]
Vertical Integration	*not relevant for analysis*	
Research & Development	*not relevant for analysis*	
Advertising/ Marketing / Sales Force Expense	*not relevant for mining*	
New Product Sales	*not relevant for mining*	
Corporate Social Responsibility	*not available*	
Quality of Product & Service	*not available*	
Inventory	*not available*	
Market/ environmental variable		
Industry Concentration	Market HHI	(9)-(16)
Industry Growth	Market supply growth	(15)
Industry Capital Investment	Market capital intensity	(10)-(16)
Industry Size	Market size	(14)
Industry Barriers to Entry	Market capital intensity	(10)-(16)
Industry Exports	Market demand growth	(8)-(16)
Industry Diversification	*not relevant for analysis*	
Industry Geographic dispersion	*not relevant for analysis*	
Industry Imports	*not relevant for analysis*	
Industry Advertising	*not relevant for mining*	
Industry Minimum Efficient Scale	*not available*	
Industry Economies of Scale	*not available*	

As for the market performance drivers, we have excluded *Industry diversification*, *Industry Geographic dispersion* and *Industry imports* because we are analyzing global metal markets compared to most of the analyses that are included in the meta-analysis and have generally focused

[348] See Table 7 - Factors used frequently enough to determine significant patterns on firm performance.
[349] Dropped due to multicollinearity reasons, see Table 39.

on the US or the UK market only. *Industry advertising* like company specific marketing expenses is an insignificant cost component in the mining industry and does not differ across the different markets under research. Finally, *Minimum efficient scale* and *Market economies of scale* could not be included since the data were not available or were hard to be approximated across the different markets under research.

Summarizing, we have covered the majority of detected profitability determinants with the variables that constitute our database. Nevertheless, we cannot ensure to cover all possible determinants. Thus, we have introduced time and market dummies that can absorb so far unconsidered effects given the available determinants.[350] In order to keep multicollinearity as low as possible we only introduce a market dummy for five out of the seven markets and nine out of the eleven years under research.[351] The Wald Test statistic χ^2 confirms the significance and hence the utilization of the time and market dummies in all of the analyzed models (1)-(16).

Multicollinearity

The most important mathematical assumption of the regression model is that its deterministic component is a linear function of the separate predictors.[352] If the separate predictors are linearly dependent the model coefficients cannot be estimated efficiently.[353] In order to ensure linear independency we hence consider the variance inflation factors (VIF) of each of the analyzed variables. The VIF of an exogenous variable is calculated based on the coefficient of determination R^2 from a linear regression that utilizes all other exogenous variable to explain the exogenous variable that is to be scrutinized for collinearity: The higher the coefficient of determination the higher the linear dependency of the analyzed variable with the other exogenous variables. In general, VIFs that exceed the threshold ten are considered to threaten the mathematical assumption of linear independency.[354]

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350 In addition, we allow for a company specific error term in the random effects model, see 4.3.2.

351 One out of the 7 and respective 11 market dummies and year dummies has to be dropped for linear dependency reasons. We have excluded an additional market dummy to instead include explanatory variables that are either market or time invariant without increasing multicollinearity.

352 See Backhaus 2011, pp.93-94.

353 This would be the case if we included time or market dummies for each of the years and metals under research.

354 See Kutner et al. 2005, pp.408-410.

Table 21 - Overview on Variance Inflation Factors of the Random Effects Models (6)-(16)

Endogenous variable:	Model										
Company EBIT margin	6	7	8	9	10	11	12	13	14	15	16
cd1 (aluminum)	1.23	1.21	1.23	1.99	2.42	2.42	2.45	2.41	30.20	2.46	3.44
cd3 (manganese)	1.30	1.30	1.30	2.15	3.01	3.02	3.03	3.12	3.34	3.09	3.85
cd4 (molybdenum)	4.16	4.19	4.21	4.21	4.26	4.55	4.33	4.51	7.11	4.25	4.38
cd5 (nickel)	1.93	1.39	1.39	3.27	3.28	3.28	3.29	3.37	4.93	3.30	10.94
cd7 (titanium)	1.32	1.29	1.33	1.84	1.88	1.89	1.96	1.96	1.90	1.88	4.31
td03 (2003)	1.39	1.73	1.87	1.87	1.91	1.91	1.91		1.91	1.99	2.70
td04 (2004)	1.39	1.54	1.55	1.55	1.78	1.78	1.78	1.85	1.78	1.87	2.39
td05 (2005)	1.45	1.42	1.42	1.43	1.78	1.78	1.79	1.74	1.79	1.84	1.99
td06 (2006)	1.48	1.43	1.47	1.48	1.94	1.94	1.95	2.04	1.94	1.95	1.94
td07 (2007)	1.57	1.45	1.46	1.47	1.94	1.94	1.94	1.92	1.94	2.00	1.94
td08 (2008)	1.54	2.04	2.04	2.05	2.16	2.15	2.19	2.19	2.17	2.16	2.22
td09 (2009)	1.41	1.41	1.47	1.47	1.47	1.46	1.48	1.39	1.47	1.59	1.73
td10 (2010)	1.45	1.52	1.53	1.54	1.57	1.57	1.57	1.53	1.57	1.74	1.72
td11 (2011)	1.46	1.85	1.86	1.86	1.90	1.90	1.90	1.88	1.90	1.95	1.90
Market Metal Price	4.93										
Company Size - Assets	1.25	1.30	1.30	1.30	1.30		2.16	1.28	1.30	1.30	1.30
Company Capital Efficiency	1.28	1.28	1.28	1.29	1.29	1.26	1.29	1.29	1.30	1.29	1.30
Company Capital Intensity	1.31	1.31	1.31	1.32	1.32	1.32	1.33	1.35	1.32	1.32	1.33
Company Market Share	1.30	1.31	1.31	1.35	1.35	1.39	1.35	1.35	1.36	1.35	1.35
Ad Valorem Transport Cost	1.42	1.36	1.38	2.55	3.15	3.15	3.16	3.56	3.43	3.15	3.98
Global Energy Cost		3.04	3.09	3.09	3.11	3.07	3.31	2.69	3.75	3.18	4.45
Market Demand Growth			1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.37	1.33
Market HHI				3.80	3.96	3.96	3.97	4.10	6.33	3.97	4.05
Market Capital Intensity					3.63	3.63	3.64	4.11	3.65	3.63	3.64
Company Size - Revenues						1.27					
Company Focus							1.94				
Company Sales Capabilities								1.07			
Market Size									37.42		
Market Size Growth										1.70	
Market instability of producing countries											11.70
Average VIF	1.73	1.67	1.67	2.01	2.25	2.26	2.29	2.26	5.21	2.26	3.33
Maximum VIF	4.93	4.19	4.21	4.21	4.26	4.55	4.33	4.51	37.42	4.25	11.70

As we can see in Table 21 the only two exogenous variables that cause concern are *Market Size* and *Market Political Stability of Producing Countries* that are introduced in model 14 and model

16. In both models but in particular in model (14), collinearity is relatively high and we thus treat the findings from these two models with care, however keep the variables for comparison reasons with the single market analyses presented in chapter 6.

Utilization of an inconsistent estimator

Utilizing an inconsistent or inefficient estimator can lead to instable estimation results of the coefficients. An estimator performs inefficiently as soon as one of the three fundamental assumptions on the properties of the standard errors is violated: This is the case if we have endogenous, heteroscedastic or correlated standard errors in the regression model.[355]

Endogenous standard errors are standard errors that are not independent of the exogenous variables, i.e. they contain a systematic error dependent on the structure of the dataset. In panel data, this is often found since clusters such as companies within the dataset lead to cluster specific error terms that are correlated to the cluster specific exogenous variables. To address this naturally occurring endogeneity, estimators such as the Random Effects or Fixed Effects estimator can be utilized.[356]

Since the requirements for the Fixed Effects Estimator are less strict[357] and hence consistent even if the Random Effects estimator is not we utilize the Hausman Test which statistically compares the differences in the coefficient estimations of the two estimators.[358] The null hypothesis of the Hausman Test postulates that cluster specific effects are random and thus both estimators perform consistently. Table 43 summarizes the χ^2 statistic and p-values of the performed Hausman Tests for all analyzed models. It shows that the null hypothesis is not rejected for any of the models (1)-(10) and (13) while we have to consider that we are testing models without cluster robust standard

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355 See Backhaus 2011, pp.90-92

356 While the Random Effects estimator introduces a random cluster specific endogenous error term (see 4.3.1), the Fixed Effects estimator allows for a fixed cluster specific but time-invariant error term. Therefore, the Fixed Effects estimator does not allow the introduction of time-invariant regressors. Since we would like to analyze time-invariant variables we prefer to utilize the Random Effects estimator as explained in 4.3.2. Thus, we test whether the preferred Random Effects Estimator performs consistently to ensure the robustness of our regression results.

357 See 4.3.1.

358 See Cameron, Trivedi 2010, pp.260-261.

errors and time-invariant regressors.[359] Thus, we do not discard the results of the Random Effects Estimator based on the results of the Hausman Test.[360]

The other two mathematical requirements on the properties of the standard errors, namely the assumption of homoscedastic and uncorrelated standard errors are met due to the utilization of cluster-robust standard errors that correct the variance-covariance matrix of the distribution of the estimator to allow heterogeneity and correlation within the defined cluster.[361]

5.3 Discussion of findings on the overall non-ferrous metal market

In this section we will first summarize the results of the regression analyses and compare these to the initially postulated hypotheses in 3.2.1. Subsequently, we interpret and discuss the findings for the overall market analyses before diving into the analyses of the single commodity markets.

5.3.1 Comparing regression results with hypotheses

Table 22 summarizes the initially hypothesized direction of the relation between the explanatory variable and the profitability of the non-ferrous metal producers and compares these with the test results of the regression analyses. In addition, the minimum statistical significances of the coefficient estimations are marked for each of the utilized estimators, namely the Random Effects estimator and the Fixed Effects estimator.

Among the hypotheses regarding the impact of the market specific explanatory variables all hypotheses apart from (H3) and (H8) could be confirmed. Neither the global energy cost nor the stability of the production countries showed a stable or significant impact on the profitability of non-ferrous metal producers across the seven markets under research. The variable *Market Capital Intensity* did have a highly significant negative impact on *Company Performance*. With regards to company specific explanatory variables all hypotheses could be confirmed apart from (H11) and (H12). As a time-invariant variable, *Company Capital Intensity*, i.e. (H11) could only be tested in

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[359] The Hausman test can only be performed on conventional standard errors (instead of cluster robust standard errors) and on regression models without time-invariant variables, such as *Company Capital Intensity* and all highly significant Commodity Dummies.

[360] To test robustness further we have also included all regressions based on the Fixed Effects Estimator in 9.6.

[361] See Cameron, Trivedi 2010, pp.82-83.

the Random Effects Model where it did prove to have a stably negative impact on company performance throughout all tested models. Nevertheless, the negative impact could not be confirmed as statistically significant. Also unlike hypothesized, *Company Market Power* measured as the market share in revenues of a specific company did not exhibit a stably positive or statistically significant impact on *Company Performance*.

Table 22 - Overview on hypotheses validation for the overall model

Hypothesis	Explanatory variable of *Company EBIT margin*	Direction of impact	Test result	Random Effects	Fixed Effects[362]
Market specific explanatory variables					
H1	Market price	+	y	*	***
H2	Market production cost: Transport cost	-	y	***	***
H3	Market production cost: Energy cost	-	n		
H4	Market growth	+	y	***[363]	***[364]
H5	Market concentration	+	y	**[365]	*
H6	Market capital intensity	+ or -	y (-)	***	***
H7	Market size	-	y	**	**
H8	Market stability of production countries	-	n		
Company specific explanatory variables					
H9	Company size	+ or -	y (-)	**[366]	**
H10	Company capital efficiency	+	y	*	***
H11	Company capital intensity	-	y		na
H12	Company market power	+	n		
H13	Company focus	+ or -	y (-)	*	

Direction of impact: + positive impact, - negative impact; *Test result:* y direction of impact was confirmed in tested models, (+/-) direction of impact for two-sided hypotheses, n direction of impact was not confirmed in tested models, * minimum statistical significance of 0.05<p≤0.1, ** minimum statistical significance of 0.01<p≤0.05, *** minimum statistical significance of p≤0.01, na not available

362 Please refer to Table 41, Table 42 and Table 42 in the appendix for the results of the fixed effectsestimator.
363 *Market Demand Growth* with stable significance level of *** whereas *Market Supply Growth* with stable significance level of **.
364 *Market Demand Growth* with stable significance level of *** whereas *Market Supply Growth* with stable significance level of *.
365 In combination with *Market Capital Intensity*.
366 Company Size measured in Assets with stable significance level of ** whereas Company Size in Revenues with negative impact yet without statistical significance.

In general, all tested explanatory variables show similar coefficient estimations and levels of significance for the two different estimators, i.e. the preferred Random Effects estimator and the Fixed Effects estimator.[367] The only differences in coefficient estimation originate from the fact that time-invariant variables such as *Company Capital Intensity* and the commodity dummies have to be excluded for the Fixed Effects Estimator for it to be applicable. Variables that could serve as a linear combination of the commodity dummies such as *Market Concentration* thus show slightly different estimations of coefficients and levels of significance.

5.3.2 Evaluation of results

In this section we will evaluate the test results of the regression analyses and put these in parenthesis to existing research that we discussed in chapter 3. Thus, when discussing the results we follow the structure of section 3.2.1 in which we deducted the hypotheses from research.

Market specific explanatory factors:

1. *Market Metal Price*

   As hypothesized, *Market Metal Price* has proven to have a positive impact on *Company Performance* from model (1) through to model (6). As soon as *Global Energy Cost* is added to the vector of explanatory variables in the regression model *Market Metal Price* can be explained as a linear combination of the other regressors and thus becomes linear dependent on the other explanatory variables. Therefore, it has been dropped from model (7) onwards. Nevertheless, the positive impact on *Company Performance* confirms that Performance in the non-ferrous metal markets under research is heavily driven by the metal's market price. This indicates that most sales volumes are indexed to some sort of global market price.

2. *Market input cost: Energy Cost*

   Besides wages and transport cost energy cost represents one of the biggest operational expenditure drivers. Nevertheless, the coefficient of the variable *Global Energy Cost* does not exhibit any statistical significance. This can be due to two facts:

[367] We prefer to utilize the Random Effects Estimator in order to test the significance of time-invariant variables.

On the one hand, energy input cost differ per metal, region and extrusion process. Thus, the metal invariant and regionally invariant variable *Global Energy Cost* is thus defined too broadly in order to grasp the significance of energy input cost for the different metals. The comparison of the regression models in the single metal markets with the overall market in 6.3 will help to understand if this issue drives the lack of significance.

Apart from the scope of the variable there is another issue with utilizing the oil price as an indication for global energy prices: oil prices used to be a good approximation for global energy prices. However, the low gas price and the introduction of renewable energy sources especially in remote areas has led to a shift from oil to other forms of energy generation in the mining industry and thus most probably contributes to the lack of significance.

3. *Market input cost: Transport Cost*

Unlike the global energy cost variable that was metal market invariant the analyzed transport cost variable is calculated as the share of maritime transport cost of the market metal price. Therefore, the transport cost reflect the ad valorem cost per metal. Throughout all models *Ad Valorem Transport Cost* have shown a statistically highly significant negative influence on *Company Performance*. Although often overlooked by mining outsiders, this finding does not come as a complete surprise since this cost component is difficult to change or optimize from a miner's perspective especially if not in-sourced. In order to weaken the dependence on this external cost driver many miners and commodity traders have built up proprietary means of maritime transportation. Nevertheless, whether in-sourced or not, slow response capability to changes in demand,[368] low capacity utilization in times of little demand and very expensive idle times of unutilized vessels paired with low metal prices in times of economic downturn lead to the high impact of ad valorem transport cost on company performance. When analyzing the potential profitability and performance of miners or mining assets, one should thus always consider the miner's

[368] Similar to the aerospace industry, maritime transportation capacity has very long lead times which complicate the quick reaction to changes in demand.

dependence on maritime transportation and its sensitivity to changes in maritime transportation cost.

4. *Market Growth*

As explained in 3.2.1, general research has found a positive impact of Market Growth on Company Performance.[369] To test whether this originates from increasing demand or adjustments in production capacity lagging behind changes in demand we have tested two different variables as explanatory variables: *Metal Demand Growth* and *Metal Supply Growth*. During the observation period both variables exhibit a statistically highly significant positive and stable impact on company performance, even when tested together. Changes in demand seem to have influenced *Company Performance* slightly stronger than changes in supply which supports the high dependency between profitability and innate demand in commoditized markets[370] and emphasizes the importance of its precise anticipation[371].

5. *Market Concentration*

The competition concentration measured by the Herfindahl-Hirschman Index has statistically proved to have a positive impact on Company Performance and thus underpins a similar finding of Slade for the years 1994-1998 in which she analyzes the profitability of entire mining companies with revenue weights per business unit to approximate firm variables and business unit performance.[372] We can thus assume that the increased competition from new market entrants especially in low cost areas like Asia which outbalanced the many mergers and acquisitions during the observation period has led to lower profitability of the single metal producers.

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[369] See Capon et al. 1996, p.57.
[370] Unlike luxury or branded products, demand cannot be generated or driven by marketing or advertizing.
[371] See Crowson 2001, pp.40-41.
[372] See Slade 2004, pp.18-19.

6. *Market Capital Intensity*

   Market Capital Intensity has been found to have a negative impact on *Company Performance*. This can be explained by two self-enforcing facts:

   First of all, *Market Capital Intensity* can serve as an entry barrier for companies not yet active in the mining industry: However, most of the companies in the dataset are already active in the mining industry and are hence used to the high asset and capital requirements in mining and the inherent risk that comes along with high capital allocation. Therefore, capital intensity does not necessarily deter mining companies that are used to these circumstances to enter new metal markets if expected profitability is sufficiently high.

   Secondly, the miner-specific variable *Company Capital Intensity*, which approximates capital investment over revenues as a time averaged variable did not exhibit any statistical significant negative impact on Company Performance as originally hypothesized.[373] Yet, since capital expenditures (CapEx) represent one of the biggest cost blocks in the mining industry the market but not time invariant measure *Market Capital Intensity* absorbs the negative impact of the capital expenditures as it better explains the measures' fluctuation over time.

7. *Market Size*

   As can be seen in Table 37 the multicollinearity of *Market Size* in model (14) is relatively high.[374] Nonetheless, in order to understand the impact of *Market Size* on *Company Performance* we have conducted a separate regression analysis excluding the commodity dummy variable for the copper market and the market concentration variable from model (10).[375] As presented in Table 38 the results confirm the negative influence of *Market Size* on *Company Performance* postulated in (H7).[376] Producers in smaller markets such as the Molybdenum market have outperformed producers in bigger markets such as the aluminum market.

