# Recapture Strategic Value Chains In The Rare Earth Market

A Contemporary Market Analysis Of Rare Earths And Their Economic Implications

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Abstract

This thesis analyzes the evolution of the contemporary rare earth market. The commodity has a growing strategic importance in key sectors, including the military-, energy-, high-tech- and automobile industry. 90 percent of the global supply has its origin from China, which binds buyers around the world to its exports. The evaluation of China’s market strategy illuminates the implications on its own supply hegemony and on foreign institutions. Within this context a major focus is placed on strategic value chains as well as on price determining factors for the rare earths. Both, Japan and the US are the largest consumer beyond Chinese border and are mostly active in researching alternative supply sources. Hence, the assessment of groundbreaking approaches to detach from China’s rare earth supremacy is carried out. The analysis outcome leads to the formulation of a competitive strategy for foreign market participants. Ultimately, the results of the examination show that the recapture of strategic value chains needs to be incentivized by economic-political measures. This will ensure to countervail against the price dependency, which is at the present days the main stimulus for the search of alternative supply sources.

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<td>Rare Earth, Strategic Value Chains, Competitive Strategy, Price Dependency, Policy Measures</td>
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Preface

The human being invented in the past centuries pioneering machines and business processes to leverage the output of human capacities, which eventually led to the industrial revolution. In the present days the world experiences the growing integration of technologies in businesses and private households. The digital age already reached many people around the world with an upward trend. Technologies that facilitate such a vast array of products and services depend heavily on rare earth metals (REM). These elements are virtually invisible components but play a significant role in smartphones, computers and many other related gadgets.

The first time I took a closer look on rare earths was in 2012 as part of a research project for students. Since then I continued reading and researching about the impact on our daily life, the influence on businesses and economic opportunities and risks that derive from the usage of such elements.

This bachelor thesis shall be my first step to enter a research field of great potentials for discoveries and further contribution to conceive the mutual coherence of business economics and technology.

I would like to thank all people that encouraged me to continue working on this as well as contributed to the development of my interest field. Thanks to my beloved ones including my family, specially my brother and my fiancé. Furthermore I thank Michael Keaney and William Simcoe, both my lecturers from Metropolia Business School Helsinki, that have taught me strategic research tools as well as critical evaluation of the data.

I am expressing my special thank to my thesis advisor from the Berlin School of Economics and Law Professor Doctor Hansjörg Herr and the second proofreader Behzad Azarhoushang, which guided and advised me throughout the research period.
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Ce        Cerium
CFL       Compact Fluorescent Lightbulbs
CRE       China Rare Earth Holdings Limited
DOE       U.S. Department Of Energy
Dy        Dysprosium
e.g.      Exempli Gratia (For Example)
Esp.      Especially
EV        Enterprise Value
FAI       Fixed-Asset Investment
GAO       United States Government Accountability Office
GDP       Gross Domestic Product
HREE      Heavy Rare Earth Element
i.a.      inter alia (Amongst Others)
i.e.      Id Est (That Is)
IBM       International Business Machines Corporation
IHS       Information Handling Services
Incl.     Including
IPR       Intellectual Property Rights
LED       Light Emitting Diodes
LREE      Light Rare Earth Element
Lu        Lutetium
Nd        Neodymium
NdFeB     The Permanent Magnet
NDRC      National Development And Reform Commission
NRC       National Research Council
PES       Price Elasticity Of Supply
POLINARES EU Policy On Natural Resources
R&D       Research And Development
REE/REM   Rare Earth Element/Rare Earth Metal
REHT      Inner Mongolia Baotou Steel Rare-Earth Hi-Tech Co. Ltd.
RIETI     Research Institute Of Economy, Trade And Industry
RoW       Rest Of The World
Sc        Scandium
SCM       Supply Chain Management
SOE       State Owned Enterprise
Tm        Thulium
US T-bill Here: US Three Month Treasury Bill (Secondary Market)
USA/US    United States Of America
USGS      U.S. Geological Survey
WTO       World Trade Organization
Y         Yttrium
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1 Introduction

David Ricardo describes in his literature "Principles of Political Economy and Taxation" that the welfare of all participating countries increases if each economy specializes in the production of goods with a comparative advantage\(^1\). His idea from 1817 has been changed dramatically. In today's world businesses outsource partial or complete operations abroad in order to increase their profit margins. Driven by the shareholder value, a number of multinational corporations achieve annual returns that exceed the GDP’s of entire economies\(^2\).

Yet, entities depend on imported raw materials and other resources to create competitive and profitable goods and services. Especially high-tech firms have made themselves increasingly dependent from virtually invisible parts of their products. The so-called rare earth elements play a central role in the development of new high tech inventions but are essential for already established technologies. In order to achieve an advantage and thus to succeed in a highly competitive and dynamic market environment, the race for sustainable supply of rare earths takes place between China and the rest of the world.

1.1 Methodology

This thesis examines China's disrupting rare earth strategy and the ramification on its market supremacy as well as on foreign institutions\(^3\). Hence, the analysis determines arising supply chain approaches to cope with the contemporary market situation. Various stages of the up- and downstream supply chain will be illuminated within the course of the analysis\(^4\).

A concentrated focus is placed on affected industries of the United States of America as well as Japan\(^5\). Both countries count amongst the largest consumer beyond Chinese border as a result of their pronounced high-tech manufacturing and depending industries, which have significant economic implications for their own and the global economy.

\(^3\) The term “foreign institutions” refers to countries and their enterprises that are located beyond Chinese border with main emphasis on the USA and Japan.
The previous reading has shown that the USA and Japan make strong efforts to compete with China's rare earth market approach. At the same time both countries have fundamental differences in their economic pattern that is reflected in their corporate governance regime. Due to the common efforts and the contrasts of their government systems, both countries will be recognized as the representative selection for this thesis. A closer examination on other countries and their industries will not be undertaken in this study due to scope limitation and dilution avoidance to the represented examples. However, the analyzed market situation, including strategic measures to overcome the current rare earth market difficulties may be applicable to other countries as well.

In order to facilitate an in depth market evaluation the research methodology comprises qualitative and quantitative statistics as well as an expert interview. By applying these three approaches the market assessment takes place from different angles. Implementing this measure will ensure an ultimate conformity and quality of the gathered data.

Primary as well as secondary sources will be used for the data collection. These include literatures and electronic publications, including scholarly journals, magazines and online newspaper articles. A particularly important source is Michael Porter’s literature *Competitive Strategy: Techniques for Analyzing Industries and Competitors*. It functions as the fundamental basis for this analysis offering theoretical and structural guidelines, models to examine market forces and tools to assess the feasibility of supply alternatives.