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[373] See 5.2.2 and below.
[374] See 5.2.3.
[375] Both of these variables have shown the highest collinearity with the variable *Market Size*.
[376] See Table 38 - Overall dataset: Random Effects Model (10) & (14) without Copper & Market HHI.

8. *Market Political Stability of Production Countries*

   Although political instability of the metals' production countries is highly important for investors to evaluate the miners' risk profiles no statistical impact could be found in the regression analysis across all non-ferrous metal markets.[377] This is most probably due to two facts:

   First of all, the variable is calculated as an average across all production countries. Thus, even if the political stability turns particularly bad for a singular production country the overall variable will only show little variation dependent on the country's production share of the metal.[378] Since the origins of the analyzed miners' production shares are not published for each miner we can only utilize an aggregate variable which does not capture the political instability that the single producers are facing in order to show a significant impact on their profitability. If these types of data will become available for the single miners it would most certainly be interesting to investigate the relation.

   Secondly, political instability should matter more in markets in which the concentration ratio of production countries is particularly high.[379] Nevertheless, the introduction of a Herfindahl Hirschman Index on the origin of the metal production has proved to be highly linear dependent on the Herfindahl Hirschman Index that measured the competition concentration among the single miners and could thus not be included in the list of potential regressors. Forward looking this might also be worthwhile to evaluate especially from an investment perspective. In the analyses of the single metal markets we will scrutinize this variable further.

Company specific explanatory factors:

After having covered the market generic variables we now evaluate the findings with regards to the company specific variables, i.e. variables that differ per observed company.

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[377] Please note also that the multicollinearity of *Market Political Stability of Production Countries* was slightly elevated as can be seen in Table 21.

[378] The variable is volume weighted across all of the metal's production countries.

[379] In that case dependence on few production countries is higher than if the ore can be sourced from many different countries.

9. *Company Size*

As already detected in the descriptive data analysis in 5.1 *Company size* measured in assets or revenues has shown to have a negative impact on company performance. When interpreting this finding we have to consider that very small, i.e. junior miners have been excluded naturally from the analysis since they do not publish sufficient production or financial data. Thus, the analyzed companies are most probably not operating at suboptimal scale and economies of scale as an explanation for higher return by larger companies can be dropped as an important profitability driver. Given this situation we are comparing mining giants such as BHP Billiton and Vale which operate globally in many different commodity markets with mid-sized miners such as Australia West which generally operate with a geographically or commodity wise more restricted focus but still at efficient scale. During the observation period these mid-sized miners have on average performed better than the mining giants.

This can be explained by the ever increasing complexity that many mining giants are experiencing nowadays: Empire building and global diversification has led to complex organization structures that require overhead to manage and control the highly differing commodity assets and value chains in very different markets.[380] Potential cost and sales advantages in procurement and marketing excellence have not paid off for the additional cost and control complexity that mining giants have to cope with.

Supporting this theory is the fact that the largest mining company BHP Billiton has recently decided to simplify its portfolio by demerging a group of high quality assets, namely all Nickel, Aluminium and Manganese assets in order to form an independent global metals and mining company South32.[381] Going forward other mining giants should also critically question whether their operating model is sufficiently lean to manage the complex portfolio of different commodities in highly differing regions.

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[380] See Amato, Wilder 1985, p.188 and Dhawan 2001, p.290.

[381] See BHP Billiton 2015, effective as of May 31st, 2015. In the conducted analyses, BHP Billiton and South32 are thus treated as one company.

10. Company Capital Efficiency

Company Capital Efficiency measured as the *Total Revenues* divided by *Total Assets* of a company has shown to have a highly positive and statistically significant effect on *Company Performance* confirming the findings of the uni-variate data analysis in 5.1.

Both, the statistical significance of the two variables *Company Size* and *Company Capital Efficiency* and the opposite directions of their coefficient estimations, show that capital efficiency is an important profitability driver[382] yet it is not explained by the variable *Company Size*.

11. *Company Capital Intensity*

The coefficients for the regressor *Company Capital Intensity* exhibit a stable negative impact on *Company Performance.* However, the estimations are statistically not significant. This can result from the measurement of this variable: Owing to the lack of data on actual capital expenditure per metal ton, the variable *Company Capital Intensity* is calculated as the average of the reported depreciation divided by the generated revenues across the observation period and is thus a time-invariant variable.

The underlying ratio of reported depreciation divided by revenues can show variations from year to year because asset quality varies over time, reporting of depreciation can be manipulated on the short run by accounting measure changes and revenues fluctuate dependent on commodity price changes. Given that the variable *Company Capital Intensity* is time invariant across the years of the observation period it cannot reflect these variations and thus causes too high standard errors when considered in the regression model as a time invariant variable.[383]

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[382] Companies generate more revenues with few assets and are thus more efficient and more profitable.

[383] See also evaluation of findings with regards to the variable *Market Capital Intensity* which has a statistically highly significant negative impact on *Company Performance*. As explained, the measure *Market Capital Intensity* varies yearly and thus compensates for fluctuations from year to year.

12. *Company Market Power*

Unlike postulated in (H12) *Company Market Power* as the *Company's Revenue Market Share* does have neither a stable nor statistically significant impact on *Company Performance* in the overall non-ferrous metal market analysis. As explained by Gale market share alone does not explain extraordinary returns but depends on other industry characteristics, including total firm size and leverage, industry growth and concentration.[384] Nevertheless, even when these factors are included in the regression model a company's market share does not seem to have a significant impact on *Company Performance*. This is plausible when considering the nature of the commodity markets under research:

Within the non-ferrous metal markets availability, proximity[385] and specification of the product are highly relevant. The utilized market shares have been calculated based on the assumption of companies participating in a global commodity market. As soon as any one of the three dimensions mentioned above matters the global market can quickly turn out to be a regional or monopolistic market. To be more specific: even if a miner possesses a high market share the required transport cost can put off the sales and cost advantages that normally accompany high market shares[386] if the end customer is located at the other side of the globe.[387] In addition and as mentioned above, most small miners have naturally been excluded since data on production and financial performance was not available. Miners operating at inefficient scale are most likely excluded from the analyses reducing the explanatory power why high market share should lead to superior performance.

13. *Company Focus*

The variable *Company Focus*, i.e. the revenues of the metal under research as the share of a miner's total revenues has proved to have a negative impact on Company Performance. In short, this finding can be interpreted as a miner's diversification across different commodity or metal markets has paid off during the observation period. This is particularly

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384 See Gale 1972, pp.422-423.

385 This is supported by the high relevance of transport cost for the profitability of miners as explained above.

386 Advantages such as high negotiation power and operations with high economies of scale.

387 Note that transport cost to the harbor of destination are paid for by the miner not the customer.

interesting in combination with the statistical significance of *Company Size* in total assets and *Company Capital Efficiency* because companies seem to have performed best if small in size, with efficient use of capital but still diversified.

Digging deeper, Table 23 gives an overview on the top ten most profitable producers. From a first glance many of the most profitable miners were extracting copper paired with byproducts. These miners' revenues are thus naturally diversified across more than one metal market given the sales of the byproducts which cover many precious metals, in particular gold and silver. As metal prices of both surged to unseen levels throughout the financial crisis in 2008, sales of the precious metals absorbed any drop in demand for the rather industrially utilized non-ferrous metals during the crisis and that way helped to maintain high levels of profitability.

Table 23 - Top ten most profitable non-ferrous metal miners during the observation period

Averages 2002 - 2012	**Company EBIT margin per specific metal market**							**Total assets**	**Company focus**
Producer	Al	Cu	Mn	Mo	Ni	Ti	Zi	(in mUS$)	(in %)
Antofagasta		*56%*		*65%*				*6,944*	*46%*
MOIL Limited			*57%*					*358*	*99%*
Codelco		*42%*		*65%*				*15,330*	*41%*
Barrick		*51%*						*32,007*	*14%*
Kazakhmys		*46%*						*7,963*	*64%*
First Quantum		*46%*						*3,147*	*91%*
Oxiana							*44%*	*1,413*	*33%*
Peñoles							*42%*	*3,642*	*26%*
Inmet Mining		*42%*						*2,189*	*57%*
ENRC			*41%*					*9,873*	*7%*

Note: *Company EBIT margin* is calculated as operating profit divided by total revenues, *Company focus* is calculated as share of metal revenues divided by total revenues

14. *Company Sales Capabilities*

The index *Company Sales Capabilities* which measures a company's capability to outperform market prices[388] did not exhibit any statistical significance as a regressor for *Company Performance*. This supports the logic that most observations in the dataset originate from markets, namely the aluminium, copper, nickel and zinc market in which metal volumes are sold via indexed contracts. If price indices in these markets change the achieved prices of the miners directly change along with them. Therefore, outperforming the market price in these price-indexed markets is difficult. For the less liquid markets under research such as the Manganese or the Titanium market[389], we scrutinize the impact of this regressor in chapter 6 to better understand the relevance of sales capabilities in these market environments.

[388] A company outperforms market prices if its achieved prices grow faster than the market price in times of growing market prices and if its achieved prices decrease slower than the market price in times of falling market prices.

[389] See Table 5 - Development stages of commodity markets.

6 Findings and comparisons of the single metal market analyses

The following chapter focuses on scrutinizing the single metal markets individually and comparing the findings thereof first among each other and subsequently with the findings from the overall market analysis.

6.1 Validation of hypotheses for the single non-ferrous metal markets

6.1.1 Process and model specification

In order to filter market specific characteristics within each commodity market we split the overall dataset before standardization in seven separate datasets, one for each of the different non-ferrous metal markets. As conducted conventionally we standardize the variables in each of the separate market data sets to obtain normally distributed regressors.[390]

For each of the different standardized datasets, we first compute the simple singular correlations between all exogenous variables and the endogenous variable in order to detect potential areas of multicollinearity for the construction of the regression models. The correlation coefficient tables can be found in the appendix.[391]

In analogy to the analyses of the overall dataset, we first analyze the impact of the control variables, namely the *Market Metal Price* plus the main company-specific variables *Company Size*, *Company Capital Efficiency*, *Company Capital Intensity* and *Company Market Share* to obtain model (1) for each of the single commodity markets.

After having tested the control variables, we test the main hypotheses that have been postulated for the specific market by adding the respective regressors to the control variables of model (1).[392] As long as multicollinearity of the regressors is sufficiently low, i.e. when the largest Variance Inflation Factor (VIF) is smaller than ten,[393] we also test the other market variables, namely *Market*

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[390] See 4.2.4 or Backhaus 2011, p.338.
[391] See 9.9.
[392] See 3.2.2.
[393] In general, VIFs that exceed the threshold ten are considered to threaten the mathematical assumption of linear independency. See 5.2.3 or Kutner et al. 2005, pp.408-410.

Ad Valorem Transport Cost, *Global Energy Cost*, *Market Demand Growth* and *Market Concentration*[394] to validate the hypotheses that we have analyzed in chapter 5.

Since we are only analyzing one specific metal market the market invariant variables that vary over time but not for each company have little variations in their values across all observations. Given this the likelihood of multicollinearity is greater in the regression analyses of the single commodity markets than for regression analyses of the overall dataset. Hence, we prefer to exclude time dummies from the regression analyses of single commodity markets to ensure the robustness of the regression results. Due to the exclusion of the time dummies as well as the smaller datasets and the different mechanics of each of the metal markets we do not expect to find the same levels of significance that we have detected for the regressors of the overall dataset in each of the single datasets. We rather focus on understanding the impact of market specific profitability determinants for each of the single metal markets.

All regression results are represented in tables which contain the coefficient estimates and their respective p-values. Again coefficients with statistically significant effects are marked with the symbols * ($0.05<p\leq0.1$), ** ($0.01<p\leq0.05$), *** ($p\leq0.01$) depending on their level of significance. In addition the VIFs for each of the regression models are directly appended.

Since the robustness of the regression results differs from market to market we will discuss areas of concern with regards to the validity of the coefficient estimations and p-values directly after presenting the regression results of the specific market. Thereby, we focus in particular on the potential issue of multicollinearity among the regressors. Again, we consider the variance inflation factors (VIFs) of each of the analyzed variables in analogy to chapter 5.2.3 to assess multicollinearity and ergo linear independency of the regressors. If multicollinearity causes concern for a specific control or market variable we drop the respective variable from the list of regressors and run the regression again.

Since the regression analyses of the overall dataset has already tested all major hypotheses and the regression analyses of the single commodity markets only focuses on the impact of singular

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394 Since the variable *Market Capital Intensity* is a weighted average of the variable yearly *Company Capital Intensity* and thus company invariant we exclude Market Capital Intensity from the regression analyses to reduce collinearity.

variables we are not concerned with potential model misspecification due to the exclusion of explanatory variables.

Furthermore, we avoid assuming fully exogenous variables by utilizing the Random Effects estimator which allows for limited endogeneity of the regressors, namely a random correlation between a company specific error term and the regressors. We prefer to utilize the Random Effects estimator over the Fixed Effects estimator in order to include the time invariant variable *Company Capital Intensity* as an indicator for a company's asset quality and required capital investments.[395] Last but not least, we have only utilized estimators that compute cluster robust standard errors to preempt heteroscedastic standard errors within company clusters.[396]

And again, all regression analyses were computed with the statistics software STATA, version 12.0 which covers all required functions.

6.1.2 Results for the different non-ferrous metal markets

In the following, we summarize the regression results for each of the single commodity markets.

Aluminium

To test the impact of energy cost on the profitability of aluminium producers we run the regression on the basic model which includes all the control variables in combination with the variable *Global Energy Cost*. As can be seen by the coefficient estimations in Table 24, we find a strong confirmation of the hypothesis.[397]

Unlike detected when analyzing the overall dataset neither *Company Size* nor *Company Capital Efficiency* seem to have a statistically significant impact on profitability in the aluminium market. Instead, the *Company Capital Intensity* of the single aluminium producers turns out to have a significant negative impact. Given the excess aluminium capacity during the observation period[398] the market was particularly competitive. The producers' ability to produce at low cost, i.e. their

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395 Since the Fixed Effects estimator does not allow testing time invariant variables such as the *Company Capital Intensity* factor it is not considered for the single commodity market analyses.

396 Also see 4.3.2.

397 As postulated in (A1), also see 3.2.2 Hypotheses for the single non-ferrous metal markets.

398 As of June 1, 2011, about 40% (1.23 Mt/yr) of US primary aluminium smelting capacity was not being used, see U.S. Geological Survey 2003-2012, Aluminium, p.57.

position on the cost curve along with their capital expenditures should hence have a significant impact on the producers' profitability.

When testing additional market variables in the aluminum market, we find a relatively high multicollinearity for the variable *Global Energy Cost*[399] and thus drop the variable from the vector of regressors in model (4): From model (4), we can detect that both, the demand for aluminium as well as the competition concentration of the aluminium market, have a high positive impact on the aluminium producers' profitability. This supports the notion of the aluminium market being highly competitive during the observation period due to excess capacity. Unlike *Market Demand Growth* and *Market HHI*, the variable *Market Ad Valorem Transport Cost* did not matter statistically. At first sight, this is rather surprising because alumina is - depending on the location of the production site - often transported over long distances to energy rich and low cost countries for further refinery to aluminium. Nevertheless, most alumina assets either are dedicated suppliers to specific aluminium refineries with long term delivery contracts or actually belong to aluminium refineries. In both cases, transport routes do not change and resulting transport cost are well priced in and optimized to vary little over time. On top of that, transport cost and their impact differ highly depending on the location of the producing mines. Thus, the ad valorem maritime transport cost should not affect all producers to the same extent. Hence, it comes as little surprise that we do not encounter any statistical significance.

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[399] See model (3) in Table 24 and the correlation coefficients in Table 48 in the appendix.

Table 24 - Aluminium: Random Effects Model - Results and VIFs

Regression results								
Endogenous variable:	Random Effects							
Company EBIT margin	1		2		3		4	
Market Metal Price	0.814	***	0.677	***	0.639	***	0.351	***
	(0.000)		(0.000)		(0.000)		(0.000)	
Company Size - Assets	-0.060		-0.020		-0.016		-0.042	
	(0.249)		(0.724)		(0.798)		(0.550)	
Company Capital Efficiency	0.100		0.057		0.037		0.017	
	(0.219)		(0.505)		(0.718)		(0.853)	
Company Capital Intensity	-0.142	*	-0.155	*	-0.156	*	-0.164	*
	(0.081)		(0.063)		(0.074)		(0.051)	
Company Market Share	-0.093		-0.113		-0.110		-0.089	
	(0.186)		(0.117)		(0.125)		(0.204)	
Global Energy Cost	-0.831	***	-0.709	***	-0.535	***		
(A1,-)	(0.000)		(0.000)		(0.004)			
Ad Valorem Transport Cost			0.103		0.055		0.041	
			(0.147)		(0.530)		(0.634)	
Market Demand Growth			0.137	*	0.110	*	0.158	***
			(0.065)		(0.060)		(0.003)	
Market HHI					0.201		0.483	***
					(0.310)		(0.001)	
Wald test: Model χ^2	142		140		173		208	
p-value	(0.000)		(0.000)		(0.000)		(0.000)	
Observations (N)	134		134		134		134	
R^2 overall	0.244		0.343		0.386		0.404	
R^2 between	0.474		0.480		0.485		0.434	
R^2 within	0.408		0.441		0.454		0.414	
Variance Inflation Factors								
Market Metal Price	2.60		3.86		4.05		1.77	
Company Size - Assets	1.38		1.39		1.40		1.40	
Company Capital Efficiency	1.38		1.41		1.47		1.46	
Company Capital Intensity	1.07		1.08		1.08		1.08	
Company Market Share	1.42		1.42		1.42		1.42	
Global Energy Cost	2.75		4.09		7.69			
Ad valorem transport cost			1.22		1.48		1.47	
Market Demand Growth			1.49		1.58		1.51	
Market HHI					4.83		2.57	
Maximum VIF	2.75		4.09		7.69		2.57	

The p-values in brackets are estimated based on cluster robust standard errors (cluster = business unit) / * 0.05<p≤0.1, ** 0.01<p≤0.05, *** p≤0.01 / All exogenous variables have been standardized before the analyses / (H, +/-) Hypotheses including postulated direction / Constant and dummy variables for commodity markets and year are not shown

Copper

For the very mature, liquid and competitive, yet very profitable copper market we had postulated that input cost factors which are hard to optimize from a copper producers' perspective, namely the *Global Energy Cost* (C1) and the *Ad Valorem Transport Cost* (C2) would play an important role in determining the profitability of the copper miners. As can be seen in Table 25 these hypotheses are confirmed by the regression results.

Nevertheless, relatively high collinearity of the *Market Metal Price* questions the validity of the coefficient estimations.[400] When dropping the metal price from the vector of regressors the variable *Global Energy Cost* still exhibits a negative relation to the Company Performance yet loses its statistical significance. This can be explained by the fact that energy cost differ from region to region and thus impact each producer to a differing extent. This again leads to larger standard errors and thus the loss of statistical significance of the regressor *Global Energy Cost*.

When turning to the company specific variables *Company Size* as measured in assets and *Company Market Share* have a negative impact on company performance. While the findings regarding the impact of *Company Size* support the results from the overall market analysis the negative impact of Company Market Share comes as surprise: Miners with small market share have outperformed miners with larger market share during the observation period. This might be explainable by higher flexibility of miners with smaller market shares that supply a constantly underprovided market. Benefitting from the constant demand for copper more flexible miners can serve as so called swing suppliers selling to the best paying customer at a certain point of time rather than entering into long term delivery contracts. Unlike in the Aluminium market the asset quality does not have a statistically significant impact on *Company Performance*. This is understandable given the undersupply of the market, thus the constantly high copper prices which did not put as much pressure on the copper producer's cost competitiveness as in the aluminium market.

[400] Also see Table 49 in the appendix.

Table 25 - Copper: Random Effects Model - Results and VIFs

Regression results								
Endogenous variable:	Random Effects							
Company EBIT margin	1		2		3		4	
Market Metal Price	0.332	***	0.021		1.002	***		
	(0.000)		(0.852)		(0.000)			
Company Size - Assets	-0.241	**	-0.270	**	-0.230	*	-0.213	*
	(0.039)		(0.014)		(0.067)		(0.068)	
Company Capital Efficiency	0.157		0.144		0.166		0.170	
	(0.183)		(0.233)		(0.103)		(0.135)	
Company Capital Intensity	-0.007		-0.015		0.000		0.001	
	(0.963)		(0.920)		(0.998)		(0.992)	
Company Market Share	-0.239	**	-0.231	*	-0.259	**	-0.240	**
	(0.046)		(0.057)		(0.026)		(0.047)	
Ad Valorem Transport Cost			-0.370	***			-0.478	***
(C2,-)			(0.001)				(0.000)	
Global Energy Cost					-0.722	***	-0.151	
(C1,-)					(0.000)		(0.141)	
Wald test: Model χ^2	71		90		146		77	
p-value	(0.000)		(0.000)		(0.000)		(0.000)	
Observations (N)	221		221		221		221	
R^2 overall	0.046		0.067		0.101		0.081	
R^2 between	0.010		0.014		0.010		0.016	
R^2 within	0.225		0.280		0.328		0.285	
Variance Inflation Factors								
Market Metal Price	1.21		4.54		8.22			
Company Size - Assets	1.33		1.33		1.33		1.34	
Company Capital Efficiency			1.77		1.77		1.78	
Company Capital Intensity	1.34		1.34		1.34		1.34	
Company Market Share	1.45		1.45		1.45		1.46	
Global Energy Cost					8.11		2.40	
Ad valorem transport cost			4.42				2.37	
Maximum VIF	1.45		4.54		8.22		2.40	

The p-values in brackets are estimated based on cluster robust standard errors (cluster = business unit) / * 0.05<p≤0.1, ** 0.01<p≤0.05, *** p≤0.01 / All exogenous variables have been standardized before the analyses / (H, +/-) Hypotheses including postulated direction / Constant and dummy variables for commodity markets and year are not shown

Manganese

In line with the analysis of the other markets we first test the control variables in the small but heterogeneous manganese market that possesses a comparable low volume to value ratio. All control variables exhibit a high statistical significance all in line with the hypothesized relationships in 3.2.1. While all findings from the overall analysis are supported, namely the positive impact of the *Market Metal Price* and the *Company Capital Efficiency* as well as the negative impact of *Company Size* on the performance of manganese producers the coefficient estimations of the two other control variables *Company Market Share* and *Company Capital Intensity* also exhibit statistical significance. Worthwhile noticing is that the manganese market is the only market under research in which *Company Market Share* has a positive impact on profitability.

After having assessed the control variables we test the relevance of *Company Sales Capabilities* (Mn1) as the main hypothesis for this illiquid and intransparent market. Unlike hypothesized the variable does not show any statistical significance. Most probably this is owed to the measurement of the market price: Due to the lack of a global manganese price index the utilized market metal price is the landed value per ton of manganese in the US published by the USGS. Although this is the best available indicator company specific achieved prices highly depend on the port and country of destination. Much of the global manganese demand has been shipped to China instead of the US due to China's thirst for steel and the manganese's important properties in the steel production process. Prices for manganese, however, were substantially lower in China than in the US.[401] The measure *Company Sales Capabilities* which captures deviations between the growth of the manganese US price and the growth of the miner's achieved prices might thus not be able to deflect the actual sales capabilities of the manganese miners. If going forward a trustworthy global manganese price index is established this variable could be tested again with more accuracy. After analyzing the impact of *Company Sales Capabilities* the other market variables are also tested to find support for the results from the regression analyses of the overall market. Noteworthy is the fact that the idiosyncratic variables lose their statistical significance as soon as the market variables are introduced which is due to the high heterogeneity of the small manganese market.

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[401] See for example U.S. Geological Survey 2002-2014, Manganese, p.2.

Table 26 - Manganese: Random Effects Model - Results and VIFs

Regression results								
Endogenous variable:	Random Effects							
Company EBIT margin	1		2		3		4	
Market Metal Price	0.521	***	0.514	***	0.646	***	0.614	***
	(0.000)		(0.000)		(0.000)		(0.000)	
Company Size - Assets	-0.283	**	-0.249	*	-0.159		-0.141	
	(0.013)		(0.059)		(0.135)		(0.211)	
Company Capital Efficiency	0.158	**	0.145	**	0.141	*	0.052	
	(0.041)		(0.028)		(0.083)		(0.554)	
Company Capital Intensity	-0.246	*	-0.307	**	-0.293	*	-0.310	
	(0.066)		(0.037)		(0.090)		(0.116)	
Company Market Share	0.357	***	0.464	***	0.235	*	0.132	
	(0.004)		(0.000)		(0.086)		(0.366)	
Company Sales Capabilities			0.002		0.035		0.083	
(Mn1, +)			(0.984)		(0.681)		(0.363)	
Global Energy Cost					-0.255	**		
					(0.031)			
Ad Valorem Transport Cost							-0.097	**
							(0.013)	
Market Demand Growth							0.147	***
							(0.000)	
Market HHI							0.269	*
							(0.065)	
Wald test: Model χ^2	126		274		209		1,818	
p-value	(0.000)		(0.000)		(0.000)		(0.000)	
Observations (N)	99		89		89		89	
R^2 overall	0.184		0.184		0.266		0.347	
R^2 between	0.028		0.106		0.158		0.230	
R^2 within	0.542		0.554		0.579		0.594	
Variance Inflation Factors								
Market Metal Price	1.13		1.11		2.33		2.04	
Company Size - Assets	1.34		1.33		1.37		1.35	
Company Capital Efficiency	1.18		1.20		1.20		1.25	
Company Capital Intensity	1.07		1.04		1.08		1.08	
Company Market Share	1.18		1.19		1.23		1.21	
Company Sales Capabilities			1.02		1.03		1.34	
Global Energy Cost					2.45			
Ad valorem transport cost							1.44	
Market Demand Growth							1.05	
Market HHI							2.10	
Maximum VIF	1.34		1.33		2.45		2.10	

The p-values in brackets are estimated based on cluster robust standard errors (cluster = business unit) / * $0.05<p\leq0.1$, ** $0.01<p\leq0.05$, *** $p\leq0.01$ / All exogenous variables have been standardized before the analyses / (H, +/-) Hypotheses including postulated direction / Constant and dummy variables for commodity markets and year are not shown

Molybdenum

According to the overall approach we first test the relevance of the control variables for the special molybdenum market. When considering the results in Table 27 it is striking that the *Market Metal Price* does not exhibit any statistical significance in the molybdenum market unlike in all other markets under research. When recalling the nature of the molybdenum production this is plausible: molybdenum is often extracted as a byproduct of the copper production.[402] The decision on production and sales volumes is thus not driven by the metal's price.[403]

Instead, we hypothesized that the price of the molybdenum's most common primary metal copper to negatively influence the profitability of the molybdenum producers (Mo2): High prices of the primary metal lead to increased production of the primary metal. Thus, potential excess volumes of molybdenum are extracted independent of the global molybdenum demand. Interesting enough this is confirmed by model (4).

As opportunity cost rather than market prices determine a miner's decision on the production volume of byproducts a miner's asset quality, i.e. the variable *Company Capital Intensity* was expected to have no impact on profitability.[404] This is validated throughout all of the different regression models (1)-(4) fitted with the molybdenum data. With regards to the other company specific variables it remains noteworthy that *Company Size* does not have a negative impact on *Company Performance* unlike in the analyses of the overall data set, of the copper or of the manganese market.

Last but not least, we had postulated to find a negative relationship between the political stability and the profitability (Mo1) supporting the fear of undersupply given political instability within the production countries.[405] This hypothesis is also confirmed with the variable *Market stability of Production Countries*.[406]

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402 78% of global molybdenum ore is produced as a byproduct from copper mines whereas only 22% originate from dedicated molybdenum mines (see Table 44).
403 See 3.2.2.
404 See 3.2.2.
405 The share of molybdenum production originating from China and thus politically more instable countries has increased dramatically during the observation period (see 2.2.4 and 3.2.2).
406 For reasons of high collinearity, we drop the competition concentration variable *Market HHI* from the set of regressors (also see Table 51 with the correlation coefficients in the appendix).

Table 27 - Molybdenum: Random Effects Model - Results and VIFs

Regression results								
Endogenous variable:	Random Effects							
Company EBIT margin	1		2		3		4	
Market Metal Price	0.109		0.116		0.143		-0.013	
	(0.277)		(0.394)		(0.293)		(0.931)	
Company Size - Assets	0.122	**	0.035		0.038		0.029	
	(0.021)		(0.720)		(0.690)		(0.755)	
Company Capital Efficiency	0.372	***	0.686	***	0.687	***	0.679	***
	(0.000)		(0.001)		(0.001)		(0.001)	
Company Capital Intensity	-0.164		-0.175		-0.179		-0.170	
	(0.338)		(0.291)		(0.262)		(0.313)	
Company Market Share	-0.176		-0.460		-0.472	*	-0.446	
	(0.326)		(0.108)		(0.093)		(0.131)	
Global Energy Cost			-0.478	***	-0.403	***		
			(0.000)		(0.002)			
Ad Valorem Transport Cost			0.009		0.030		0.037	
			(0.939)		(0.779)		(0.740)	
Market Demand Growth			0.009		0.072		-0.052	
			(0.901)		(0.497)		(0.659)	
Market HHI			-0.173				-0.266	
			(0.154)				(0.140)	
Market stab. of prod. countries			-0.260		-0.367	***		
(Mo1, -)			(0.122)		(0.005)			
Copper Market Price							-0.297	**
(Mo2, -)							(0.013)	
Wald test: Model χ^2	49		.		.		.	
p-value	(0.000)		.		.		.	
Observations (N)	72		72		72		72	
R^2 overall	0.281		0.398		0.392		0.360	
R^2 between	0.393		0.430		0.447		0.461	
R^2 within	0.334		0.388		0.362		0.311	
Variance Inflation Factors								
Market Metal Price	1.58		2.50		2.37		1.91	
Company Size - Assets	1.04		1.09		1.09		1.09	
Company Capital Efficiency	1.92		2.16		2.16		2.17	
Company Capital Intensity	1.10		1.12		1.12		1.12	
Company Market Share	1.39		1.51		1.48		1.50	
Global Energy Cost			4.53		3.52			
Ad valorem transport cost			2.04		1.96		2.10	
Market Demand Growth			3.38		2.67		1.85	
Market HHI			5.42				4.80	
Market stab. of prod. countries			6.08		4.02			
Copper Market Price							4.98	
Maximum VIF	1.92		6.08		4.02		4.98	

The p-values in brackets are estimated based on cluster robust standard errors (cluster = business unit) / * 0.05<p≤0.1, ** 0.01<p≤0.05, *** p≤0.01 / All exogenous variables have been standardized before the analyses / (H, +/-) Hypotheses including postulated direction / Constant & dummy variables for commodity, year are not shown

Nickel

As can be seen in Table 28 all hypotheses that have been postulated for the nickel market can be confirmed based on the nickel data set: the external cost factors *Global Energy Cost* (N1) as well as *Ad Valorem Transport Cost* (N2) have a highly negative impact on profitability. *Global GDP Growth* (N3) seems to be a good indicator for Nickel demand supporting similar results that have been found before by Humphreys.[407] This particularly interesting since the actual demand variable *Market Demand Growth* measured as the Seaborne Metal Volumes does not exhibit any statistical significant relation to profitability in the nickel market.

Given that this demand variable cannot capture volumes that are transported via rail or truck this is understandable: In the nickel market a comparably high share of global volumes is transported via rail, in particular from Kazakhstan or Russia to Asia or Europe. In the nickel market, the explanatory power of the variable *Market Demand Growth* is thus limited.

When considering the company specific variables we find evidence for the findings of the overall market: *Company Size* matters in the nickel market: during the observation period, nickel mining giants have been outperformed by smaller nickel miners. Apart from that, *Company Capital Intensity* is very close to statistical significance throughout the four tested models also influencing profitability negatively.

Last but not least, the coefficient estimations for the competition concentration ratio *Market HHI*, on the contrary, does not exhibit any distinctive features and probably offers too little variation in the single market perspective in order to explain different levels of profitability.

[407] See Humphreys 2010, p.2.

Table 28 - Nickel: Random Effects Model - Results and VIFs

Regression results								
Endogenous variable:	Random Effects							
Company EBIT margin	1		2		3		4	
Market Metal Price	0.426	***	0.724	***	0.691	***	0.589	***
	(0.000)		(0.000)		(0.000)		(0.000)	
Company Size - Assets	-0.504	***	-0.305	***	-0.317	***	-0.316	***
	(0.000)		(0.000)		(0.001)		(0.002)	
Company Capital Efficiency	0.242	**	0.179	*	0.160	**	0.152	**
	(0.026)		(0.063)		(0.029)		(0.025)	
Company Capital Intensity	-0.105		-0.092		-0.104	*	-0.089	
	(0.120)		(0.100)		(0.063)		(0.113)	
Company Market Share	0.210	**	0.076		0.067		0.065	
	(0.015)		(0.342)		(0.530)		(0.581)	
Global Energy Cost			-0.316	***	-0.358	*	-0.343	*
(N1,-)			(0.002)		(0.065)		(0.079)	
Ad Valorem Transport Cost			-0.261	***	-0.180	*	-0.181	**
(N2,-)			(0.000)		(0.051)		(0.032)	
Market Demand Growth					0.099		-0.020	
					(0.393)		(0.886)	
Market HHI					-0.014		-0.177	
					(0.940)		(0.283)	
Global GDP Growth							(0.294)	***
(N3,+)							(0.003)	
Wald test: Model χ^2	233		4,172		13,250		5,248	
p-value	(0.000)		(0.000)		(0.000)		(0.000)	
Observations (N)	101		101		101		101	
R^2 overall	0.348		0.469		0.476		0.510	
R^2 between	0.433		0.469		0.470		0.446	
R^2 within	0.355		0.465		0.471		0.516	
Variance Inflation Factors								
Market Metal Price	1.09		1.98		3.04		3.32	
Company Size - Assets	1.36		1.48		1.50		1.50	
Company Capital Efficiency	1.06		1.10		1.17			
Company Capital Intensity	1.22		1.23		1.23		1.24	
Company Market Share	1.16		1.24		1.28		1.28	
Global Energy Cost			1.86		2.39		2.40	
Ad valorem transport cost			1.57		4.05		4.05	
Market Demand Growth					2.66		3.07	
Market HHI					1.76		4.80	
Global GDP Growth							2.47	
Maximum VIF	1.36		1.98		4.05		4.80	

The p-values in brackets are estimated based on cluster robust standard errors (cluster = business unit) / * $0.05<p\leq0.1$, ** $0.01<p\leq0.05$, *** $p\leq0.01$ / All exogenous variables have been standardized before the analyses / (H, +/-) Hypotheses including postulated direction / Constant and dummy variables for commodity markets and year are not shown

Titanium dioxide

With titanium dioxide's many different end markets and its low value to volume ratio the mechanism of the titanium dioxide market differ from the other non-ferrous metal markets under research. Due to its low value to volume ratio we had postulated that transport cost as a share of total metal prices, namely *Ad Valorem Transport Cost* should have a negative influence on profitability (T1). This is confirmed by the regression results of the models (2)-(4) as can be seen in Table 29.

Apart from that, we would like to point out that the competition concentration based on revenue market shares has a negative relation while the competition concentration based on volume market share has a positive relation to a miner's performance. When considering the correlation coefficient between the two variables in Table 53 we can detect that both measures are highly negatively correlated: What has happened to cause this negative correlation?

There were no significant mergers or acquisitions,[408] yet the market became more concentrated when considering the revenue market shares. That means that the titanium dioxide producers with high revenue market share managed to increase sales while the smaller players retained their revenues. The increase of sales however was purely driven through higher sales prices as a consequence of increased production cost of the larger titanium producers and thus did not yield any increases in profitability. The measured increase in market concentration and thus decrease in competition did therefore not lead to higher profitability. If we, on the other hand, regard the development of the market concentration based on volume market shares, we can observe a decrease in market concentration and thus an increase in competition. This competition increase is based on originally larger, more expansive and hence less competitive players, such as Iluka Resources, decreasing their production volumes and smaller players such as Kenmare increasing their production volumes. Overall, this shift from more expansive to cheaper titanium dioxide producers has hampered profitability of titanium producers overall. Altogether, we prefer to utilize the Herfindahl-Hirschman Index based on volumes not revenues.[409]

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[408] The only two noteworthy changes that balanced each other out were AngloAmerican selling its assets to Exxaro in 2008 while Kenmare entered the market in 2009 (see Figure 23 and Figure 24)

[409] Due to the high correlation of the two measures we cannot include both in the list of regressors, see Table 53.