Michael Heine’s and Hansjörg Herr’s economic literature “*Volkswirtschaftslehre: Paradigmenorientierte Einführung in die Mikro- und Makroökonomie*” will be considered as the main source for economic term explanations due to its emphasized theoretical elaboration of relevant topics. Furthermore the expert opinion of Mr. Karl Gschneidner serves as a parameter for the comparison of the evaluated data.

Primary sources that provide the actual data about the rare earth market are the U.S. Geological Survey as well as the annual reports of various REE producers. Amongst important and reliable secondary sources are the Mineral Commodity Summaries, CRS Reports for Congress and the Financial Times newspaper. These particular sources make a significant contribution to this thesis due to their up-to-dateness and credibility, thus allowing a qualitative data evaluation.

The analysis starts with the introduction where the current market situation is briefly reflected and is followed by the definition of rare earths. This crucial step gives the reader a first overview about the topic, which will enhance the understanding for the strategic importance of rare earths within the context of the value chain reclamation.

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7 Mr. Gschneidner is Professor in the *Department of Materials Science and Engineering* at the Iowa State University. He founded the Rare Earth Information Center in 1966. With over 60 years of experience in this field, Mr. Gschneidner is considered as the world’s most important rare earth expert.
The main body of the analysis is subdivided into three parts, starting firstly with the evaluation of the historical data, secondly the application of Porter’s Five Forces Model and thirdly the formulation of a competitive strategy.

The first objective of the historical data analysis is to determine key factors for the rare earth market evolution and thereafter China’s strategy for entering and attaining the market leadership, which exists down to the present day. Carrying out this phase allows to analyze how market forces have evolved and furthermore how a quasi-monopoly impacts the global trade of rare earths. These results enhance the understanding for the formation of the current market structure and contribute substantially to the development of a competitive strategy.

The analysis of the current rare earth market examination utilizes Porter’s Five Forces Model and within this context evaluates the interrelationship between the market participants and the commodity. This measure allows an adequate differentiation of each forces bargaining power.

The implementation of Porter’s model begins with the assessment of the supplier side that comprises an evaluation of its market position. Unlike the buyer, the supplier provides the market with the raw material as well as the end product in several forms and functionalities and thus receives more extensive examination. The analysis of the buyer side involves the assessment of its influence on supply and price formation will be allocated. Subsequently, the rare earth demand driver will be determined and the mutual interference with supplier presented.

The third essential step comprises the analysis of new entrants. In this context the required time and the associated costs for entering the supplier market will be determined. Particularly the political and legal conditions, technological expertise, resource constraints and environmental restrictions will be discussed in detail.

The fourth section assesses the substitutability of rare earth elements. Essential focus is placed on a comparison of REM’s and other available and feasible materials. In this manner, the assessment of the research progress for alternative materials is enhanced. The substitutability analysis shows the potential threats to China’s rare earth hegemony. It furthermore clarifies efforts and importance for foreign countries to recapture strategic value chains. In addition, the coherence between rare earth metals and technologies that have the capability to leverage economic activities will be provided. Moreover the rare earth recycling is considered amongst the substitutions as well.

The competitive rivalry will be analyzed in the final stage of the Five Forces analysis. The assessment enhances the comprehension for the mutual interactions of the market forces. It further functions as the groundwork for the formulation of a competitive strategy for institutions beyond China. Eventually, the strategy formulation takes place through the implementation of an external benchmarking with the airline industry.

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8 Referring to the phrase “other available and feasible materials”: It comprises naturally occurring and synthetic materials.
The last part of the thesis stresses the economic implications of the high-tech industry and its far-reaching effects on businesses, consumers and thus the global economy for the year 2025. The high-tech industry is chosen due to its high dependency on rare earth elements. The final outcome of the analysis provides an essential contribution to the understanding of international efforts nowadays to detach from China’s predominant supply.

Based on the analysis procedure described above, the research question “Does China’s rare earth strategy disrupt its quasi-monopoly and thereby stimulate innovative supply approaches in the global rare earth market?” will be proven on its stability. The thesis statement has been developed to support the evaluation of the question and reads as follows: “Foreign institutions take advantage of China’s disrupting rare earth policies to recapture strategic value chains and secure the supply of their growing demand”.

1.2 Brief Market Overview

Rare earth elements are an indispensable part in the daily life of technologically advanced societies. This commodity accelerates innovations and is applied in various industries, ranging from commercial to military products, including consumer electronics, green technologies and defense systems. Beyond that, its application takes place in heavy industries including steel-, catalyst- and the glass manufacturing.

Research and development (R&D) of alternative supply sources have been neglected until China started to restrict its exports in 2005 despite international demand growth. That levered up price volatility and supply shortages. In early 2015, after ten years of export restrictions on rare earths, China lifted the regulations due to the conclusion of the World Trade Organization (WTO) that such measures violate against global trade rules. Partly responsible for the country’s strategic realignment is China’s growing domestic demand. The contemporary market situation is largely responsible for the urge to find alternative and sustainable supply solutions in order to overcome the current and potential future scarcities of this strategic commodity.

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13 The term “institution” refers to as countries and firms
That is in a direct linkage to the operating efficiency of firms and economic stability of countries. The following chapters will provide an explicit examination of the points referred to above.

1.3 Rare Earth Term Definition

The rare earths are 17 difficult to mine minerals, which comprise scandium, yttrium and fifteen lanthanides. These commodities are not as rare as their name may imply. They are available all over the world mainly in the earth's crust. In fact, the two least abundant rare earths Thulium and Lutetium are 200 times more common than gold.

However, they do not appear in greater concentrated volumes everywhere and moreover the production and refining process is toxic, radioactive, costly and complicated that bring negative externalities in large quantities to the environment and has deleterious effects for every living being. In addition, not all mines achieve an acceptable cut-off grade, which represents the required minimum value to consider a mine economically feasible. Moreover, governmental regulations impede the establishment of feasible and reliable supplies, which is an additional reason for their naming.

Figure 1 (p.6) shows major applications that depend on these elements. Not visible in the first place is the differentiation of light and heavy rare earths. The distinction between light (LREE) and heavy (HREE) rare earth metals indicates the atomic number, which defines physical and chemical properties. Heavy rare earths are less abundant than the lighter ones but at the same time are more frequently used in a wider range of applications despite their scarcity.

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14 Following acronyms will be used in the context: rare earths, rare earth elements, rare earth oxides, RE, REE, REO, minerals, metals, strategic metals, lanthanides, commodities.
19 The term “scarcity” refers to the market availability of the commodity, rather than the actual natural occurrence.
Around five percent of all mined rare earths are heavy and commercially important. They find major end use in hybrid engines, lasers, screens, surface alloys and medical devices. These applications make use of the HREE’s on a large scale.