Table 29 - Titanium: Random Effects Model - Results and VIFs

Regression results								
Endogenous variable:	Random Effects							
Company EBIT margin	1		2		3		4	
Market Metal Price	0.358	**	0.227	*	0.447	***	0.671	**
	(0.013)		(0.064)		(0.008)		(0.020)	
Company Size - Assets	-0.059		-0.026		-0.024		-0.028	
	(0.535)		(0.761)		(0.774)		(0.752)	
Company Capital Efficiency	0.175		0.155		0.147		0.149	
	(0.424)		(0.341)		(0.354)		(0.376)	
Company Capital Intensity	0.040		0.030		0.025		0.027	
	(0.800)		(0.843)		(0.868)		(0.859)	
Company Market Share	-0.027		-0.006		-0.006		-0.006	
	(0.753)		(0.930)		(0.930)		(0.937)	
Global Energy Cost			0.189		0.239		0.243	
			(0.274)		(0.199)		(0.166)	
Ad Valorem Transport Cost			-0.200	*	-0.203	*	-0.285	*
(T1, -)			(0.082)		(0.076)		(0.051)	
Market Demand Growth			0.093		0.145		0.275	*
			(0.333)		(0.157)		(0.086)	
Market HHI - Revenues			-0.369	**				
			(0.024)					
Market HHI - Volumes					0.512	**	0.524	**
					(0.025)		(0.022)	
Company Sales Capabilities							0.339	*
(T2,+)							(0.083)	
Wald test: Model χ^2	16		341		323		454	
p-value	(0.008)		(0.000)		(0.000)		(0.000)	
Observations (N)	94		94		94		94	
R^2 overall	0.147		0.248		0.256		0.294	
R^2 between	0.067		0.050		0.066		0.048	
R^2 within	0.213		0.274		0.280		0.323	
Variance Inflation Factors								
Market Metal Price	1.04		3.13		3.19		4.50	
Company Size - Assets	1.14		1.17		1.17		1.17	
Company Capital Efficiency	2.01		2.15		2.16		2.16	
Company Capital Intensity	1.91		1.98		1.98		1.98	
Company Market Share	1.17		1.18		1.18		1.18	
Global Energy Cost			2.86		3.13		3.13	
Ad valorem transport cost			2.68		2.68		2.86	
Market Demand Growth			1.57		1.51		1.95	
Market HHI - Revenues			1.89					
Market HHI - Volumes					3.29		3.29	
Company Sales Capabilities							2.99	
Maximum VIF	2.01		3.13		3.29		4.50	

The p-values in brackets are estimated based on cluster robust standard errors (cluster = business unit) / * $0.05<p\leq0.1$, ** $0.01<p\leq0.05$, *** $p\leq0.01$ / All exogenous variables have been standardized before the analyses / (H, +/-) Hypotheses including postulated direction / Constant and dummy variables for commodity markets and year are not shown

The second hypothesis that we had postulated for the titanium dioxide market addresses the lack of a market wide metal price index and thus the importance of a miner's excellence in sales and negotiation expressed by the variable *Company Sales Capabilities*. This hypothesis can also be confirmed as can be seen in model (4) of Table 29. Apart from this, no other company specific variable exhibits any statistical significance for the titanium dioxide producers.[410]

Zinc

Similar to the copper and the nickel market we had postulated that cost drivers would be important performance determinants in the zinc market. As summarized in Table 30 the importance of the *Ad Valorem Transport Cost* (Z2) can be confirmed.[411] Nevertheless, the variable *Global Energy Cost* (Z1) does not show stable results across the different statistical models. Only in model 3 it exhibits a positive and statistically significant impact on the profitability of zinc miners. This positive impact can be explained by the positive correlation of global oil prices with global GDP. The variable *Global Energy Cost* thus rather reflects demand for zinc instead of the energy cost component.

Unlike in the overall market analysis, *Company Size* does not show any statistically significant relation to the zinc miners' performance. Instead, *Company Market Share* exhibits a negative relation to company performance, most probably following a similar rationale as the one for the negative relation of company size and profitability in the overall data analysis.[412] Apart from *Company Market Share* the capital intensity and the capital efficiency of zinc miners are the most important and statistically significant performance drivers.

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[410] Unlike in the overall market model, *Company Size* does not belong to the list of profitability drivers.

[411] *Market Metal Price* has to be excluded in model 3 and 4 due to its high collinearity with *Transport Cost*.

[412] There is a high positive correlation between *Company Size* and *Company Market Share,* see Table 54 in the appendix.

Table 30 - Zinc: Random Effects Model - Results and VIFs

Regression results								
Endogenous variable:	Random Effects							
Company EBIT margin	1		2		3		4	
Market Metal Price	0.476	***	0.266	**				
	(0.000)		(0.011)					
Company Size - Assets	0.135		0.118		0.110		0.127	
	(0.187)		(0.280)		(0.273)		(0.249)	
Company Capital Efficiency	0.086	*	0.086	*	0.094	**	0.106	***
	(0.084)		(0.074)		(0.041)		(0.004)	
Company Capital Intensity	-0.242	***	-0.321	***	-0.444	***	-0.397	***
	(0.000)		(0.000)		(0.000)		(0.000)	
Company Market Share	-0.303		-0.302		-0.281		-0.356	*
	(0.138)		(0.138)		(0.130)		(0.068)	
Global Energy Cost			0.013		0.106	**	-0.013	
(Z1,-)			(0.785)		(0.031)		(0.834)	
Ad Valorem Transport Cost			-0.198	**	-0.342	***	-0.239	***
(Z2,-)			(0.020)		(0.000)		(0.000)	
Market Demand Growth							0.073	
							(0.176)	
Market HHI							0.199	**
							(0.028)	
Wald test: Model χ^2	147		220		199		443	
p-value	(0.000)		(0.000)		(0.000)		(0.000)	
Observations (N)	102		102		102		102	
R^2 overall	0.418		0.427		0.423		0.418	
R^2 between	0.235		0.232		0.239		0.202	
R^2 within	0.721		0.735		0.725		0.765	
Variance Inflation Factors								
Market Metal Price	1.68		12.91					
Company Size - Assets	1.79		1.84		1.84		1.84	
Company Capital Efficiency	1.23		1.23		1.22		1.23	
Company Capital Intensity	1.56		3.91		1.12		1.27	
Company Market Share	1.46		1.46		1.46		1.46	
Global Energy Cost			3.27		1.72		2.67	
Ad valorem transport cost			5.50		1.69		2.20	
Market Demand Growth							1.92	
Market HHI							4.80	
Maximum VIF	1.79		12.91		1.84		4.80	

The p-values in brackets are estimated based on cluster robust standard errors (cluster = business unit) / * 0.05<p≤0.1, ** 0.01<p≤0.05, *** p≤0.01 / All exogenous variables have been standardized before the analyses / (H, +/-) Hypotheses including postulated direction / Constant and dummy variables for commodity markets and year are not shown

6.2 Comparing regression results with hypotheses

Table 31 summarizes the initially hypothesized direction of the relation between the explanatory variable and the profitability of the non-ferrous metal producer and compares these with the test results of the regression analyses.

Table 31 - Overview on hypotheses validation for the single commodity markets

Hypothesis	Explanatory variable of *Company EBIT margin*	Direction of impact	Test results	Random Effects
Aluminium market specific explanatory variables		(see Table 24)		
A1	Market production cost: Energy cost	-	y	***
Copper market specific explanatory variables		(see Table 25)		
C1	Market production cost: Energy cost	-	y	***[413]
C2	Market production cost: Transport cost	-	y	***
Manganese market specific explanatory variables		(see Table 26)		
Mn1	Company sales capabilities	+	n	
Molybdenum market specific explanatory variables		(see Table 27)		
Mo1	Market stability of production countries	-	y	***[414]
Mo2	Copper market price	-	y	**
Nickel market specific explanatory variables		(see Table 28)		
N1	Market production cost: Energy cost	-	y	*
N2	Market production cost: Transport cost	-	y	*
N3	Growth of global GDP	+	y	***
Titanium dioxide market specific explanatory variables		(see Table 29)		
T1	Market production cost: Transport cost	-	y	*
T2	Company sales capabilities	+	y	*
Zinc market specific explanatory variables		(see Table 30)		
Z1	Market production cost: Energy cost	-	(y)	[415]
Z2	Market production cost: Transport cost	-	y	**

Direction of impact: + positive impact, - negative impact; *Test result:* y direction of impact was confirmed in all tested models, (y) variable with significant impact on company performance, yet contrary direction of impact, n direction could not be confirmed, * minimum statistical significance of 0.05<p≤0.1, ** minimum statistical significance of 0.01<p≤0.05, *** minimum statistical significance of p≤0.01

[413] In combination with *Ad Valorem Transport Cost* no statistical significance due to high positive correlation among the two variables (see Table 49).

[414] In combination with *Market HHI* no statistical significance due to high positive correlation among the two variables (see Table 51).

[415] Only significant in basic model without *Market Metal Price*, *Market Supply Growth* and *Market HHI* due to high correlation to these variables (see Table 54).

Apart from (Mn1) all single market hypotheses can be confirmed by the regression analyses. Unlike hypothesized sales capabilities of manganese miners did not impact *Company Performance* during the observation period. This is most probably due to the calculating of the variable *Company Sales Capabilities*. The measure *Company Sales Capabilities* which captures deviations between the growth of the manganese US price and the growth of the miner's achieved prices might not be able to deflect the actual sales capabilities of the manganese miners. As explained in 6.1.2 this is due to the lack of a globally accepted manganese price index and varying manganese prices per geography and type of product.

6.3 Comparing the single metal markets with the overall non-ferrous metal market

In section 6.1.2 we have tested the main hypothesis for the single commodity markets. What remains to be analyzed and is of particular interest given the broad database that covers seven different markets is the direct comparison of how the seven markets react to different profitability drivers in the light of the findings of the overall market.

Table 32 - Comparing hypotheses validation for overall and single metal markets

Explanatory variable of *Company EBIT margin*	**Overall model**	**Al**	**Cu**	**Mn**	**Mo**	**Ni**	**Ti**	**Zi**
Market specific explanatory variables								
Market price	+*	+***	+***	+***		+**	+**	+***
Market production cost: Energy cost		-***	-***	-**		-***		
Market production cost: Transport cost	-***		-**			-***		-***
Market demand growth	+***	+***						
Market concentration	+**	+***	-***				+/-**[416]	+***
Company specific explanatory variables								
Company size	-**	(-)**	-*	-*	(+)*	(-)***	(-)***	
Company capital efficiency	+*	(+)*		(+)**	+***	(+)**	(+)**	+*
Company capital intensity		(-)*				(-)*		-***
Company market power			(-)**	(+)*			(+)**	(-)*

Based on results obtained with Random Effects estimator, +/- = statistically significant positive/negative relationship in all tested models, (+)/(-) = statistically significant positive/negative relationship in subset of tested models, * statistical significance of 0.05<p≤0.1, ** stat. significance of 0.01<p≤0.05, *** stat. significance of p≤0.01

[416] Direction of impact depends on the basis of the competition concentration variable. When based on revenues its impact is negative. When based on volumes its impact is positive.

In order to compare the results of the single market examination with the findings of the overall market analysis on a like for like basis we have fitted the basic model (10) of the overall non-ferrous metal market analyses in chapter 5 for each of the single metal markets. While the process and the results of these regressions are presented in the appendix in Table 45, Table 46 and Table 47 we will focus on the interpretation of these results in this section.

In Table 32 we have summarized the detected relations between Company Performance first in the overall non-ferrous metal market analysis and subsequently for the single metal markets.

Let us first analyze the differences in the regression results with regards to the market variables:

The relevance of market prices found in the overall market analysis is confirmed throughout all single markets apart from the Molybdenum market which is plausible given molybdenum's nature as a byproduct of copper.

Energy Cost in particular have been found to have a negative impact on the profitability in all of the seven markets under research.[417] Nevertheless, only in four out of the seven markets this impact exhibits statistical significance confirming our initial hypotheses that these cost drivers matter especially in the more mature markets of copper and nickel and partially zinc. As postulated in 5.3.2 and confirmed by the results in Table 46 the highly varying coefficient estimations for the variable *Global Energy Cost* explain why the variable did not show any significance in the overall market model: While the aluminium market exhibits a very high coefficient estimation of -0.831 the likewise affected Molybdenum market only has a coefficient estimation of -0.250. These coefficient estimations are too distinct and thus generate a high standard error which reduces the statistical significance when fitting the overall model.

As hypothesized, transport cost only mattered in all of the rather mature and liquid markets apart from the aluminium market. This is a clear indicator that these mature markets are the most cost sensitive to this highly relevant external cost driver. For aluminium, the impact of this cost driver is not relevant or at least not on a market level since transport routes normally do not change and

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[417] See Table 46, the high collinearity between the energy cost and the market metal price in the copper market could question the validity of the results. However, when taking a closer look at the copper market in Table 25 we can observe that the coefficient estimation for the variable Global Energy Cost remains close to significance in the absence of the disturbing variable Global Energy Cost.

their impact highly differ depending on the location of the producing asset.[418] Hence, it comes as little surprise that we do not encounter any statistical significance.

Market demand growth had displayed statistical significance in the overall market analysis yet in the single markets it only exhibits significance in the aluminium market. This is plausible given that the aluminium producers had to cope with surplus production in most years of the observation period while the demand for the other non-ferrous metals outpaced their supply.[419] Changes in demand would thus affect the aluminium market more than the other markets.

The level of the competition concentration that also exhibits a clear positive impact on company performance in the overall market analyses affects the single markets as well, however not consistently throughout all markets. In the manganese, molybdenum and nickel market the competition concentration does not exhibit any statistical significance. Given that the variable in general does not vary highly over time and is more meaningful when comparing different markets this is also understandable. Interesting enough, the variable has a negative impact on copper producers. This in contradictory to most findings in research.[420] Nevertheless, while copper demand and usage were surging throughout the entire observation period it was not met by sufficient supply coming on stream from the many smaller copper producers entering the market.[421] Thus, as rivalry was practically inexistent the high competition concentration did not dampen the profitability margins within the industry.[422]

After having compared the impact of the market specific variables we now assess the differences of the impact of company specific variables:

As outlined in the evaluation of the findings from the overall market analysis *Company Size* has a negative impact on profitability in the overall analysis.[423] This is confirmed in most of the single market analyses. Only in the molybdenum market, the relationship is found to be positive. With the market size of molybdenum being very small compared to the other non-ferrous metal markets

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[418] See 6.1.2 for more details.
[419] See Crane, Price 2015, p.5.
[420] High competition is stated as a hindrance to market profitability as high rivalry effects costs, prices and investment requirements, see Capon et al. 1996, p.57.
[421] See Keung 2013, p.55.
[422] See Figure 33 - Development of producer concentration in metal markets from 2002 until 2012.
[423] See 5.3.2.

companies and assets operating below efficient scale could justify the positive impact of *Company Size* on Company Performance.[424] In addition, 78% of global molybdenum ore production is extracted as a byproduct.[425] In this case profitability is not dampened by *Company Size*-dependent factors such as high overhead cost because this cost item is allocated to the primary metal.

The positive yet often not statistically robust impact of *Company Capital Efficiency* on profitability rationalizes the management focus of optimized asset allocation and helps to dismiss the interpretation of *Company Size* as a measure of inefficient capital usage.[426]

Introduced to give an indication on a miner's capital intensity and asset quality the variable *Company Capital Intensity* did not exhibit any significance in the overall market analysis. However, it does so in the most mature and competitive single markets, namely the aluminium, nickel and zinc market. Given the high competitiveness in those markets asset quality and cost advantages are important profitability drivers.

Last but not least, the variable *Company Market Power* influences profitability positively in the least transparent and mature markets, namely the manganese and the titanium market. This indicates that in those markets a higher market share and thus higher bargaining power can indeed lead to elevated levels of profitability. In the more mature markets of copper and zinc, the opposite seems to be the case: Companies with smaller market shares and thus higher flexibility and most probably smaller and better to manage complexity have outperformed companies with higher market share. This logic supports the findings with regards to the impact of *Company Size*.

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424 The global molybdenum market only produces 260 thousand metric tons per annum. This constitutes around 0.5% of annual aluminium production, see Table 1.

425 See Table 44 - Share of molybdenum extracted as byproduct versus from dedicated assets.

426 Meaning that larger companies utilize their assets less efficiently and are thus less profitable.

7 Overall conclusion and outlook

In this chapter, we reconcile the results of this dissertation with the objectives that were formulated in chapter 1 and give an overall conclusion distilling the results of chapter 5 and 6. Thereafter, we briefly discuss potential implications for research and the mining industry, point out the limits of the conducted analyses and deduct areas for further research.

7.1 Reconciliation with objectives

As outlined in section 1.2, the starting point of this paper was to seek the answer to the following two fundamental questions against the background of recent developments in the non-ferrous metal markets:

- What influenced profitability of primary non-ferrous metal producers from 2002 until 2012?
- How did profitability drivers differ between non-ferrous metal markets from 2002 until 2012?

Both questions arose given Chinas growth trajectory along with the commodity boom in the early years of this millennium and the implosion of metal prices after the financial crisis in 2008. Both fundamentally changed the production landscape of non-ferrous metal markets. We thus aimed to understand how non-ferrous metal producers have coped given these two trends, first from an overall perspective and secondly given a metal market specific view. In order to further substantiate these research questions, the following five practical objectives were defined:

1. Build an in-depth understanding of non-ferrous metals, of value creation in mining and of the mining industry and structure for the markets under research.
2. Distill potential performance determinants from research on the economics of mining as well as metal markets and on company performance analyses beyond these markets.
3. Develop the required dataset to measure the identified profitability determinants and select appropriate statistical techniques to test these potential profitability determinants.
4. Combine all of the above to gain a holistic view on the relevance of identified profitability determinants in the overall non-ferrous metal market.

5. Test the identified profitability determinants and compare the results thereof among different markets and findings for the overall non-ferrous metal market.

Regarding the first objective, an in-depth understanding of non-ferrous metals in general was built in chapter 2: After explaining that mining did not only add value by the mere extraction of ore but also by asset development, transport provision and sales of the mineral or metal we gave on overview of the generalized production process, volumes and the major end applications per non-ferrous metals. In addition, we described how metal markets develop in general and metal prices have developed since the introduction of global metal prices. At last, we gave a detailed introduction to each of the seven metals selected for further research covering specific metal characteristics, their production process, volumes as well as countries of origin, the producer landscape in volumes, sales and potential changes therein as well as a final outlook per metal.

The second objective was tackled in chapter 3 in which we derived potential profitability determinants for the mining industry. This was attained in three steps: First, we gained an understanding on so far analyzed profitability determinants in the metals and mining industry. More specifically, we screened the research - on how it arose in the first place, regarding metal prices and other profitability determinants and at last regarding specific non-ferrous metal markets and their so far detected economical characteristics. In a second step, we took a glance beyond research on the mineral and mining industry to seek further inspiration on potential profitability determinants from the general field of company performance analysis. In a third step, we combined findings from both research fields and distilled potential profitability determinants as well as their anticipated impact on company performance as the main hypotheses of this dissertation.

To attain the third objective, we developed a comprehensive database including more than 72 variables each substantiated with more than 800 observations to deduct the measures and indices that were required to test the hypotheses. This was accomplished by manually retrieving the required business unit data from the segment reporting of over 1000 annual reports and ensuring their consistency across the entire observation period. In addition, we carefully tested various estimators and selected the Random Effects estimator as the estimator of choice because it best met the statistical requirements given the panel structure of the dataset while it also allowed testing time invariant variables.