LREE’s are abundant and comprise about 95 percent of all mined rare earths. However, they find fewer applications in the industries. They are used i.a. in laptops, headphones, TV-coloration and auto catalysts and are subordinated to “Glass”, “Catalysts” and “Other” applications, as Figure 1 displays.

At the present days the only country that is able to produce heavy rare earths on a larger scale is China. This is possible not least because of its highly competitive prices, very low production costs and fewer environmental regulations. According to the United States Geological Survey (USGS) of 2013 China possesses at the present days about 41 million tons (37 percent) of the 110 million tons of the global rare earth deposits and supplies the world with over 90 percent of all rare earths.

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1.4 Rare Earth: By-Product And Joint-Product

The rare earth commercialization process starts in the early 1950’s through its implementation in the iron industry, which will be comprehensively examined in the next chapter. However, its initial commercial appearance in the steel manufacturing takes place as a by-product. At that time, rare earth is not the main driver for mining, but rather it is iron.

By-products are defined as goods that are extracted from a superior or main product. Hence, the material value of the by-product derives from the main product. The separation process of certain by-products is more expensive and thus increases the market price, which in the case of rare earths exceeds the price of the steel, as it will be discussed in the relevant chapters. Even if the by-product has a comparatively more expensive market price, it is not perceived as the main, but rather as a minor income source for firms. The stage at which rare earths are separated from the iron is called split-off point. Until that point the costs for production are considered as overheads. Only after the split-off, costs are directly attributable to the rare earth. Therefore separate cost or price specification for individual REE’s is not given. This is an important note to bear in mind for the understanding of cost and market price composition.

However, by-products must not be underestimated despite their apparent minor importance. Besides being complementary revenue sources they increase the overall production costs, since additional steps are required to extract the by-product. Therefore it complicates the real costs as well as profits that are made with the trade of rare earths as by-products. Subsequently, the cost allocation is too burdensome and therefore within the course of the analysis only one general price for rare earths will be stated.

To sum up, rare earths are the subsidiary products that evolve from the production of a main good while the by-product output is strongly connected to its superior good.

27 Siegel, Joel G., and Jae K. Shim.(2012). p.212
28 The Institute of Chartered Accountants of India. (n.d.).
29 This implies that there will be no price differentiation for each rare earth.
30 Ibid.
The most common feature of joint- and by-products is that both share the same source of origin. From the accounting perspective the operation costs of joint products are perceived also as overheads until the split-off point that subsequently makes them individual goods\(^{31}\). Other than by-products, joint products represent equal income sources for the company. Secondly, they are characterized by their equality in production and refining process\(^{32}\). Therefore, none of the joint products is superior or subordinated. To put it briefly, if more than one product with an equal value contribution for a company results from the same process, then it is called joint product. For example, nowadays, rare earths and iron are partly perceived as joint products. Both commodities are the main and equal driver for the mining and production and contribute in the same way to a company’s success\(^{33}\).

At this point it should be noted that rare earths have a unique characteristic in terms of their product type. In Japan, where the contemporary rare earth recovery takes place from metal scrap on a large scale, the commodity is considered as a by-product according to accounting standards\(^{34}\). Some iron ores in the US produce REE’s as well but due to low concentration in the near earth crust, the commodity is considered as a by-product. On the other hand, China’s largest rare earth mine Bayan-Obo is mining and refining rare earth metals besides iron, reflecting the typical properties of a joint-product operation\(^{35}\). The market evolution impacts the circumstance whether the REE is considered a by- or joint-product. That will be analyzed in the next three chapters.

\(^{31}\) Siegel, Joel G., and Jae K. Shim.(2012). p. 212

\(^{32}\) The Institute of Chartered Accountants of India. (n.d.).


2 Historical Development Of The Rare Earth Market

2.1 The Rare Earth Market From 1950 To 1980

This paragraph analyzes the rare earth market with a concentrated focus on the period from 1950 to 1980 and can be recognized as the first phase of the market evolution. The initial market entrants, the formation of competitors and a significant increase of rare earth production take place around that timeframe due to the commercial deployment of these metals, as Figure 2 displays. Back in the middle of the 20th Century the rare earth market did not exist as it does nowadays. Rare earths were considered as by-products of the iron mining. The Mountain Pass in the United States, which was discovered in the late 1940’s, is at that time the largest rare earths mining deposit, producing around 2000 metric tons annually. However, Figure 2 shows specially until the mid 1960’s no strong differentiation of producer but rather summarizes them under the term “Other”. Since rare earths are the by-product of iron, they found first major application in the steel industry adding stainless, alloying features and increasing the electric steel grade of metal products. Although the trend towards incorporation of REE’s increased due to further inventions and discoveries, the acceptance for them was still low because of the complicated recovery as well as their availability. 

Figure 2 - Rare earth production eras. Source: Gschneidner, K. (2011).

40 Ibid.
Starting from around 1965 the US increases its outputs significantly and floods the market with rare earths, incentivized by additional application possibilities in steel products but also by the color television, which was introduced at that time. Specifically, the dramatic rise in 1968 is a result of the enhanced understanding of applications and side effects of rare earths.

The supply was still dominated by the US with annual outputs of approximately 15,000 to 20,000 tons (see Figure 3), which is around 13 to 18 percent of today's production. In contrast, China's production volume in the mid 1970’s of 1000 tons is only a fraction of the US output. Canadian and US steel companies mainly drove rare earth consumption.

Two key factors influenced the demand in the iron and steel industry and thus shaped the buyer market dramatically in the early 1970’s. These are firstly the increased availability of rare earths. Secondly, the learning curves of rare earth applications in the steel industry accompanied by innovations in the steel manufacturing. Firms without rare earth experience were often deterred from using these metals because of failures; others however improved their products drastically. These advancements influence the high-rise-building-, airplane- and car manufacturing positively.

It must also be pointed out that there is a clear correlation of both mentioned key factors. The deployment of rare earth was at that time influenced to a large extent by the advancements of the steel industry, which enabled broader applications of REE’s. At the same time, the discovery of the rare earth potentials encouraged more supply as well as demand.

In 1972 the consumption rises around the world, primarily due to Japanese and European steel companies\(^\text{43}\). Over 90 percent of the worldwide rare earth usage is driven by the steel industry, mainly due to pipeline production\(^\text{44}\). Noticeable is that up to this point the steel industry commonly used so-called “mischmetal”, known as a combination of several rare earths. It can be therefore summarized that a targeted use of each rare earth type is not upheld due to technological limitations as well as massive production costs for rare earths\(^\text{45}\).