The fourth objective was realized in chapter 5: After a qualitative analysis of the different potential profitability determinants, we tested the statistical relation between various market specific as well as company specific variables and the profitability of different producers. To mention the statistically significant results: we have found a clear positive impact of metal prices, of growth in demand as well as in supply, of competition concentration and of the miners' efficient capital usage as well as their diversification on the profitability of miners. On the contrary, we have found a negative impact of ad valorem maritime transport cost, of market capital intensity, of market size and in particular of the miners' size on their profitability.[427]

Last but not least, the fifth objective was dealt with in chapter 6: For each of the seven non-ferrous metals under research we conducted a thorough regression analysis to detect the different profitability determinants per market and to enable a comparison of these markets. In short, all of the markets differed from each other yet a few findings can be generalized: First of all, as a good indicator for the general supply and demand situation metal prices proved to be highly relevant for all markets apart from the molybdenum market. Instead, profitability in the molybdenum market was negatively affected by the copper price which can be explained given molybdenum's nature as a byproduct of copper production. The molybdenum market was also the only market under research whose returns were driven by the average political instability of its production countries. The manganese market was the only market under research in which market share offered a positive explanation of higher returns. Last but not least, we can summarize that the more liquid and mature markets of aluminium, copper, nickel and zinc have proven to react more sensitively to cost variables such as transport, energy and capital intensity.

Given all of the above, all a priori defined objectives were thus targeted throughout this thesis.

7.2 Implications for the mining industry

In order to avoid redundancy, this section will refrain from repeating the results of the key analyses. However, we would like to offer a few concluding remarks for the mining industry:

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[427] Neither energy cost measured as global oil prices nor the stability of production countries nor company capital intensity nor the miners' sales capabilities exhibit any statistical significant relation with the mining companies' profitability in the overall analysis.

As expected market metal prices demonstrated to have a high positive impact on the mining industries' profitability, in general more important than any other positive profitability determinant.[428] Although this comes as no surprise the strategy of taking market metal prices as an external god given factor and blaming low market prices for meager returns might be worthwhile to reconsider, especially, as there are two fundamental reasons why market metal prices have not re-climbed the heights that were achieved prior to the financial crisis.[429]

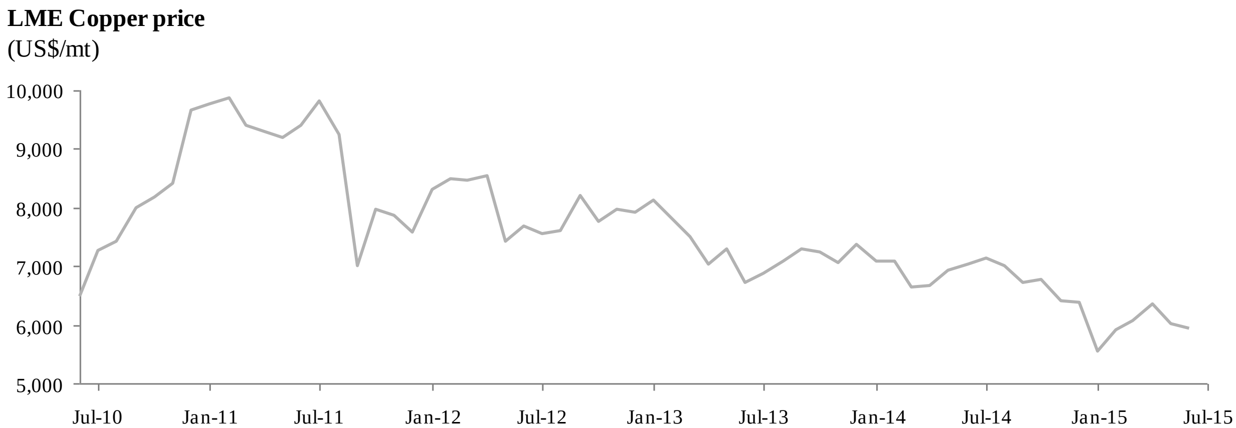

Figure 39 - Copper price development from 2010 until 2015[430]

On the one hand, cheaper producers have emerged and professionalized, mostly in Asian countries, which have decreased overall transport cost to the end customer as well as production cost and efficiency.[431] For all mining companies, the key to sustained profitability thus remains continuous asset optimization in order to ensure cost competitiveness in the highly commoditized non-ferrous metal markets and especially in the more mature metal markets.

On the other hand, demand is always price driven. Unjustified high metal prices over a longer period will initiate the development of substitutes or alternatives where possible. Being highly dependent on expensive foreign copper supply, China's State Grid, one of the largest global copper

[428] Such as competitor concentration, demand or sales capabilities. Thus, considering for example the highly scattered yet highly profitable copper market the high profitability throughout the observation period can be traced back to the high copper prices unimpaired by the low competitor concentration.

[429] See for example the development of copper prices from 2010 until 2015 in Figure 39.

[430] See Bloomberg 2015.

[431] These producers are often either state owned, subsidized or protected by export bans such as the Nickel production in Indonesia and are thus particularly difficult to compete with.

consumers, is now contemplating a move to replace copper with aluminum in power cables.[432] In addition, high demand levels can be feigned by speculative activities rather than originating from sustained long-term drivers.[433] It is thus essential to have an in-depth understanding of mid to long term global demand along with supply rather than to rely on short term market trends when considering capacity expansion projects such as new assets developments or acquisition of other, mostly junior miners.[434]

Apart from lower metal prices, mandatory cost competitiveness and the importance to anticipate changes in demand, there remains one last strategic point to be made: it concerns the mining industry's liking for size, understandably, since in most operations size has helped to cut cost and increase efficiency. However, when it comes to mining giants our analyses have shown that smaller mining companies have outperformed larger miners. Although striking from an outside-in perspective, it becomes surprisingly easy to understand from the inside perspective of large, multi-metal if not even multi-commoditized globally expanded mining empires. Management willingness to increase controlling paired with lacking knowledge on the highly differing regions, minerals, metals, cultures, politics, pitfalls, challenges but also opportunities drives complexity and decreases efficiency and focus on the core business.

Supporting this notion is the fact that BHP Billiton which is often cited as the benchmark in the mining industry is taking an important step into that direction by demerging its former gigantic business group into two separate companies. These can independently operate more efficiently and with more focus on their core operations and activities.[435]

On another note, when comparing the oil and gas industry with the metal industry, Garcia and Camus also conclude that the higher margins of oil and gas producers can be explained by their higher focus on their core value creation activities, namely the thorough exploration or acquisitions

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[432] See Financial Times 2015. This move was driven by the relatively cheap price of aluminum in China as a result of aggressive output expansion over recent years, see 2.2.1.

[433] See for example The Wall Street Journal 2014.

[434] Beware that in-house trading desks might help to gather an understanding of the market, yet are high risk undertakings which normally require significant investment in capabilities as well as transport/stocking/production capacity. Our analysis have shown that in mature markets, a miner's sales capabilities did not lead to higher profitability during the observation period.

[435] See BHP Billiton 2015.

of assets and their successful transformation into economic reserves to replace those successfully consumed.[436]

Overall, it is all about focus on the core business.

7.3 Critical assessment and areas for future research

Reflecting company performance analyses in general, research has rightfully bemoaned three major points: the limitation of predicting future performance based on profitability determinants identified from the past, the competitive instability of identified performance drivers and the complexity surrounding company performance.[437]

Regarding the retrospective perspective of this dissertation, we do not dare to generalize our findings from the analysis of the years 2002 until 2012 to future performance in the mining industry and would like to ask our readers to refrain from doing so as well, especially given that innovations such as autonomous mining are expected to re-shape the way future mining operations will work.[438] Nevertheless, understanding the past is always a great starting point to venture into the unknown.

As for the instabilities of performance advantages, this supports the above mentioned notion. Most identified profitability determinants can be copied by other market participants and will thus not lead to sustained excess profitability. Regarding for example that company size has been found to be negatively correlated to the profitability of producers, other miners in the industry might follow the example of BHP Billiton[439] quickly evening out the competitive advantage of having a streamlined and focused organization. On another note, the above mentioned advantage of higher copper prices between 2002 and 2012 has not proven to be sustainable considering the decreasing copper prices since 2012.[440] Overall, with any identified competitive advantage it is thus worthwhile to consider its longevity before jumping to conclusions and into action.

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436 See Garcia, Camus 2011.

437 See March, Sutton 1997, pp.700-702 and Woywode 2004, pp.22-37.

438 Nevertheless, Crowson has argued that most of any cost reductions will flow through to consumers via lower prices, see Crowson 2001, p.40.

439 See BHP Billiton 2015.

440 See Figure 39.

At last, considering the valid remark with regards to the oversimplification of complex worlds we agree that the world is neither simple nor linear. Certainly, we did not cover all possible explanatory profitability drivers that could possibly be relevant to explain the profitability of the mining and metals industry.[441] Some determinants might have been omitted due to mere ignorance, yet some just lacked the required data to be measurable. Nevertheless, as data availability is constantly improving we would like to encourage future research on a few determinants that we had excluded in this dissertation: Altogether, we see potential for further research in the following three directions:

1. Expanding and detailing the variety of explanatory variables to cover organizational and thus company specific factors such as plant and equipment newness, location of assets or production cost per ton.[442] Clearly, this depends on the availability of the data. As soon as available these data and their analyses would enable a more detailed company specific as well as geography specific discussion on profitability and risk-return relations in the mining industry.
2. Scrutinizing other commodities as well as metal markets such as the omitted precious metal markets,[443] rarer metal markets or simply metal markets in which too large a share was privately or state owned and thus did not offer sufficient data to conduct neither the qualitative nor the quantitative analyses of this thesis.[444] As explained in 2.1.5, commodity markets normally undergo certain development stages. If metal markets that are now small and illiquid, grow in volume and value, they generally professionalize, become more standardized and transparent. The analyses that were conducted in this paper could thus be extended to other metal markets as soon as transparency has increased such as it has happened and is just happening in the molybdenum market.
3. Extending the analyzed time span to gather more trends and developments in the mining and metal markets over a longer period. While data availability is rather limited for the period before 2002 when data proliferation started to be facilitated through globalization

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[441] Although we have without need to mention it tried our best to include all available and relevant data.
[442] As mentioned in 5.2.3 we have not covered organizational factors due to a lack of these data from the secondary
[443] As explained in 2.1.6 we had excluded precious metals from the analyses in this study given that we aimed to analyze mining companies in metal markets whose demand do not to a large extent underlie investment purposes.
[444] Examples for these markets are the lead, tin, chromium, cobalt, vanadium or lithium market.

and internet, prolonging the observation period beyond 2012 would be interesting in order to understand how market power is shifting in the mineral and metal industry given the new competition from Asia.

The above described suggestions for further research represent only a small fraction of the possibilities. It is hoped that the insights regarding the seven non-ferrous metal markets and their profitability determinants that we developed in this dissertation will serve as a sound basis for further analyses of the non-ferrous metal markets and its mining companies and that they can contribute to the broader field of commodity market research. On the whole, we are interested to see further research evolving in this area.

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9 Appendices

9.1 Overview on company filings included in the dataset

Table 33 - Overview of companies included per year in the dataset

Years	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
Aluminium											
Alcan	1	1	1	1	1						
Alcoa	1	1	1	1	1	1	1	1	1	1	1
Aluminium of Greece				1	1	1	1	1	1	1	1
BHP Billiton	1	1	1	1	1	1	1	1	1	1	1
ENRC							1	1	1	1	1
Falc Xstr Nor	1	1	1	1	1	1	1	1	1	1	1
Hindalco	1	1	1	1	1	1	1	1	1	1	1
Hydro						1	1	1	1	1	1
Nalco	1	1	1	1	1	1	1	1	1	1	1
Pechiney	1	1									
Rio Tinto	1	1	1	1	1	1	1	1	1	1	1
Rusal							1	1	1	1	1
Vale	1	1	1	1	1	1	1	1	1	1	
Vedanta	1	1	1	1	1	1	1	1	1	1	1
Vimetco			1	1	1	1	1	1	1	1	1
Votorantim					1	1	1	1	1	1	1
Copper											
Anglo American	1	1	1	1	1	1	1	1	1	1	1
Antofagasta	1	1	1	1	1	1	1	1	1	1	1
Barrick					1	1	1	1	1	1	1
BHP Billiton	1	1	1	1	1	1	1	1	1	1	1
Codelco	1	1	1	1	1	1	1	1	1	1	1
Equinox Minerals								1	1		
Falconbridge	1	1	1	1							
FCX	1	1	1	1	1	1	1	1	1	1	1
First Quantum		1	1	1	1	1	1	1	1	1	1
FNX Mining Company				1	1	1	1				
Grupo Mexico	1	1	1	1	1	1	1	1	1	1	1
Inmet Mining	1	1	1	1	1	1	1	1	1	1	1
Jiangxi Copper	1	1	1	1	1	1	1	1	1	1	1
Kazakhmys			1	1	1	1	1	1	1	1	1
KGHM International										1	1
KGHM Polska Miedz	1	1	1	1	1	1	1	1	1	1	1
Norilsk Nickel	1	1	1	1	1	1	1	1	1	1	1
OZ Minerals							1	1	1	1	1
Phelps Dodge	1	1	1	1	1						
Placer Dome	1	1	1	1							

quadra				1	1	1	1				
quadra FNX								1	1		
Rio Tinto	1	1	1	1	1	1	1	1	1	1	1
Teck	1	1	1	1	1	1	1	1	1	1	1
Vale			1	1	1	1	1	1	1	1	1
Vedanta	1	1	1	1	1	1	1	1	1	1	1
Xstrata	1	1	1	1	1	1	1	1	1	1	1
Manganese											
Anglo American	1	1	1	1	1	1	1	1	1	1	1
Assmang	1	1	1	1	1	1	1	1	1	1	1
BHP Billiton	1	1	1	1	1	1	1	1	1	1	1
CITIC Dameng						1	1	1	1	1	1
Consolidated Minerals									1	1	1
ERAMET	1	1	1	1	1	1	1	1	1	1	1
Eurasian Natural Resources			1	1	1	1	1	1	1	1	1
Minera Autlan	1	1	1	1	1	1	1	1	1	1	1
MOIL Manganese ore	1	1	1	1	1	1	1	1	1	1	1
OM Holdings ltd					1	1	1	1	1	1	1
Vale	1	1	1	1	1	1	1	1	1	1	1
Molybdenum											
Antofagasta	1	1	1	1	1	1	1	1	1	1	1
China Moly					1	1	1	1	1	1	1
Codelco	1	1	1	1	1	1	1	1	1	1	1
FCX	1	1	1	1	1	1	1	1	1	1	1
Grupo Mexico	1	1	1	1	1	1	1	1	1	1	1
Mercator Min								1	1	1	1
Rio Tinto	1	1	1	1	1	1	1	1	1	1	1
TCM						1	1	1	1	1	1
Nickel											
Anglo American	1	1	1	1	1	1	1	1	1	1	1
Antam	1	1	1	1	1	1	1	1	1	1	1
BHP Billiton	1	1	1	1	1	1	1	1	1	1	1
ERAMET	1	1	1	1	1	1	1	1	1	1	1
Inco	1	1	1	1							
Ino & Falcando	1	1	1								
Nickel Asia Corp							1	1	1	1	1
Norilsk Nickel	1	1	1	1	1	1	1	1	1	1	1
Sherritt	1	1	1	1	1	1	1	1	1	1	1
Vale					1	1	1	1	1	1	1
Votorantim								1	1	1	1
Western Areas NL								1	1	1	1
Xstrata				1	1	1	1	1	1	1	1
Titanium											
Anglo American	1	1	1	1	1	1					
BeMax				1	1	1					
BHP Billiton	1	1	1	1	1	1	1	1	1	1	1

DuPont	1	1	1	1	1	1	1	1	1	1	1
Exxaro Kumba	1	1	1	1	1	1	1	1	1	1	1
Iluka Resources	1	1	1	1	1	1	1	1	1	1	1
Kenmare								1	1	1	1
Kerala Mineral and Metals Ltd	1	1	1	1	1	1	1	1	1	1	1
Kronos	1	1	1	1	1	1	1	1	1	1	1
Rio Tinto	1	1	1	1	1	1	1	1	1	1	1
Ticor	1	1	1	1							
Zinc											
Anglo American	1	1	1	1	1	1	1	1	1		
Boliden	1	1	1	1	1	1	1	1	1	1	1
Breakwater Resources Ltd.	1	1	1	1	1	1	1	1	1		
Falconbridge	1	1	1	1							
Glencore										1	1
Noranda	1	1	1								
Nyrstar										1	1
Oxiana				1	1	1					
Peñoles	1	1	1	1	1	1	1	1	1	1	1
Teck	1	1	1	1	1	1	1	1	1	1	1
Vedanta	1	1	1	1	1	1	1	1	1	1	1
Volcan Compañía Minera S.A.A.	1	1	1	1	1	1	1	1	1	1	1
Xstrata	1	1	1	1	1	1	1	1	1	1	1
Zinifex	1	1	1	1							
Total observations	67	68	71	75	74	75	76	80	81	80	79

9.2 Integrative framework for viewing Firm Financial Performance

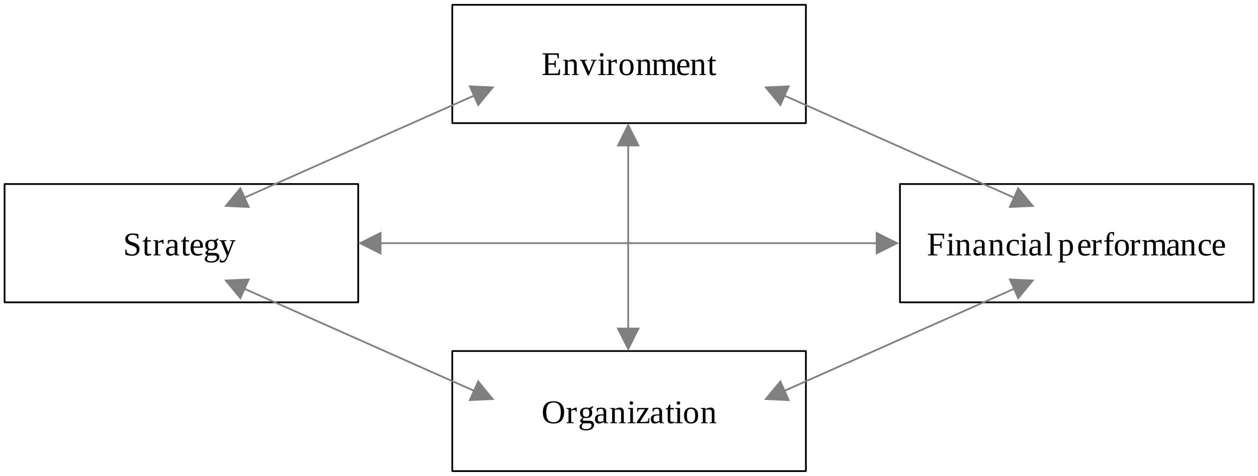

Figure 40 - An Integrative Framework for Viewing Firm Financial Performance[445]

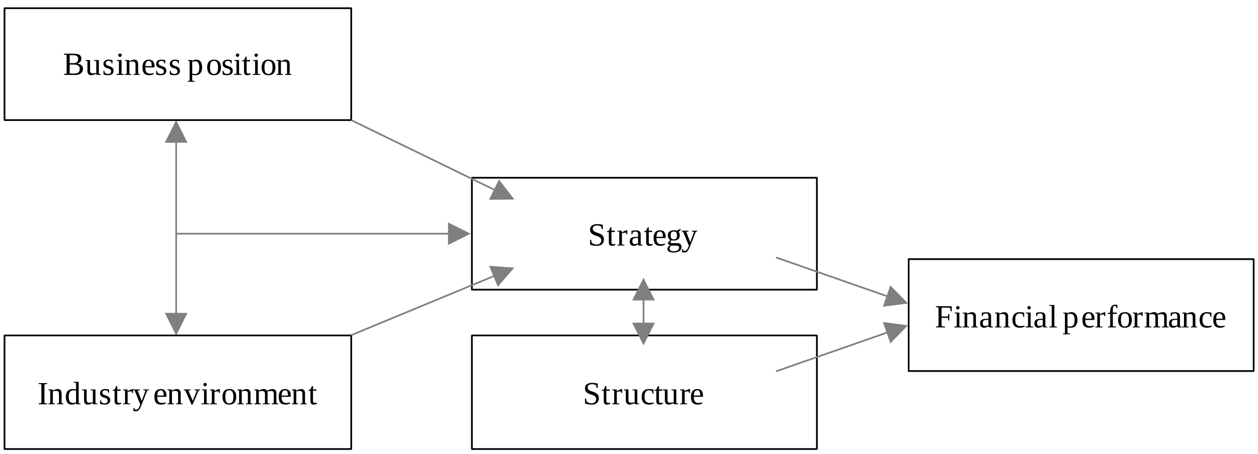

Figure 41 - The White/Hamermesh model as an integrative model to explain performance[446]

445 See Capon et al. 1996, p.6.
446 See Capon et al. 1996, p.49.

9.3 Company Size measured in logarithms

Table 34 - Comparing different measures of company size

Regression results								
Endogenous variable:	Random Effects							
Company EBIT margin	1		2		3		4	
Company Size in total assets	-0.089	**						
	(0.034)							
Company Size in natural logarithm of total assets			0.060					
			(0.262)					
Company Size in total revenues					0.007			
					(0.893)			
Company Size in natural logarithm of total revenues							-0.112	**
							(0.039)	
Constant	-0.090		-0.079		-0.086		-0.091	
	(0.213)		(0.278)		(0.226)		(0.203)	
Wald test: Model χ^2	4		1		0		4	
p-value	(0.034)		(0.262)		(0.893)		(0.039)	
Observations (N)	823		823		826		826	
R^2 overall	0.005		0.002		0.001		0.012	
R^2 between	0.000		0.006		0.000		0.002	
R^2 within	0.008		0.001		0.000		0.011	

The p-values in brackets are estimated based on cluster robust standard errors (cluster = business unit) / * 0.05<p≤0.1, ** 0.01<p≤0.05, *** p≤0.01 / All exogenous variables have been standardized before the analyses

9.4 Metal price development

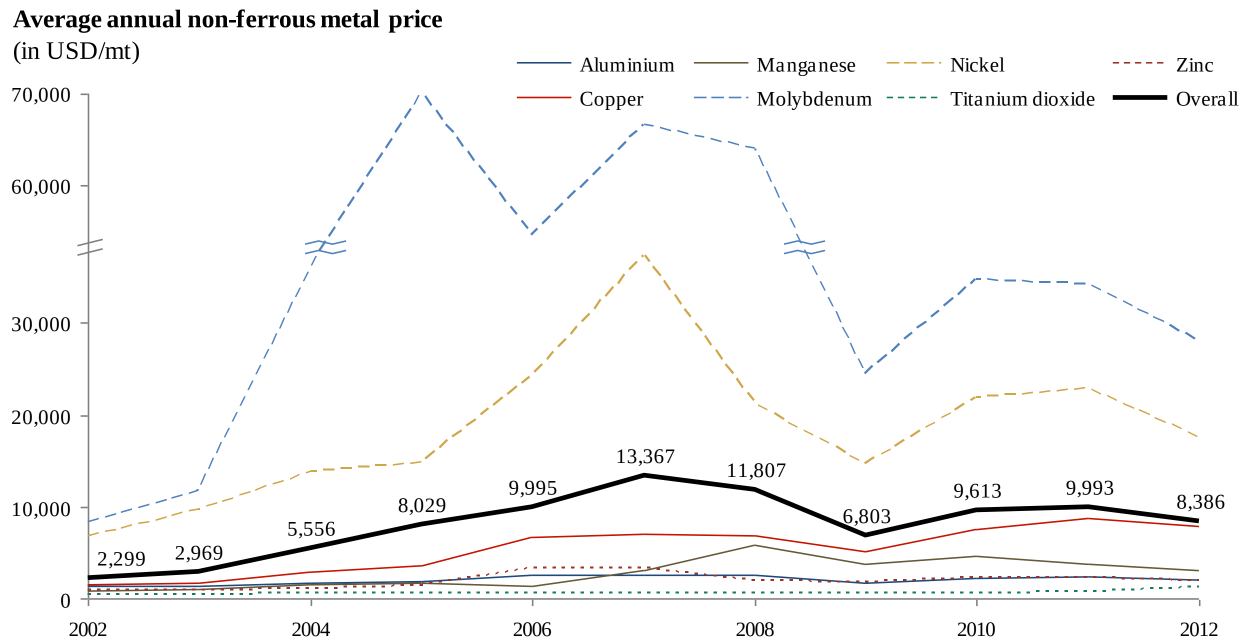

Figure 42 - Metal price development from 2002 until 2012

9.5 Further regression results with the Random Effects Estimator

Table 35 - Overall dataset: Random Effects Models (1)-(5) including Market Metal Price

Endogenous variable: *Company EBIT margin*	Random Effects 6		7		8		9		10	
Market Metal Price	0.162	*	0.161	*	0.168	**	0.182	**	0.106	
(H1, +)	(0.060)		(0.064)		(0.048)		(0.033)		(0.220)	
Company Size - Assets	-0.106	***	-0.109	**	-0.110	**	-0.101	**	-0.108	**
(H9, + or -)	(0.007)		(0.013)		(0.012)		(0.021)		(0.020)	
Company Capital Efficiency	0.117	***	0.117	***	0.112	***	0.106	***	0.087	**
(H10, +)	(0.002)		(0.002)		(0.003)		(0.007)		(0.039)	
Company Capital Intensity	-0.026		-0.026		-0.028		-0.039		-0.025	
(H11, -)	(0.655)		(0.655)		(0.634)		(0.495)		(0.646)	
Company Market Share	0.004		0.005		0.003		-0.023		-0.025	
(H12, +)	(0.943)		(0.933)		(0.965)		(0.698)		(0.699)	
Ad Valorem Transport Cost	-0.336	***	-0.335	***	-0.349	***	-0.363	***	-0.238	***
(H2, -)	(0.000)		(0.000)		(0.000)		(0.000)		(0.000)	
Global Energy Cost			0.005		0.020		0.027		-0.006	
(H3, -)			(0.914)		(0.684)		(0.574)		(0.898)	
Market Demand Growth					0.085	***	0.084	***	0.074	***
(H4, +)					(0.001)		(0.001)		(0.001)	
Market HHI							0.110	*	0.162	***
(H5, +)							(0.072)		(0.006)	
Market Capital Intensity									-0.356	***
(H6, + or -)									(0.000)	
Wald test: Commodity χ^2	21	***	21	***	23	***	31	***	46	***
Wald test: Year χ^2	123	***	125	***	140	***	145	***	82	***
Wald test: Model χ^2	329		340		419		473		544	
p-value	(0.000)		(0.000)		(0.000)		(0.000)		(0.000)	
Observations (N)	823		823		823		823		823	
R^2 overall	0.305		0.305		0.312		0.321		0.357	
R^2 between	0.222		0.221		0.228		0.245		0.252	
R^2 within	0.335		0.335		0.345		0.346		0.406	

The p-values in brackets are estimated based on cluster robust standard errors (cluster = business unit) / * 0.05<p≤0.1, ** 0.01<p≤0.05, *** p≤0.01 / All exogenous variables have been standardized before the analyses / (H, +/-) Hypotheses including postulated direction / Constant and dummy variables for commodity markets and year are not shown

Table 36 - Overall dataset: Random Effects Models (11)-(16) including Market Metal Price

Endogenous variable: *Company EBIT margin*	Random Effects 11	12	13	14	15	16
Market Metal Price (H1, +)	0.104 (0.230)	0.112 (0.200)	0.068 (0.433)	0.088 (0.306)	0.088 (0.314)	0.104 (0.230)
Company Size - Assets (H9, + or -)		-0.141 *** (0.008)	-0.093 ** (0.039)	-0.108 ** (0.015)	-0.107 ** (0.021)	-0.108 ** (0.019)
Company Capital Efficiency (H10, +)	0.101 ** (0.016)	0.083 ** (0.045)	0.070 * (0.065)	0.084 ** (0.045)	0.087 ** (0.038)	0.087 ** (0.038)
Company Capital Intensity (H11, -)	-0.026 (0.629)	-0.027 (0.614)	-0.023 (0.692)	-0.029 (0.593)	-0.026 (0.632)	-0.026 (0.636)
Company Market Share (H12, +)	-0.035 (0.595)	-0.021 (0.745)	-0.030 (0.632)	-0.019 (0.779)	-0.026 (0.687)	-0.025 (0.700)
Ad Valorem Transport Cost (H2, -)	-0.237 *** (0.000)	-0.234 *** (0.000)	-0.256 *** (0.000)	-0.252 *** (0.000)	-0.237 *** (0.000)	-0.241 *** (0.000)
Global Energy Cost (H3, -)	-0.022 (0.605)	0.008 (0.858)	11.417 *** (0.000)	0.035 (0.480)	-0.011 (0.796)	0.003 (0.957)
Market Demand Growth (H4, +)	0.073 *** (0.001)	0.074 *** (0.001)	0.105 *** (0.000)	0.076 *** (0.001)	0.068 *** (0.003)	0.074 *** (0.001)
Market HHI (H5, +)	0.167 *** (0.006)	0.159 *** (0.007)	0.183 *** (0.002)	0.100 (0.153)	0.160 *** (0.008)	0.162 *** (0.007)
Market Capital Intensity (H6, + or -)	-0.356 *** (0.000)	-0.365 *** (0.000)	-0.326 *** (0.000)	-0.350 *** (0.000)	-0.359 *** (0.000)	-0.357 *** (0.000)
Company Size - Revenues (H9, + or -)	-0.072 (0.112)					
Company Focus (H13, + or -)		-0.113 * (0.068)				
Company Sales Capabil.			0.007 (0.782)			
Market Size (H7, -)				-0.278 ** (0.035)		
Market Supply Growth (H4, +)					0.037 (0.113)	
Market stability of prod. countries (H8, +)						0.022 (0.785)
Wald test: Commodity χ^2	48 ***	57 ***	62 ***	19 ***	48 ***	43 ***
Wald test: Year χ^2	82 ***	83 ***	81 ***	85 ***	69 ***	73 ***
Wald test: Model χ^2	536	556	520	549	540	541
p-value	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations (N)	823	823	724	823	823	823
R^2 overall	0.357	0.372	0.371	0.357	0.358	0.357
R^2 between	0.264	0.270	0.342	0.248	0.251	0.251
R^2 within	0.401	0.407	0.372	0.410	0.408	0.406

The p-values in brackets are estimated based on cluster robust standard errors (cluster = business unit) / * 0.05<p≤0.1, ** 0.01<p≤0.05, *** p≤0.01 / All exogenous variables have been standardized before the analyses / (H, +/-) Hypotheses including postulated direction / Constant & dummy variables for commodity, year are not shown

Table 37 - Overview on VIFs of the Random Effects Models (6)-(16) incl. Market Metal Price

Endogenous variable:	Model										
Company EBIT margin	6	7	8	9	10	11	12	13	14	15	16
cd1 (aluminum)	1.23	1.23	1.26	1.99	2.44	2.44	2.47	2.45	30.99	2.50	3.44
cd3 (manganese)	1.30	1.31	1.31	2.15	3.03	3.04	3.04	3.14	3.34	3.14	3.86
cd4 (molybdenum)	4.16	4.19	4.21	4.21	4.26	4.55	4.33	4.51	7.11	4.25	4.38
cd5 (nickel)	1.93	1.95	1.95	4.16	4.24	4.24	4.24	4.26	5.48	4.25	12.55
cd7 (titanium)	1.32	1.32	1.35	1.85	1.89	1.90	1.97	1.99	1.91	1.90	4.32
td03 (2003)	1.39	1.73	1.87	1.87	1.91	1.91	1.91		1.91	1.99	2.71
td04 (2004)	1.39	1.56	1.56	1.56	1.78	1.78	1.78	1.85	1.78	1.88	2.40
td05 (2005)	1.45	1.47	1.47	1.47	1.79	1.79	1.80	1.76	1.80	1.84	2.01
td06 (2006)	1.48	1.49	1.53	1.54	1.96	1.96	1.97	2.07	1.96	1.96	1.96
td07 (2007)	1.57	1.60	1.61	1.61	2.00	2.00	2.00	2.03	2.01	2.04	2.00
td08 (2008)	1.54	2.10	2.10	2.10	2.19	2.18	2.22	2.24	2.20	2.20	2.25
td09 (2009)	1.41	1.41	1.47	1.47	1.47	1.47	1.48	1.39	1.47	1.61	1.74
td10 (2010)	1.45	1.54	1.54	1.55	1.58	1.58	1.58	1.54	1.58	1.74	1.73
td11 (2011)	1.46	1.86	1.87	1.87	1.90	1.90	1.90	1.88	1.90	1.95	1.91
Market Metal Price	4.93	5.00	5.01	5.10	5.25	5.25	5.26	5.98	5.45	5.65	5.31
Company Size - Assets	1.25	1.30	1.30	1.30	1.30		2.17	1.29	1.30	1.30	1.30
Company Capital Efficiency	1.28	1.28	1.29	1.30	1.30	1.26	1.30	1.29	1.30	1.30	1.30
Company Capital Intensity	1.31	1.31	1.31	1.32	1.32	1.32	1.33	1.35	1.33	1.32	1.33
Company Market Share	1.30	1.31	1.31	1.35	1.35	1.39	1.35	1.35	1.36	1.35	1.35
Ad Valorem Transport Cost	1.42	1.44	1.45	2.57	3.15	3.15	3.16	3.59	3.44	3.15	3.99
Global Energy Cost		3.09	3.13	3.13	3.15	3.11	3.33	2.72	3.87	3.20	4.54
Market Demand Growth			1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.38	1.33
Market HHI				3.87	4.00	4.00	4.01	4.10	6.58	4.01	4.10
Market Capital Intensity					3.74	3.74	3.74	4.16	3.75	3.76	3.76
Company Size - Revenues						1.27					
Company Focus							1.94				
Company Sales Capabilities								1.08			
Market Size									38.82		
Market Size Growth										1.82	
Market instab. of prod. countries											11.82
Average VIF	1.73	1.88	1.87	2.29	2.51	2.51	2.54	2.56	5.36	2.54	3.62
Maximum VIF	4.93	5.00	5.01	5.10	5.25	5.25	5.26	5.98	38.82	5.65	12.55

Table 38 - Overall dataset: Random Effects Model (10) & (14) without Copper & Market HHI

Endogenous variable: *Company EBIT margin*	Random Effects			
	10		14°	
Market Metal Price				
Company Size - Assets	-0.106	**	-0.113	***
	(0.022)		(0.009)	
Company Capital Efficiency	0.093	**	0.090	**
	(0.033)		(0.032)	
Company Capital Intensity	-0.021		-0.022	
	(0.705)		(0.685)	
Company Market Share	-0.026		-0.002	
	(0.704)		(0.975)	
Ad Valorem Transport Cost	-0.239	***	-0.257	***
	(0.000)		(0.000)	
Global Energy Cost	0.001		0.061	
	(0.973)		(0.173)	
Market Demand Growth	0.072	***	0.076	***
	(0.003)		(0.002)	
Market HHI	0.150	**		
	(0.016)			
Market Capital Intensity	-0.373	***	-0.352	***
	(0.000)		(0.000)	
Market Size			-0.435	***
			(0.000)	
Wald test: Model χ^2	513		504	
p-value	(0.000)		(0.000)	
Observations (N)	823		823	
R^2 overall	0.353		0.349	
R^2 between	0.246		0.233	
R^2 within	0.403		0.408	

The p-values in brackets are estimated based on cluster robust standard errors (cluster = business unit) / * 0.05<p≤0.1, ** 0.01<p≤0.05, *** p≤0.01 / All exogenous variables have been standardized before the analyses / Constant and dummy variables for commodity markets and year are not shown

9.6 Further analyses to test robustness of overall regression analyses

Table 39 - Correlation coefficients for Company Performance with Company Size & Debt

	Variables	*(1)*	*(2)*	*(3)*	*(4)*
(1)	*Company Performance*	*1.00*			
(2)	*Company Size - Assets*	-0.07	*1.00*		
(3)	*Company Size - Revenues*	-0.04	**0.93**	*1.00*	
(4)	*Company Debt*	-0.06	**0.95**	**0.88**	*1.00*

The table shows the pair-wise Pearson correlation coefficients measure ρ ranging from ρ= -1 – absolute negative linear correlation to ρ= 1 – absolute positive linear correlation. Bold figures show correlations coefficients above 0.10 or below -0.10.