The growth trend of supply and demand was followed by a sharp decline caused by the oil crisis in 1973. In fact, the oil shock triggered the recession in the US as well as Europe and Japan, thus reflecting the susceptibility of rare earths towards oil\(^\text{46}\).

However, the effect of the global economic deterioration on the rare earth consumption becomes noticeable after 1974, clearly reflected in both, Figure 2 and 3. Demand plunge because new orders were drying up and demand remained weak. This affected the supply of rare earths to the same degree. Specifically the manufacturing and construction industry, that involves the processing of steel are most exposed to crisis\(^\text{47}\). The effects of that particular sector on the rare earth production can summarize the strong evidence that the steel industry was playing an essential part in the rare earth deployment. Therefore it can be assumed that the striking parallels and mutual interactions of both, the steel- and REE manufacturing show a positive correlation. Eventually, until the late 1970’s the rare earth consumption recovers and is in terms of supply and demand volumes on the same level as it was before the crisis.

**Summarized**, this paragraph analyzed the first phase of the rare earth market evolution. It can be ascertained that the steel industry played the initial role in the expansion of these metals. Strategic benefits, technological limits and thus the potential of this market from the perspective of its early stage are identified. In addition it can be concluded with respect to the market forces that the US dominated the market. Towards the end of the 1970’s diversification took place through an increase of entrants causing the enlargement of global supply and demand.

\(^{44}\) Ibid.
\(^{45}\) Ibid. p.104
Furthermore, according to the theory available in Heine’s and Herr’s economic book “Volkswirtschaftslehre” a direct quantitative relationship of two variables expresses the degree of elasticity. Applied on rare earths it can be concluded that due to its nature of being a by-product of iron, its production will correlate strongly with the iron industry. This conclusion is supported by the evidence that the underlying economic situation influences the steel industry, which itself determines the rare earth production strongly, since a diverse application of REE’s was limited as the analysis of Figure 2 and 3 reveals.

2.2 China’s Market Penetration 1980 To 2000

A closer examination of China’s market entrance will be made from 1980 to 2000. This period may be considered as the second phase of the rare earth market evolution and most relevant for China’s participation that changed the marketplace substantially. In addition, the aggregated data until the 1980’s is based on estimates since there are not enough sufficient statistics about China’s rare earth exploitation operations. Nonetheless, the pre-1980 period with focus on China will be outlined briefly to offer an enhanced picture of the market penetration. China’s rare earth production started in 1957, producing rare earths as a by-product of iron but on a much smaller scale than in the US. As discovered in the previous paragraph, the Chinese mine “Bayan Obo” achieves an annual production volume of 1.000 tons only in the late 1970’s, which is less than a quarter of the output of the Mountain Pass mine. A sudden price hike that is followed by fluctuations characterizes the price development in the 1970’s as Table 1 shows.

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<td>1968</td>
<td>401</td>
</tr>
<tr>
<td>1969</td>
<td>420</td>
</tr>
<tr>
<td>1970</td>
<td>412</td>
</tr>
<tr>
<td>1971</td>
<td>1,040</td>
</tr>
<tr>
<td>1972</td>
<td>3,690</td>
</tr>
<tr>
<td>1973</td>
<td>2,150</td>
</tr>
<tr>
<td>1974</td>
<td>3,070</td>
</tr>
<tr>
<td>1975</td>
<td>2,050</td>
</tr>
<tr>
<td>1976</td>
<td>4,380</td>
</tr>
<tr>
<td>1977</td>
<td>2,600</td>
</tr>
</tbody>
</table>


Prices increase at a rate of 1000 percent from around US$ 400 in 1968 up to US$ 4000 on its peek in 1976. Despite the increasing production of rare earths, the prices are not developing proportionally (see Figure 4). According to the theory, elasticity of a good and the gradient are not correlating, which is an additional evident that rare earth prices and supply do not interact directly. Rather, the rare earth metals seem to have a low but positive price elasticity of supply (PES) because the increase in supply does not affect their price development strongly, as Figure 4 shows. It can be concluded for the market in the 1980’s that the supply of rare earths correlates with the steel supply but the price development of rare earth is not in a direct linkage to the steel price (see Figure 3).

However, a strong indicator for the rising price tendency in the late 1970’s that lasted into the next decade is particularly due to the inflation adjustment and increasing operation costs. Subsequently, the adjustment is not the primary source for the rising demand but rather has its nature in the entire economic activities. Since demand is one component of the economic activities and thus influences the market condition as well, it plays an essential role in the implementation of inflation adjusting measures and thus must not be underestimated.

The other component that causes sharp price rises is the cost of operations. Reason therefore is the shift from rare earth applications into the heavy industry, including “mischmetal” and other similar products towards a more targeted implementation into electronic devices in the 1980’s. Further value adding steps increase the value of the commodity on the one hand but the downside is the increasing costs due to an enlarged supply chain.

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Although operation prices in the rest of the world (RoW) rise until 1985, China is able to produce and supply rare earth metals due to a subsidization program by the government, effecting the undercutting of the global prices. At the same time in the RoW supply and demand decline due to the avoidance of rare earth containing catalysts that are used for petroleum cracking causing a rebound of the entire rare earth market until the end of the 1980’s. The usage of rare earths declines elsewhere, while China's market opening increases steadily its integration into global economic activities and attracts foreign investors. The positive effects of China's rural industrialization are besides the orientation towards global market also the increasing domestic demand for goods and thus its output of iron respectively its by-product rare earth.

Particularly the effects on the US economy are clearly visible according to a statistic of the Research Institute of Economy, Trade and Industry (RIETI) and China.org.cn, an official Chinese government portal, showing the mutual impacts of China's and US industrial production.

In 1980’s China expands its rare earth production further, which leads to price drops just as caused by the US between 1950’s and 1970’s as displayed in Figure 4. This is not only possible due to China's annual output that is around 6.000 tons in 1982 and rises to 20.000 tons in 1985. That represents an annual increase of more than 100 percent based on the initial amount. More important is the export discount for rare earths that is part of the subsidization program that promotes further exports. Eventually, China outpaces the US in terms of rare earth production and global supply around 1985. This time frame represents also the intersection of China's and the US’s rare earth production, as Figure 2 displays. Until this point China keeps its annual rare earth output moderate in a global comparison.

It can be recognized that China is taking gradually control over the rare earth supply market. Its aggressive market strategy leads to an increase in supply and demand. Furthermore the reformation of China’s economic system enabled foreigners to invest in the country and access a labor market that is cost-effective in the global comparison. Beside that, the technological advancements since the late 1980’s increased the need of cheap production sources that benefited China’s reformations additionally.

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China's strength, its abundant rare earth resources as well as the competitive market factors including cheap labor and low environmental regulations triggered and catalyzed its increasing participation in the market.