Table 40 - Overall dataset: Fixed Effects Models (1)-(5) - Introduction of Control Variables

Endogenous variable:	**Fixed Effects**									
Company EBIT margin	1		2		3		4		5	
Market Metal Price	0.201	***	0.218	***	0.195	***	0.195	***	0.195	***
(H1, +)	(0.000)		(0.000)		(0.000)		(0.000)		(0.000)	
Company Size - Assets			-0.150	***	-0.115	**	-0.115	**	-0.114	**
(H9, + or -)			(0.001)		(0.015)		(0.015)		(0.016)	
Comp. Capital Efficiency					0.161	***	0.161	***	0.162	***
(H10, +)					(0.000)		(0.000)		(0.000)	
Company Capital Intensity							(omitted)		(omitted)	
(H11, -)										
Company Market Share									-0.011	
(H12, +)									(0.885)	
Observations (N)	826		823		823		823		823	
R^2 overall	0.184		0.184		0.161		0.161		0.163	
R^2 between	0.115		0.080		0.042		0.042		0.043	
R^2 within	0.263		0.272		0.291		0.291		0.291	

The p-values in brackets are estimated based on cluster robust standard errors (cluster = business unit) / * 0.05<p≤0.1, ** 0.01<p≤0.05, *** p≤0.01 / All exogenous variables have been standardized before the analyses / (H, +/-) Hypotheses including postulated direction / Constant and dummy variables for commodity markets and year are not shown

Table 41 - Overall dataset: Fixed Effects Models (6)-(10) - Development of the basic model

Endogenous variable: *Company EBIT margin*	Fixed Effects 6	7	8	9	10
Market Metal Price	0.160 ***				
(H1, +)	(0.001)				
Company Size - Assets	-0.152 ***	-0.162 ***	-0.165 ***	-0.161 ***	-0.169 ***
(H9, + or -)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)
Comp. Capital Efficiency	0.142 ***	0.152 ***	0.147 ***	0.146 ***	0.114 ***
(H10, +)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
Company Capital Intensity (H11, -)	(omitted)	(omitted)	(omitted)	(omitted)	(omitted)
Company Market Share	-0.012	-0.017	-0.023	-0.037	-0.046
(H12, +)	(0.867)	(0.814)	(0.751)	(0.624)	(0.521)
Ad Val. Transport Cost	-0.361 ***	-0.363 ***	-0.381 ***	-0.377 ***	-0.254 ***
(H2, -)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Global Energy Cost		0.046	0.060	0.066	0.017
(H3, -)		(0.305)	(0.176)	(0.143)	(0.694)
Market Demand Growth			0.080 ***	0.079 ***	0.071 ***
(H4, +)			(0.002)	(0.002)	(0.004)
Market HHI				0.046	0.103 *
(H5, +)				(0.446)	(0.076)
Market Capital Intensity					-0.376 ***
(H6, + or -)					(0.000)
Observations (N)	823	823	823	823	823
R^2 overall	0.233	0.217	0.222	0.216	0.207
R^2 between	0.117	0.094	0.098	0.091	0.071
R^2 within	0.337	0.328	0.337	0.338	0.406

The p-values in brackets are estimated based on cluster robust standard errors (cluster = business unit) / * 0.05<p≤0.1, ** 0.01<p≤0.05, *** p≤0.01 / All exogenous variables have been standardized before the analyses / (H, +/-) Hypotheses including postulated direction / Constant and dummy variables for commodity markets and year are not shown

Table 42 - Overall dataset: Fixed Effects Models (11)-(16) - Additional performance drivers

Endogenous variable:	**Fixed Effects**					
Producer profitab.	11	12	13	14	15	16
Market Metal Price (H1, +)						
Comp. Size – Assets (H9, + or -)		-0.169*** (0.001)	-0.146*** (0.005)	-0.168*** (0.001)	-0.168*** (0.001)	-0.169*** (0.001)
Company Capital Efficiency (H10, +)	0.134*** (0.000)	0.113*** (0.001)	0.107*** (0.004)	0.110*** (0.001)	0.113*** (0.001)	0.114*** (0.001)
Company Capital Intensity (H11, -)	(omitted)	(omitted)	(omitted)	(omitted)	(omitted)	(omitted)
Company Market Share (H12, +)	-0.050 (0.482)	-0.045 (0.537)	-0.034 (0.662)	-0.033 (0.641)	-0.048 (0.497)	-0.046 (0.518)
Ad Val. Transport Cost (H2, -)	-0.254*** (0.000)	-0.254*** (0.000)	-0.255*** (0.000)	-0.259*** (0.000)	-0.252*** (0.000)	-0.256*** (0.000)
Global Energy Cost (H3, -)	-0.004 (0.923)	0.017 (0.692)	-0.063 (0.185)	0.067 (0.166)	0.009 (0.842)	0.027 (0.623)
Market Demand Growth (H4, +)	0.069*** (0.005)	0.071*** (0.004)	0.100*** (0.000)	0.072*** (0.003)	0.063** (0.011)	0.071*** (0.004)
Market HHI (H5, +)	0.108* (0.063)	0.102* (0.079)	0.133** (0.037)	0.045 (0.480)	0.105* (0.068)	0.105* (0.072)
Market Capital Intensity (H6,+ or -)	-0.375*** (0.000)	-0.377*** (0.000)	-0.336*** (0.000)	-0.364*** (0.000)	-0.376*** (0.000)	-0.376*** (0.000)
Comp. Size - Revenues(H9,+or-)	-0.128 ** (0.014)					
Company Focus (H13, + or -)		-0.009 (0.936)				
Company Sales Capabil.			0.006 (0.801)			
Market Size (H7, -)				-0.324 ** (0.023)		
Market Supply Growth (H4, +)					0.048 * (0.076)	
Market stab. of prod. count. (H8, +)						0.024 (0.769)
Observations (N)	823	823	724	823	823	823
R^2 overall	0.205	0.208	0.202	0.281	0.204	0.209
R^2 between	0.074	0.072	0.098	0.155	0.068	0.072
R^2 within	0.401	0.406	0.373	0.410	0.408	0.406

The p-values in brackets are estimated based on cluster robust standard errors (cluster = business unit) / * 0.05<p≤0.1, ** 0.01<p≤0.05, *** p≤0.01 / All exogenous variables have been standardized before the analyses / (H, +/-) Hypotheses including postulated direction / Constant and dummy variables for commodity markets and year are not shown

Table 43 - Hausman test on Random Effects estimator consistency

Model	χ^2	p-value
(1)	7.65	0.6634
(2)	9.66	0.5612
(3)	15.49	0.2157
(4)	17.11	0.1454
(5)	18.04	0.156
(6)	19.68	0.1406
(7)	18.58	0.1817
(8)	18.73	0.2263
(9)	19.19	0.2588
(10)	19.05	0.2019
(11)	30.12	0.0255
(12)	30.89	0.0296
(13)	23.22	0.1080
(14)	31.01	0.0287
(15)	32.69	0.0182
(16)	38.38	0.0035

χ^2 statistics and p-values for the Hausman Test performed on regression models (1)-(16) with conventional standard errors and excluding all time-invariant regressors

9.7 Sources of Molybdenum from dedicated mines and as a byproduct

Table 44 - Share of molybdenum extracted as byproduct versus from dedicated assets

Country	**Molybdenum Ore Production 2013** (in mio. mt)		**Total**
Primary metal asset	*Copper asset*	*Molybdenum asset*	
Chile	327		327
China	27	182	209
USA	124	34	158
Mexico	148		148
Peru	105		105
Canada	65	16	82
Iran	34		34
Mongolia	26		26
Armenia	19		19
Russia		17	17
South Korea		2	2
Kazakhstan		1	1
Total	874	252	1,126
Share of Total	78%	22%	100%

Source: RMG database, 2014

9.8 Comparing single metal markets: Like for like

In order to ensure that we are comparing like for like we have also fitted the same models for each of the seven markets. Hereby, we start by explaining company profitability with the control variables, i.e. in analogy to model 5 of the overall data analysis. Then, we analyze the impact of the market variables and especially the potential cost drivers. To do so, we first add the *Global Energy Cost* to the control variables. At last, we add the other market variables, namely *Market Ad Valorem Transport Cost*, *Market Demand Growth* and *Market HHI* though we have to drop *Global Energy Cost* to avoid multicollinearity.

Please refer to chapter 6.3 for the discussion and evaluation of the results.

Table 45 - Comparing single metal markets: Random Effects Model with control variables

Regression results														
Endogenous variable:							Random Effects							
Company EBIT margin	Al		Cu		Mn		Mo		Ni		Ti		Zi	
Market Metal Price	0.201	***	0.332	***	0.521	***	0.109		0.358	**	0.426	***	0.476	***
	(0.002)		(0.000)		(0.000)		(0.277)		(0.013)		(0.000)		(0.000)	
Company Size - Assets	-0.182	**	-0.241	**	-0.283	**	0.122	**	-0.059		-0.504	***	0.135	
	(0.013)		(0.039)		(0.013)		(0.021)		(0.535)		(0.000)		(0.187)	
Company Capital Efficiency	0.202	*	0.157		0.158	**	0.372	***	0.175		0.242	**	0.086	*
	(0.076)		(0.183)		(0.041)		(0.000)		(0.424)		(0.026)		(0.084)	
Company Capital Intensity	-0.157		-0.007		-0.246	*	-0.164		0.040		-0.105		-0.242	***
	(0.158)		(0.963)		(0.066)		(0.338)		(0.800)		(0.120)		(0.000)	
Company Market Share	-0.041		-0.239	**	0.357	***	-0.176		-0.027		0.210	**	-0.303	
	(0.672)		(0.046)		(0.004)		(0.326)		(0.753)		(0.015)		(0.138)	
Wald test: Model χ^2	53		71		126		49		16		233		147	
p-value	(0.000)		(0.000)		(0.000)		(0.000)		(0.008)		(0.000)		(0.000)	
Observations (N)	134		21		99		72		94		101		102	
R^2 overall	0.099		0.046		0.184		0.281		0.147		0.348		0.418	
R^2 between	0.002		0.010		0.028		0.393		0.067		0.433		0.235	
R^2 within	0.298		0.225		0.542		0.334		0.213		0.355		0.721	
Variance Inflation Factors														
Market Metal Price	1.06		1.21		1.13		1.58		1.04		1.09		1.68	
Company Size - Assets	1.35		1.33		1.34		1.04		1.14		1.36		1.79	
Company Capital Efficiency	1.33		1.77		1.18		1.92		2.01		1.06		1.23	
Company Capital Intensity	1.07		1.34		1.07		1.10		1.91		1.22		1.56	
Company Market Share	1.41		1.45		1.18		1.39		1.17		1.16		1.46	
Average VIF	1.24		1.42		1.18		1.41		1.45		1.18		1.54	
Maximum VIF	1.41		1.77		1.34		1.92		2.01		1.36		1.79	

The p-values in brackets are estimated based on cluster robust standard errors (cluster = business unit) / * $0.05<p\leq0.1$, ** $0.01<p\leq0.05$, *** $p\leq0.01$ / All exogenous variables have been standardized before the analyses / Constant and dummy variables for commodity markets and year are not shown

Table 46 - Comparing single metal markets: Random Effects Model with Global Energy Cost

Regression results							
Endogenous variable:	Random Effects						
Company EBIT margin	Al	Cu	Mn	Mo	Ni	Ti	Zi
Market Metal Price	0.814 ***	1.002 ***	0.675 ***	0.131	0.598 ***	0.432 ***	0.513 ***
	(0.000)	(0.000)	(0.000)	(0.153)	(0.000)	(0.008)	(0.000)
Company Size - Assets	-0.060	-0.230 *	-0.184 *	0.165 *	-0.353 ***	-0.041	0.153
	(0.249)	(0.067)	(0.051)	(0.064)	(0.000)	(0.677)	(0.131)
Company Capital Efficiency	0.100	0.166	0.166 **	0.387 ***	0.211 **	0.208	0.086 *
	(0.219)	(0.103)	(0.045)	(0.000)	(0.033)	(0.318)	(0.100)
Company Capital Intensity	-0.142 *	0.000	-0.224	-0.169	-0.091 *	0.064	-0.223 ***
	(0.081)	(0.998)	(0.127)	(0.310)	(0.099)	(0.702)	(0.000)
Company Market Share	-0.093	-0.259 **	0.249 *	-0.228	0.108	-0.030	-0.300
	(0.186)	(0.026)	(0.073)	(0.304)	(0.157)	(0.729)	(0.144)
Global Energy Cost	-0.831 ***	-0.722 ***	-0.250 **	-0.080	-0.342 ***	-0.134	-0.048
	(0.000)	(0.000)	(0.015)	(0.464)	(0.001)	(0.258)	(0.212)
Wald test: Model χ^2	142	146	139	52	2,227	27	147
p-value	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations (N)	34	221	99	72	101	94	102
R^2 overall	0.408	0.101	0.226	0.296	0.421	0.158	0.418
R^2 between	0.244	0.010	0.035	0.389	0.450	0.007	0.235
R^2 within	0.474	0.328	0.577	0.337	0.415	0.213	0.721
Variance Inflation Factors							
Market Metal Price	2.60	8.22	2.63	1.83	1.64	1.52	3.96
Company Size - Assets	1.38	1.33	1.38	1.08	1.47	1.17	1.83
Company Capital Efficiency	1.38	1.77	1.19	1.93	1.08	2.11	1.23
Company Capital Intensity	1.07	1.34	1.09	1.11	1.23	1.96	2.36
Company Market Share	1.42	1.45	1.22	1.46	1.23	1.17	1.46
Global Energy Cost	2.75	8.11	2.77	1.36	1.83	1.61	2.86
Maximum VIF	2.75	8.22	2.77	1.93	1.83	2.11	3.96

The p-values in brackets are estimated based on cluster robust standard errors (cluster = business unit) /* $0.05<p\leq0.1$, ** $0.01<p\leq0.05$, *** $p\leq0.01$ / All exogenous variables have been standardized before the analyses / Constant and dummy variables for commodity markets and year are not shown

Table 47 - Comparing single metal markets: Random Effects Model with market variables

Regression results							
Endogenous variable:				Random Effects			
Company EBIT margin	Al	Cu	Mn	Mo	Ni	Ti	Zi
Market Metal Price	0.351 ***	0.290 ***	0.733 ***	-0.032	0.579 ***	0.347 **	-0.089
	(0.000)	(0.007)	(0.000)	(0.829)	(0.000)	(0.014)	(0.561)
Company Size - Assets	-0.042	-0.282 ***	-0.185 **	0.020	-0.386 ***	-0.015	0.133
	(0.550)	(0.008)	(0.050)	(0.829)	(0.000)	(0.864)	(0.205)
Company Capital Efficiency	0.017	0.100	0.051	0.647 ***	0.163 **	0.192	0.110 ***
	(0.853)	(0.427)	(0.581)	(0.000)	(0.024)	(0.280)	(0.004)
Company Capital Intensity	-0.164 *	-0.029	-0.234	-0.161	-0.115 **	0.057	-0.430 ***
	(0.051)	(0.840)	(0.141)	(0.343)	(0.040)	(0.729)	(0.000)
Company Market Share	-0.089	-0.190	0.183	-0.428	0.110	-0.015	-0.360 *
	(0.204)	(0.113)	(0.241)	(0.156)	(0.327)	(0.854)	(0.063)
Ad valorem transport cost	0.041	-0.265 **	0.164	0.096	-0.286 ***	-0.138	-0.275 ***
	(0.634)	(0.013)	(0.209)	(0.369)	(0.000)	(0.174)	(0.000)
Market Demand Growth	0.158 ***	-0.039	0.050	-0.070	-0.006	0.084	0.097
	(0.003)	(0.359)	(0.457)	(0.552)	(0.940)	(0.377)	(0.134)
Market HHI	0.483 ***	-0.276 ***	0.157	-0.008	0.063	-0.277 **	0.211 ***
	(0.001)	(0.000)	(0.141)	(0.938)	(0.664)	(0.023)	(0.009)
Wald test: Model χ^2	208	112	280	.	1,283	173	292
p-value	(0.000)	(0.000)	(0.000)	.	(0.000)	(0.000)	(0.000)
Observations (N)	134	221	99	72	101	94	102
R^2 overall	0.414	0.097	0.288	0.345	0.423	0.235	0.415
R^2 between	0.404	0.021	0.096	0.467	0.525	0.101	0.198
R^2 within	0.434	0.338	0.562	0.295	0.402	0.261	0.766
Variance Inflation Factors							
Market Metal Price	1.77	6.73	3.72	1.89	2.79	1.98	16.57
Company Size - Assets	1.40	1.33	1.38	1.08	1.46	1.16	1.80
Company Capital Efficiency	1.46	1.88	1.47	2.09	1.17	2.04	1.23
Company Capital Intensity	1.08	1.35	1.11	1.11	1.23	1.92	3.02
Company Market Share	1.42	1.48	1.22	1.48	1.26	1.17	1.46
Ad valorem transport cost	1.47	4.74	4.63	1.87	3.82	2.38	5.51
Market Demand Growth	1.51	1.37	1.56	1.82	2.44	1.56	2.94
Market HHI	2.57	2.27	2.93	1.31	1.64	1.22	3.00
Maximum VIF	2.57	6.73	4.63	2.09	3.82	2.38	16.57

P-values based on CRSE / * 0.05<p≤0.1, ** 0.01<p≤0.05, *** p≤0.01 / Exogenous variables standardized / Constant & dummy variables are not shown

9.9 Correlation tables for the single commodity markets

Table 48 - Aluminium: Correlation coefficients for the endogenous and exogenous variables

Variables	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*	*(16)*
(1) Company Performance	*1.00*															
(2) Market Metal Price	**0.20**	*1.00*														
(3) Company Size - Assets	**-0.12**	**0.12**	*1.00*													
(4) Company Capital Efficiency	**0.20**	0.05	**-0.18**	*1.00*												
(5) Company Capital Intensity	**-0.25**	-0.03	**0.11**	**-0.29**	*1.00*											
(6) Company Market Share	-0.09	-0.08	**0.36**	**0.33**	-0.04	*1.00*										
(7) Ad Valorem Transport Cost	**0.30**	**0.17**	**-0.11**	**0.13**	-0.07	0.02	*1.00*									
(8) Global Energy Cost	**-0.30**	**0.70**	**0.21**	**-0.18**	0.04	**-0.12**	**-0.12**	*1.00*								
(9) Market Demand Growth	**0.44**	**0.41**	-0.02	**0.24**	-0.03	0.04	-0.02	-0.01	*1.00*							
(10) Market HHI	**0.50**	**-0.31**	**-0.23**	**0.36**	-0.07	**0.14**	**0.40**	**-0.77**	**0.27**	*1.00*						
(11) Company Size - Revenues	-0.07	**0.14**	**0.92**	0.10	0.02	**0.50**	-0.04	**0.17**	0.03	**-0.13**	*1.00*					
(12) Company Focus	-0.04	**0.15**	**-0.55**	**0.12**	**-0.27**	**-0.12**	-0.03	**0.21**	-0.03	**-0.20**	**-0.54**	*1.00*				
(13) Company Sales Capabilities	-0.03	**-0.11**	**-0.10**	-0.06	-0.06	0.02	**0.14**	-0.06	-0.06	0.05	**-0.15**	0.08	*1.00*			
(14) Market Size	**-0.45**	**0.47**	**0.23**	**-0.27**	0.07	**-0.12**	**-0.45**	**0.92**	-0.09	**-0.91**	**0.16**	**0.21**	-0.07	*1.00*		
(15) Market Size Growth	**0.36**	**0.41**	-0.01	**0.19**	-0.04	0.03	**0.11**	0.04	**0.59**	**0.13**	0.04	-0.05	**-0.17**	-0.04	*1.00*	
(16) Market instab. of prod. countries	**0.33**	**-0.19**	**-0.20**	**0.21**	-0.08	0.08	**0.59**	**-0.56**	**-0.10**	**0.77**	**-0.13**	**-0.11**	**0.13**	**-0.75**	**-0.20**	*1.00*

The table shows the pair-wise Pearson correlation coefficients measure ρ ranging from ρ= -1 – absolute negative linear correlation to ρ= 1 – absolute positive linear correlation. Bold figures show correlations coefficients above 0.10 or below -0.10.