The annual output of China is in the late 1980’s around 30,000 tons, which is an increase of almost 40 percent compared to the previous year. Thus representing for the first time since its market entrance a hegemonial supply power. This second wave of increased production in 1994 leads simultaneously to a further weakening of its main rival, the US based producer. Due to governmental support and increasing profit margins for Chinese companies in the rare earth market, many Chinese startups established businesses in this industry. As a consequence, prices decline over the course of the 1990’s until the early 2000’s, as Figure 4 shows.

In 1995 China produces nearly 50,000 tons reflecting a 67 percent increase in comparison to the preceding year. Despite sharp demand growth, the excess capacities in China cause an abundant availability in the global market at a price range that eliminates gradually rare earth producer in other countries. Moreover, China's intense investment in research and development contributes largely to the advancement of technologies for rare earth production and usage. The state-of-the-art facilities enable the country to cover the entire supply chain process that comprises mining-, separation-, refinement-, formation- and manufacturing.

The downside of China's strategy is that domestic competition fragments the entire market including the destruction of foreign competitors. The lucrative profits that existed to date are becoming significantly smaller incentivizing the shift from official mining and trading towards illegal exploitation and smuggling. Towards the late 1990’s China possesses thousands of mines, many illegally established in order to avoid any safety and environmental regulations. Other companies in China minimize the processing to such an extent that the rare earth would fall into another category and thus exempting the export from the restrictions. Nevertheless, the main incentive is the profit maximization that gradually decreases because of high competition. The increased production level experiences a slight drop due to the financial crisis in Asia in 1997. However, despite the setback it has limited effects on the expansion of the rare earth production. According to the Federal Reserve, as soon as institutions (whether countries or enterprises) seem to be or actually become insolvent, the pressure leads to a market shakeout.

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65 Calculated as following: ((50,000*100)/30,000) - 100 = 66.67 percent
67 Ibid.
70 Bailey Grasso, V. (2013). p.11
The self-adjusting mechanism does not apply to Chinese enterprises, thus exempts the country from greater economic damages during that crisis. Unlike many other Asian countries China continues to increase its economic activities, including the expansion of the infrastructure providing even better access to rare earths.

Therefore, in 1998 China picks up its production faster than its global competitors and reaches an annual output of 75,000 tons. China's market penetration with very low prices causes predatory pricing and destructive competition. Due to liberal market rules in the Western countries Chinese companies penetrate the markets under facilitated conditions.

Additionally, China's largest rare earth producer are state-owned, state-controlled and receive subsidies while the US corporations are privately run enterprises, which are additionally tight to governmental as well as environmental policies. Nonetheless, the US based companies are not only outperformed by China's prices, but also due to increasing environmental regulations required by the US government that essentially complicates the rare earth production. This reflects as well the price increases for REE’s sold by the US producer. Despite that, the US is able to supply enough rare earths for its own demand.

By this time, the global rare earth supply is mainly driven by seven Chinese mines, all specialized in the production of different kinds of rare earths. The largest amongst them, the Bayan Obo mine, accounts for about 95 percent of China's known deposits and 50 percent of its entire output. This mine incorporates light rare earths (LREE) and iron as equal products. The other mines are chiefly responsible for the more strategic heavy rare earths (HREE). Nonetheless, there are other mines around the world that possess capacities but size and volume are not known. China is the only country that is able to supply heavy and light rare earths in any processed form.

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76 Morrison, W.M.; Tang, R. (2012). pp. 8-10
**Summarized**, China’s competitive strength in the REE production, the substantial differences of environmental requirements, the increasing global cost pressure for other REE producer enabled China to become the predominant supplier, which exists down to the present day. The incentivizing measures that China took in the 1980’s and 1990’s lead to a sharp increase of rare earth producer and volume. The strategy proves itself as successful with regards to the global market leadership acquisition. However, the production and export outflows control apparently failed considering the fact that China is known for its state directed corporate governance.

The apparent abundant availability in the 1980’s and 1990’s and technological innovations associated with large earning potentials have incentivized companies worldwide for stronger integration of these metals. According to Heine’s and Herr’s literature “Volkswirtschaftslehre” a monopoly is present if one enterprise is the sole supplier of a specific good in a market. Since other suppliers are operating during this time period as well, China should be rather seen as the main actor in an oligopolistic market.

All in all, China's market penetration can be recognized as a strategic move in the right place and at the right time. The country realizes the rapidly growing demand and trend towards stronger integration of REE’s in the 1980’s. Not only has it established a rare earth hegemony, which includes the entire supply chain but also created a hub for the production of rare earth depending products.

### 2.3 Effects Of A Market Hegemony 2000 To 2014

This paragraph analyzes the effects of a concentrated market structure with main focus on the period 2000 to 2014. Aim is to illuminate the coherence of the global rare earth sector and the ramifications of China's market strategy. Therefore this section is subdivided into two parts, starting with the effects on the domestic market and thereafter the impacts on foreign countries. As already discovered in previous paragraphs, the rare earth output correlates strongly with the iron exploitation. Since the 1980’s China is a steel importer but does not import rare earths at that time.

However, that may be seen as an early sign of China's domestic demand growth for rare earths that eventually exceeds its own production volume, which subsequently puts China into the position of a net importer and thus makes the country dependent on foreign supplier.

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After becoming the primary source of the worldwide supply China starts to quote its exports in 2005, three years after the Californian based Mining Corporation Molycorp stops its REE exploitation (in 2002). China's rare earth regulations range from domestic restrictions to export barriers in order to regain control over the domestic rare earth market. That has a major impact on the global REE supply due to the large dependency of the world on China.

Within the framework of the new regulations China consolidates several mines that operate illegally. In addition, it is from each mining company required to achieve a minimum production volume of 20,000 metric tons annually. Moreover, each production company has to have a fixed-asset investment (FAI) of 20 percent at least, which measures the investments in physical assets that are held in the company for more than one year.

The country initially possesses about 1000 mines that merge or are acquired by the state, which leads to the shutdown of 70 percent of all mines. Additionally, ⅓ out of 23 remaining REE mines and the half (= 50 facilities) of the smelting processors in China will be shut down subsequent to the new regulations. Another indicator for China's strategic move is to prevent further expansion of illegal mining that captures around 15 to 30 percent of China's domestic rare earth sector. The increasing illegal exports are responsible for tremendous environmental damages such as radioactive contamination and groundwater pollution, which has long-term environmental and financial consequences. Taking furthermore into account that China's own demand for rare earths is predicted to grow steadily, a sustainable exploitation may not be guaranteed if the sector stays insufficiently regulated.