Table 49 - Copper: Correlation coefficients for the endogenous and exogenous variables

Variables	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*	*(16)*
(1) Company Performance	*1.00*															
(2) Market Metal Price	**0.15**	*1.00*														
(3) Company Size - Assets	-0.04	**0.31**	*1.00*													
(4) Company Capital Efficiency	-0.08	0.03	**-0.17**	*1.00*												
(5) Company Capital Intensity	**0.15**	0.03	0.10	**-0.49**	*1.00*											
(6) Company Market Share	**-0.12**	-0.04	**0.20**	**0.46**	**-0.19**	*1.00*										
(7) Ad Valorem Transport Cost	**-0.23**	**-0.85**	**-0.28**	-0.02	-0.04	0.05	*1.00*									
(8) Global Energy Cost	0.02	**0.92**	**0.30**	0.02	0.03	-0.04	**-0.69**	*1.00*								
(9) Market Demand Growth	0.06	-0.08	-0.09	**0.20**	-0.01	-0.01	0.06	-0.05	*1.00*							
(10) Market HHI	-0.04	**0.71**	**0.23**	-0.04	0.00	-0.02	**-0.51**	**0.71**	**-0.36**	*1.00*						
(11) Company Size - Revenues	0.01	**0.30**	**0.93**	0.07	0.01	**0.38**	**-0.25**	**0.29**	-0.05	**0.21**	*1.00*					
(12) Company Focus	-0.03	0.08	**-0.63**	**0.32**	**-0.35**	**0.12**	**-0.10**	0.06	0.02	0.03	**-0.56**	*1.00*				
(13) Company Sales Capabilities	-0.06	**-0.24**	-0.02	0.09	-0.04	0.06	**0.12**	**-0.24**	**-0.17**	**-0.12**	-0.04	0.01	*1.00*			
(14) Market Size	0.03	**0.82**	**0.34**	-0.09	0.06	-0.04	**-0.86**	**0.82**	**-0.13**	**0.57**	**0.28**	0.07	-0.08	*1.00*		
(15) Market Size Growth	-0.09	**-0.27**	-0.03	-0.05	0.01	0.01	-0.09	**-0.23**	**-0.30**	-0.09	-0.06	-0.01	**0.25**	0.09	*1.00*	
(16) Market instab. of prod. countries	**0.19**	**-0.10**	**-0.12**	**0.14**	-0.04	-0.02	**0.12**	**-0.12**	**0.43**	**-0.18**	-0.08	0.01	**-0.14**	**-0.24**	**-0.62**	*1.00*

The table shows the pair-wise Pearson correlation coefficients measure ρ ranging from ρ= -1 – absolute negative linear correlation to ρ= 1 – absolute positive linear correlation. Bold figures show correlations coefficients above 0.10 or below -0.10.

Table 50 - Manganese: Correlation coefficients for the endogenous and exogenous variables

	Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
(1)	*Company Performance*	*1.00*															
(2)	*Market Metal Price*	**0.37**	*1.00*														
(3)	*Company Size - Assets*	-0.07	0.09	*1.00*													
(4)	*Company Capital Efficiency*	**0.13**	**0.13**	**-0.31**	*1.00*												
(5)	*Company Capital Intensity*	**-0.39**	0.02	**-0.12**	-0.09	*1.00*											
(6)	*Company Market Share*	-0.08	**-0.18**	**0.31**	0.00	-0.01	*1.00*										
(7)	*Ad Valorem Transport Cost*	**-0.11**	**-0.27**	-0.03	-0.03	0.02	0.05	*1.00*									
(8)	*Global Energy Cost*	**0.15**	**0.75**	**0.13**	0.07	**0.12**	**-0.21**	**-0.16**	*1.00*								
(9)	*Market Demand Growth*	**0.14**	**-0.10**	-0.05	**0.12**	-0.05	0.03	0.07	**-0.17**	*1.00*							
(10)	*Market HHI*	-0.07	**-0.68**	**-0.15**	0.08	**-0.14**	**0.19**	**0.28**	**-0.88**	0.06	*1.00*						
(11)	*Company Size - Revenues*	-0.03	0.07	**0.94**	**-0.19**	**-0.16**	**0.42**	-0.02	**0.12**	-0.02	**-0.12**	*1.00*					
(12)	*Company Focus*	0.00	**0.15**	**-0.68**	**0.28**	**0.11**	**-0.48**	-0.04	**0.14**	-0.03	**-0.13**	**-0.69**	*1.00*				
(13)	*Company Sales Capabilities*	0.00	-0.03	0.06	**-0.13**	0.06	0.04	**0.46**	0.05	-0.09	0.00	0.03	0.01	*1.00*			
(14)	*Market Size*	-0.02	**0.56**	**0.16**	**-0.15**	**0.16**	**-0.20**	-0.07	**0.88**	-0.10	**-0.95**	**0.12**	**0.13**	**0.13**	*1.00*		
(15)	*Market Size Growth*	**0.12**	0.10	0.00	0.06	-0.04	0.04	**0.19**	0.00	**0.41**	**-0.24**	0.02	-0.02	-0.06	**0.17**	*1.00*	
(16)	*Market instab. of prod. countries*	0.08	**0.28**	0.06	**0.14**	0.03	**-0.12**	**-0.66**	**0.60**	**-0.19**	**-0.55**	0.08	0.05	**-0.33**	**0.47**	**-0.12**	*1.00*

The table shows the pair-wise Pearson correlation coefficients measure ρ ranging from ρ= -1 – absolute negative linear correlation to ρ= 1 – absolute positive linear correlation. Bold figures show correlations coefficients above 0.10 or below -0.10.

Table 51 - Molybdenum: Correlation coefficients for the endogenous and exogenous variables

	Variables	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*	*(16)*	*(17)*	*(18)*
(1)	*Company Performance*	*1.00*																	
(2)	*Market Metal Price*	**0.25**	*1.00*																
(3)	*Company Size - Assets*	-0.07	0.00	*1.00*															
(4)	*Company Capital Efficiency*	**0.41**	**0.50**	-0.08	*1.00*														
(5)	*Company Capital Intensity*	0.00	-0.06	**0.16**	0.07	*1.00*													
(6)	*Company Market Share*	**-0.14**	0.05	-0.06	**0.45**	**-0.16**	*1.00*												
(7)	*Ad Valorem Transport Cost*	0.07	**0.18**	**0.11**	**-0.11**	-0.07	-0.09	*1.00*											
(8)	*Global Energy Cost*	**-0.11**	**0.23**	**0.17**	-0.03	0.03	**-0.28**	0.10	*1.00*										
(9)	*Market Demand Growth*	**0.11**	0.08	**-0.12**	**0.16**	-0.01	**0.20**	**0.25**	**-0.53**	*1.00*									
(10)	*Market HHI*	0.03	-0.07	**-0.21**	**0.21**	0.00	**0.31**	**-0.40**	**-0.74**	**0.52**	*1.00*								
(11)	*Company Size - Revenues*	0.00	0.07	**0.96**	**0.12**	**0.17**	0.05	0.04	**0.19**	**-0.11**	**-0.18**	*1.00*							
(12)	*Company Focus*	**-0.26**	0.04	**-0.42**	**-0.36**	0.04	**-0.21**	0.08	**0.23**	**-0.12**	**-0.24**	**-0.48**	*1.00*						
(13)	*Company Sales Capabilities*	-0.04	-0.06	0.07	-0.05	**0.13**	0.02	**-0.17**	0.07	**-0.39**	-0.05	0.08	-0.03	*1.00*					
(14)	*Market Size*	**-0.13**	-0.04	**0.19**	**-0.22**	0.04	**-0.31**	0.07	**0.88**	**-0.55**	**-0.87**	**0.18**	**0.23**	0.08	*1.00*				
(15)	*Market Size Growth*	**0.20**	**0.56**	-0.07	**0.25**	-0.02	**0.12**	0.00	**-0.20**	**0.43**	**0.22**	-0.03	-0.02	**-0.15**	**-0.20**	*1.00*			
(16)	*Market instab. of prod. countries*	**0.27**	**0.47**	**-0.13**	**0.46**	-0.06	**0.26**	-0.02	**-0.56**	**0.30**	**0.55**	-0.08	**-0.19**	-0.02	**-0.74**	**0.17**	*1.00*		
(17)	*Copper Metal Price*	-0.05	**0.16**	**0.19**	-0.06	0.02	**-0.29**	**0.19**	**0.92**	**-0.55**	**-0.76**	**0.20**	**0.20**	0.06	**0.91**	**-0.26**	**-0.49**	*1.00*	
(18)	*Zinc Metal Price*	**0.18**	**0.47**	**0.12**	**0.21**	-0.04	**-0.12**	**0.32**	**0.45**	**-0.41**	**-0.61**	**0.15**	0.06	0.06	**0.40**	**-0.16**	**0.21**	**0.68**	*1.00*

The table shows the pair-wise Pearson correlation coefficients measure ρ ranging from ρ= -1 – absolute negative linear correlation to ρ= 1 – absolute positive linear correlation. Bold figures show correlations coefficients above 0.10 or below -0.10.

Table 52 - Nickel: Correlation coefficients for the endogenous and exogenous variables

Variables		*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*	*(16)*	*(17)*
(1)	*Company Performance*	*1.00*																
(2)	*Market Metal Price*	**0.32**	*1.00*															
(3)	*Company Size - Assets*	**-0.39**	**0.15**	*1.00*														
(4)	*Company Capital Efficiency*	**0.26**	**0.15**	**-0.11**	*1.00*													
(5)	*Company Capital Intensity*	**-0.23**	**0.13**	**0.43**	**-0.12**	*1.00*												
(6)	*Company Market Share*	-0.07	0.00	**0.37**	-0.02	**0.23**	*1.00*											
(7)	*Ad Valorem Transport Cost*	**-0.17**	**-0.61**	**-0.15**	0.04	**-0.15**	0.08	*1.00*										
(8)	*Global Energy Cost*	**-0.25**	**0.47**	**0.30**	-0.07	**0.24**	-0.09	**-0.34**	*1.00*									
(9)	*Market Demand Growth*	**0.17**	-0.01	-0.03	0.07	0.02	-0.05	**-0.39**	0.10	*1.00*								
(10)	*Market HHI*	**0.33**	0.07	**-0.21**	**0.33**	**-0.17**	**0.13**	**0.51**	**-0.40**	-0.03	*1.00*							
(11)	*Company Size - Revenues*	**-0.29**	**0.19**	**0.93**	**0.12**	**0.34**	**0.34**	**-0.12**	**0.27**	0.00	-0.09	*1.00*						
(12)	*Company Focus*	**0.32**	-0.02	**-0.66**	-0.05	-0.02	-0.04	-0.02	-0.10	0.03	0.02	**-0.67**	*1.00*					
(13)	*Company Sales Capabilities*	**0.11**	**0.29**	**0.10**	0.04	**0.33**	**0.18**	-0.07	0.08	**-0.21**	**0.11**	**0.15**	0.08	*1.00*				
(14)	*Market Size*	**-0.17**	**0.28**	**0.22**	-0.09	**0.18**	-0.09	**-0.54**	**0.75**	**0.33**	**-0.44**	**0.19**	-0.02	0.10	*1.00*			
(15)	*Market Size Growth*	**0.20**	**0.30**	0.07	0.03	**0.10**	-0.08	**-0.52**	**0.37**	**0.71**	**-0.17**	0.09	0.05	**0.10**	**0.62**	*1.00*		
(16)	*Market instab. of prod. countries*	**-0.15**	**0.48**	**0.21**	0.06	**0.14**	-0.02	**-0.30**	**0.76**	**0.10**	0.00	**0.21**	-0.10	0.06	**0.66**	0.08	*1.00*	
(17)	*Global GDP growth*	**0.48**	**0.30**	**-0.14**	**0.26**	-0.07	0.05	**0.11**	**-0.15**	**0.33**	**0.62**	-0.03	0.08	**0.19**	-0.09	**0.53**	**-0.18**	*1.00*

The table shows the pair-wise Pearson correlation coefficients measure ρ ranging from ρ= -1 – absolute negative linear correlation to ρ= 1 – absolute positive linear correlation. Bold figures show correlations coefficients above 0.10 or below -0.10.

Table 53 - Titanium: Correlation coefficients for the endogenous and exogenous variables

	Variables	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*	*(16)*	*(17)*
(1)	*Company Performance*	*1.00*																
(2)	*Market Metal Price*	**0.35**	*1.00*															
(3)	*Company Size - Assets*	-0.01	**0.18**	*1.00*														
(4)	*Company Capital Efficiency*	**0.14**	0.00	-0.02	*1.00*													
(5)	*Company Capital Intensity*	-0.07	0.02	-0.01	**-0.69**	*1.00*												
(6)	*Company Market Share*	0.01	0.04	**0.29**	**0.24**	**-0.14**	*1.00*											
(7)	*Ad Valorem Transport Cost*	**-0.25**	**-0.63**	-0.10	0.08	-0.03	0.01	*1.00*										
(8)	*Global Energy Cost*	**0.13**	**0.58**	**0.22**	**0.12**	0.02	0.08	**-0.19**	*1.00*									
(9)	*Market Demand Growth*	0.07	**-0.13**	-0.08	0.06	-0.02	0.01	**0.49**	**-0.12**	*1.00*								
(10)	*Market HHI - Revenues*	**-0.18**	**0.27**	**0.19**	0.01	0.02	0.09	**-0.19**	**0.62**	**-0.30**	*1.00*							
(11)	*Company Size - Revenues*	0.04	**0.14**	**0.97**	0.08	**-0.11**	**0.31**	-0.05	**0.23**	-0.04	**0.17**	*1.00*						
(12)	*Company Focus*	-0.03	0.04	**-0.72**	0.00	-0.06	**-0.34**	-0.04	0.04	-0.01	0.03	**-0.76**	*1.00*					
(13)	*Company Sales Capabilities*	**-0.20**	**-0.75**	-0.10	-0.01	-0.01	-0.03	**0.46**	**-0.37**	**-0.18**	**-0.10**	-0.08	-0.02	*1.00*				
(14)	*Market Size*	**0.18**	**0.68**	**0.24**	0.09	0.02	0.07	**-0.40**	**0.95**	**-0.31**	**0.68**	**0.23**	0.04	**-0.42**	*1.00*			
(15)	*Market Size Growth*	**0.26**	-0.04	0.00	0.09	0.01	-0.03	**-0.15**	**0.18**	**-0.14**	**-0.23**	0.03	-0.01	-0.02	**0.19**	*1.00*		
(16)	*Market instab. of prod. countries*	0.08	**-0.47**	**-0.13**	0.07	-0.02	-0.03	**0.30**	**-0.36**	**0.20**	**-0.40**	-0.09	-0.06	**0.12**	**-0.37**	**0.31**	*1.00*	
(17)	*Market HHI - Volumes*	-0.02	**-0.67**	**-0.23**	-0.01	-0.02	-0.09	**0.38**	**-0.78**	**0.19**	**-0.87**	**-0.20**	-0.05	**0.44**	**-0.84**	**0.26**	**0.57**	*1.00*

The table shows the pair-wise Pearson correlation coefficients measure ρ ranging from ρ= -1 – absolute negative linear correlation to ρ= 1 – absolute positive linear correlation. Bold figures show correlations coefficients above 0.10 or below -0.10.

Table 54 - Zinc: Correlation coefficients for the endogenous and exogenous variables

	Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
(1)	*Company Performance*	*1.00*															
(2)	*Market Metal Price*	**0.64**	*1.00*														
(3)	*Company Size - Assets*	-0.02	**0.12**	*1.00*													
(4)	*Company Capital Efficiency*	0.06	**0.23**	**-0.32**	*1.00*												
(5)	*Company Capital Intensity*	**-0.44**	**-0.51**	**0.19**	**-0.16**	*1.00*											
(6)	*Company Market Share*	-0.07	0.09	**0.56**	**-0.24**	0.06	*1.00*										
(7)	*Ad Valorem Transport Cost*	**-0.51**	**-0.80**	**-0.21**	**-0.17**	**0.10**	**-0.10**	*1.00*									
(8)	*Global Energy Cost*	**0.24**	**0.54**	**0.31**	**0.10**	**0.21**	**0.15**	**-0.49**	*1.00*								
(9)	*Market Demand Growth*	**0.60**	**0.90**	**0.13**	**0.17**	**-0.39**	0.08	**-0.67**	**0.48**	*1.00*							
(10)	*Market HHI*	**0.45**	**0.71**	**0.23**	**0.11**	**-0.11**	**0.14**	**-0.61**	**0.66**	**0.71**	*1.00*						
(11)	*Company Size - Revenues*	0.01	**0.16**	**0.89**	**-0.17**	0.01	**0.44**	**-0.16**	**0.22**	**0.15**	**0.19**	*1.00*					
(12)	*Company Focus*	0.01	**0.15**	**-0.55**	**0.35**	**-0.18**	**-0.20**	-0.09	-0.05	**0.13**	0.06	**-0.62**	*1.00*				
(13)	*Company Sales Capabilities*	-0.10	-0.10	-0.04	0.09	**0.19**	-0.04	0.00	**0.10**	**-0.14**	0.00	-0.10	0.08	*1.00*			
(14)	*Market Size*	**0.11**	**0.36**	**0.36**	0.05	**0.48**	**0.15**	**-0.53**	**0.89**	**0.35**	**0.57**	**0.21**	**-0.10**	**0.15**	*1.00*		
(15)	*Market Size Growth*	-0.06	0.06	-0.02	0.07	**-0.27**	-0.03	**0.17**	0.07	-0.06	**-0.27**	0.01	0.01	0.01	0.05	*1.00*	
(16)	*Market instab. of prod. countries*	-0.06	-0.08	**-0.32**	0.02	**-0.55**	**-0.13**	**0.45**	**-0.60**	**-0.14**	**-0.37**	**-0.16**	**0.15**	**-0.18**	**-0.82**	**0.21**	*1.00*

The table shows the pair-wise Pearson correlation coefficients measure ρ ranging from ρ= -1 – absolute negative linear correlation to ρ= 1 – absolute positive linear correlation. Bold figures show correlations coefficients above 0.10 or below -0.10