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The Chinese government published in a white paper its political interest to protect their rare earth resources. Furthermore, China's ecological awareness is according to the published paper another major reason for its export restrictions. This course of action should encourage other nations to extend the capabilities of rare earth element supplies. There is a radical disagreement between China as the major supplier and its foreign customers. Since the USA and Japan are the largest consumer, their concerns and ambitions to ensure a constant supply of REE’s is enormous.

Notably the US and Japan perceive the Chinese government actions as an undesirable obstacle. Japan has experienced an export embargo that had massive impacts on its highly technology driven industries. While further restrictions for REE exports are implemented, the worldwide demand keeps rising that soars up the prices. The high demand and the lack of supply in the global market changes the perception of the rare earths. Until the early 2000’s the metals seem to be abundant in terms of their market availability, prices were relatively low.

China aims to be more conscious about environmental protection in order to create a sustainable exploitation. However, China's domestic rare earth market reformation has significant implications on the global supply particularly between 2005 and 2010. Its restrictions raise the awareness of foreign buyers for the need of alternative supplies. China argued the case that the world has been drawing primarily on its resources although rare earth deposits can be found in large quantities elsewhere. Since the domestic demand of the metals is rising dramatically, consequently China has an interest to save its deposits in order to supply its industries sufficiently.

Nevertheless, this is interpreted from the rest of the world as an unfair move that enhances China's competitive advantage.

In contrast, export restriction measures have been taken by the US to protect their shale oil and gas resources in order to meet domestic demand. The US, which is one of the largest oil producer in the world, influences global prices for oil to a large extent with its strategic measures that however, has not been acknowledged as a violation of WTO laws.

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96 Ibid.
98 Ibid.
China’s REE regulations chiefly affect domestic mines, as highlighted in the previous section\(^9\). Therefore the tighter control of China’s REE production can be considered as an essential step for securing domestic supply and beyond that as an improvement of environmental conditions. Further tightening of the export regulations by Chinese authorities effect nearly a tenfold increase in prices, as stated in Table 2. Eventually the price for rare earths is on its all-time high where the cost per metric ton exceeds US$ 50,000. Specifically between 2008 and 2012 there is an extreme price and demand fluctuation noticeable. This is due to the financial crisis in 2008 causing a drop of demand and subsequently a slump of the REE prices.

Nonetheless, sharp price increases as of 2010 are because of China's export restrictions and the supply risks involved\(^100\). In addition targeted export embargoes against Japan, which evolve from maritime conflicts between both countries impact Japan’s rare earth supply dramatically\(^101\). Many sources argue that China exercises political pressure through large interruptions of rare earth exports\(^102\). As a result of supply shortages, extreme price volatility and China's REE restrictions, it is harder for foreign industries to operate efficient. Notably is that foreign companies defray the costs of China's actions since rare earth prices outside of China are more then 500 percent higher than for domestically located companies, as Table 2 displays\(^103\).

Eventually, in 2012 the US, Japan and the EU accuse China of using unfair practices and bring this case to the World Trade Organization (WTO)\(^104\). In 2014 the export quotas are lifted in the orders of the WTO\(^105\). The Chinese Ministry of Commerce comments on its website following statement:


<table>
<thead>
<tr>
<th>Rare Earth Oxide</th>
<th>Chinese Domestic Prices ($ per kg)</th>
<th>Chinese Export Prices ($ per kg)</th>
<th>Percent Difference Between Chinese Export Prices and Chinese Domestic Prices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lanthanum Oxide</td>
<td>18.3</td>
<td>66.5</td>
<td>263.4%</td>
</tr>
<tr>
<td>Cerium Oxide</td>
<td>20.7</td>
<td>59.3</td>
<td>186.5%</td>
</tr>
<tr>
<td>Neodymium Oxide</td>
<td>122.8</td>
<td>244.2</td>
<td>98.9%</td>
</tr>
<tr>
<td>Praseodymium Oxide</td>
<td>107.0</td>
<td>209.6</td>
<td>95.9%</td>
</tr>
<tr>
<td>Samarium Oxide</td>
<td>14.5</td>
<td>95.3</td>
<td>557.2%</td>
</tr>
<tr>
<td>Dysprosium Oxide</td>
<td>1,085.4</td>
<td>2,032.1</td>
<td>87.2%</td>
</tr>
<tr>
<td>Europium Oxide</td>
<td>2,228.4</td>
<td>3,000.0</td>
<td>70.5%</td>
</tr>
<tr>
<td>Terbium Oxide</td>
<td>1,765.1</td>
<td>2,973.9</td>
<td>60.5%</td>
</tr>
</tbody>
</table>


\(^102\) Ibid.

\(^103\) Wayne, M. and Tang, R. p.27.

\(^104\) Politi, J. (2014).

“[…] The cancelling of the quotas was a specific policy to integrate domestic and foreign markets and resources, which fully manifested China's decision to give full play of the decisive effect of the market in resources allocation. […] China will continue to strengthen the protection of resources products […] promote resources and environment protection, safeguard fair competition and realize sustainable development.”

In other words, China will act according to the WTO’s law enforcement and exports its rare earths without quotations but countermeasures will be introduced. These comprise the retention of export licenses to control the outflows and the introduction of higher resource taxes. The latter measure has direct influence on the pricing of rare earths since the taxes will rise between 7.5 to 11.5 percent for light rare earths and 27 percent for heavy rare earths. Companies that depend on this commodity but produce beyond Chinese border are particularly affected by the new measures.

Table 3 below summarizes China's motives for its strategic change. The left column represents motives that arise from China, whereas the right column lists reasons from abroad that influence China's strategic realignment:

<table>
<thead>
<tr>
<th>China</th>
<th>Rest of the World</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncontrolled expansion of domestic market</td>
<td>WTO intervention</td>
</tr>
<tr>
<td>Increasing illegal mining around 15 - 30 percent in 2010</td>
<td>Increasing competitive advantage towards foreign companies</td>
</tr>
<tr>
<td>China's production does not meet the needs of its own demand sufficiently</td>
<td>Influence on global demand and supply</td>
</tr>
<tr>
<td>Rare earth import</td>
<td>Strong foreign demand growth trend</td>
</tr>
<tr>
<td>Strong domestic demand growth trend</td>
<td>Global price development</td>
</tr>
<tr>
<td>Environmental restrictions</td>
<td>Environmental requirements/critique</td>
</tr>
</tbody>
</table>

Table 3 - Summary of China's motives for its strategic realignment. Source: Kadir Ider

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109 Table content is based on the research results in this thesis.
Summarized, the analysis of this section shows that the effects of a concentrated ownership in the rare earth market are influenced by domestic and international reasons. China's strategic actions seem to be restructing and protection measures of its own rare earth sector. The domestic sector is dominated by three driving factors that include firstly the rapid development of rare earth mines and traders, secondly China's gradual loss of market control that it aims to regain through stronger governmental influence. Thirdly, China's rare earth exploitation is associated with large environmental destruction that the country aims to minimize.

China's preferred market position is due to its relatively large concentration of rare earths and the possession of specific and hard to copy production processes\textsuperscript{110}. This is associated with a low price market strategy in its early stage that changes dramatically over the course of the 2000's.

Furthermore the analysis reveals the influence of foreign countries, represented by the WTO. It can be concluded that supply shortages of rare earths have a direct link to governmental levels. Companies address the issues to the authorities, which, in turn, lodge the complaints to the WTO that deals with the trade rules amongst its member states. International interests and pressure show the limits of China's political influence on the rare earth market. This conclusion is made considering the fact that the US, Japan and China are all member of the WTO\textsuperscript{111}. If China would resign from the membership, its rights and obligations towards other members would forfeit.

Consequently, each individual Chinese producer would be more vulnerable on the market in contrast to perceiving all producers as one “Chinese unit”. Considering China as the public corporation, it can be recognized as the main market supplier of rare earths but not as the monopoly. Rather it is a particular form of an oligopoly with one major supplier who dictates the prices. As a result the other significantly smaller supplier will follow passively\textsuperscript{112}.

2.4 Hotelling’s Theory Of Non-Renewable Resources

According to Hotelling's Theory, if prices of a non-renewable resource increase faster than prevailing interest rates, producer tend to maximize their production and supply\textsuperscript{113}. This is because the yields of these non-renewables would be higher than market returns.

\begin{flushleft}
\end{flushleft}
However, if in the opposite case the price of the non-renewable resource is expected to stay below the growth rate of interest rates, it deters producer from bringing out these resources because market yields offer better returns\textsuperscript{114}. Hotelling’s Theory states that the market mechanism is the natural process that adjusts the behavior of producer according to the market conditions. This theory is based on the assumption that owner of non-renewables are profit motivated\textsuperscript{115}. In order to check if the theory is suitable for the rare earth market, two scenarios will be applied. The first scenario comprises an evaluation of the relative price changes including all figures while the second scenario evaluates the data after expunging the outliers. The adjustment for the statistical outlier is only made for the rare earth prices. This procedure is performed because the historical development of the rare earth market has shown extreme price fluctuations in certain years.

**Scenario 1:**

The price growth rate of rare earths in the first phase (1950 to 1980) is at 32.00 percent, placing this rate clearly above the US three-month treasury bills (US T-bill) interest rate that is at 4.50 percent\textsuperscript{116}. As the historical data analysis reflects, during this time period the rare earth mining and price development is higher than the US T-bill. The large divergence between both figures confirms Hotelling’s Theory and can be recognized here as proven true\textsuperscript{117}. The price growth between 1980 and 2000 continues at a rate of 13.00 percent in the rare earth market and 6.60 percent of the US T-bills. The apparent decline of the relative price rate for the rare earths is because the prices have been more stable than in the first phase. Here again Hotelling’s Theory is applicable, since the growth of rare earth prices is still twice as high relative to the market returns. In the third phase (2000 to 2014) a sharp increase of about 36.00 percent for the rare earth prices is identified whereas the US T-bills decrease to 1.50 percent. The major reason for the rare earth price increase is not the production rate but rather China’s export restriction that causes a supply bottleneck beyond its borders. However, the growth rate of REE’s from 1950 to 2014 is on average 25 percent. According to Hotelling’s Theory, the higher yields in the REE market are responsible for the producer’s decision to extract the resource rather then investing into the markets.


\textsuperscript{115} Ibid.


\textsuperscript{117} The percentage figures are rounded. For more information please see Appendix A and C.
It has to be considered that the price changes of rare earths are not solely due to the market mechanism but rather because of the direct influence of China. Therefore, Hotelling’s Theory is only partly applicable in this case, which shows the limits of this hypothesis.

**Scenario 2:**
The rare earth market experiences in its early stage small growth rates, prices remain low, as Figure 4 (p.13) displays. The mean of the REE price increase of 3.10 percent is below the US three-month treasury bills interest rate of 4.50 percent, which proves Hotelling’s Theory\textsuperscript{118}. In the second phase the rare earth price is at a growth rate of 3.20 percent and the US T-bills interest rate at 6.60 percent and shows that both values are drifting even further apart\textsuperscript{119}. During this time period production and supply increase dramatically as shown in Figure 6. Although Hotelling’s Theory states that such market constellation discourages producer to extract the resource, China does the opposite and floods the market with rare earths\textsuperscript{120}. As a consequence of extreme price pressure other participants are pushed out of the market. This controversy shows the weakness of Hotelling’s Theory, which is often criticized. Nonetheless the theoretical framework establishes a link between non-renewable resources and the entire market.

The third phase is characterized by rare earth price growth rates of 8.50 percent and US T-bills interest rates of 1.50 percent growth\textsuperscript{121}. This phase is the turnaround for the rare earth market. Due to the high growth rates of prices associated with the export restrictions the rare earth market creates increasingly incentives for other potential entrants.

On average between 1950 and 2014 the rare earth market grows at a rate of 4.90 whereas the T-bills are at 4.20 percent\textsuperscript{122}. The comparison of the Federal Reserve's (FED) T-bills and the price development of rare earths reinforce the conclusions of the historical data analysis\textsuperscript{123}.

**Summarized**, the comparison shows the potentials and limits of Hotelling’s Theory. The natural market adjustment is distorted if only quantitative determinants are considered in the calculation but not exogenous variables such as China’s interventions. These interventions cause a strong distortion of the statistical data evaluation. In fact, after the exclusion of outliers the data reveals that the price development of the REE’s and the T-Bills shows only a small deviation.

\textsuperscript{119} Ibid.
\textsuperscript{120} The mean (average) is calculated for each phase individually. Statistical outlier are neglected for rare earth prices in Scenario 2, because they cause significant deviations of the results. The relative changes to the prior year are calculated firstly. Thereafter the mean of all rates are calculated. For more information please refer Appendix A; US treasury bills have been taken as an representative example since the US is a major market player in the rare earth industry at that time and prices are denominated in USD.
\textsuperscript{122} Please note here, that statistical outlier are neglected for the price development of rare earths as well.
2.5 Interim Conclusion

The analysis of the historical market development has been subdivided into three phases. Phase one lasts from 1950 to 1980 and shows that the rare earths evolve as by-products of the iron mining. The US becomes the production and supply hub but the range of rare earth applications is limited because research is in existence for a short time. Therefore rare earths play a less important role in industries.

The second phase exists from 1980 to 2000 and is characterized by China's market penetration and increased competition. Furthermore the research and development of rare earth applications influence the perception of rare earths since unknown potentials are discovered. Rare earths become increasingly relevant in various industries due to further application discoveries because the research and development expand the possibilities for their use. China passes its main rival, the US, in production capacities and eventually becomes the chief supplier. In addition, low environmental regulations, cheap labor costs, and the utilization of critical intellectual property rights of foreign companies enhance China's privileged conditions. The historical analysis reveals that later entrants accumulate their experiences faster than the first market player. Late entrants observe and learn from the pioneers and adapt more optimized market strategies associated with up-to-date technologies.

The third phase starts in 2000 and ends in 2014. This period is characterized by a price and supply supremacy of China. Rare earths are widely established and indispensable components in several industries. In addition the export quotations limit the supply to customers outside China. Although the world possesses rich rare earth deposits to produce enough output in order to meet global demand but due to political and environmental constraints the setup of manufacturing plants takes up to 15 years. This condition does not ensure sufficient flexibility and reaction time for market changes. Rather it creates a time lag, which is responsible for delayed actions. The long lead-time is associated with pre-investments of up to US$ 1 billion to set-up and run a mine at its full capacities. In this respect the extreme competition that results in price pressure acts as a disincentive for market entrance.

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The underlying literature “Minerals, Critical Minerals, and the U.S. Economy”, published in 2008, dates from a period where the export restrictions have been existent for three years. Figure 5 displays the criticality of rare earth applications within the scope of the supply restrictions. It should be pointed out, that the size of each circle does not reflect quantitative measures. Rather the position indicates the susceptibility to supply risk exposure. The criticality increases the further the circle moves towards the upper-right corner. The yellow circle shows the average mean of all circles. The impact of supply restrictions (y-axis) scores a 3 out of 4 while the supply risk exposure (x-axis) scores a 4. The high score shows the sensitivity of rare earth supply towards the implemented restrictions. Particularly the high-tech industry that utilizes the rare earth magnets for the development of innovative products (red circle) is mostly exposed to risk. Due to constant demand growth of this sector it can be concluded that small changes in supply or prices have dramatic effects on the availability of REE’s. Ultimately, this Figure summarizes visually the conclusion of the historical development. It shows primarily the susceptibility of the market towards economic-political regulations.

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131 Ibid. p.4.
3 Porter’s 5 Forces Analysis

This section aims to determine each force’s bargaining power and mutual effects on one another in the existing market. The analysis focus will be placed on the competencies and the competitive positions in order to avoid inward-looking perspectives\textsuperscript{132}. The enhanced understanding of competitors is necessary for the evaluation of each market player’s position\textsuperscript{133}. Economic-political goals, legal and technological necessities will be taken into account as well. These include i.a. driving factors for the competition, actions that firms and countries are taking to handle supply shortages. Eventually, the analysis of the five forces will provide the important data, firstly to detect the strategic value chains and secondly to formulate a competitive strategy for institutions beyond China\textsuperscript{134}.

3.1 The Buyer Power

The goal of the buyer side assessment is to detect the types of buyers and to determine their influence respectively bargaining power towards the other forces. Within this scope the relevance of rare earths for the entire business operations of the buyers is taken into account. It will not be exactly determined, which company is purchasing certain quantities due to the given market structure that consists of complex supply chain models, numerous participants and a range of geopolitical conditions within several stages of the value chain\textsuperscript{135}. Rather a comparison of annual reports of leading Chinese and foreign REE producer (besides other sources) is used to assess roughly the global demand distribution. This measure will offer an intensified picture of the buyer side\textsuperscript{136}.

There are seven key factors that are considered for the evaluation that will be analyzed in the following subchapters:

\textsuperscript{133} Porter, M. (1998). p.XV
3.1.1 Purchase Volumes

Particularly the purchase volumes of individual buyers relative to seller volumes provide information about the bargaining power\(^{137}\). The demand and thus the purchase volumes refer to downstream products that integrate rare earths\(^{138}\). The development of these downstream markets influences the demand for rare earths and therefore reflects a correlation between supply and demand.

With respect to the consumption by country, China is the largest consumer, followed by Japan and the US\(^{139}\). China's domestic demand accounts for about 70 percent of the 225,000 tons global consumption\(^ {140}\). Although Figure 6 creates the appearance that China is able to meet its own demand, it has to be considered that the country is a net importer of certain rare earth types, as discovered in the historical analysis (Chapter 2.5.).

However, in the light of the overall production China produces more REE’s than it consumes. The large demand in China is due to the production of REE depending products that are destined for the domestic or foreign markets\(^{141}\). According to the annual report of China Rare Earth Holdings Limited (CRE) of 2014, 74 percent of the output is sold in China whereas 26 percent is exported, which reflects the data in Figure 6. Furthermore, CRE states that Japan buys around five percent of its rare earths. According to the Information Handling Services (IHS) and a working paper published by the EU Policy On Natural Resources (POLINARES), it is stated that Japan accounts for 20 percent of China's rare earth exports\(^{142}\).

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139 Polinares, (2012). p.3
140 Based on the estimated data of Figure 6 for 2015, the calculation is conducted as follows: \((160,000 \times 100) / 225,000\)
It can be concluded that CRE’s exports to Japan reflect only a fraction of the total value. Seven percent according to CRE are the sales to the US, which is close to the 12 percent according to POLINARES\textsuperscript{143}. In accordance with CRE’s annual report of 2014, its largest (sole) customer accounts for 20 percent of its sales while the five largest combined around 40 percent\textsuperscript{144}. Both figures do not differentiate domestic or foreign customer but it can be assumed that they are Chinese based since more than 70 percent of CRE’s sales are staying within the domestic territory.

### 3.1.2 Seasonality Of Demand

The demand of rare earths is also influenced by seasonal reasons\textsuperscript{145}. Based on Molycorp’s annual report of 2013 the empirical data shows a strong global decline of rare earth production due to Chinese New Year and the Spring Festival period that is celebrated widely in Asia. Therefore demand in the first quarter of each year is relatively low, while the strongest demand for rare earths is in the third quarter because productions in this period increase due to Christmas.

The demand in Japan is at the end of the fiscal year in correspondence with the first quarter. Due to accounting purposes firms increase their efforts to minimize inventories specifically towards the end of the fiscal year. This impacts the value of goods that are kept in stock, which affect the payable tax amount\textsuperscript{146}.

### 3.1.3 Financial Leverage

This paragraph determines the approximate leverage power of rare earths according to each application area. Hence, the buyer’s susceptibility towards rare earth supply can be ascertained with a better accuracy\textsuperscript{147}. Despite their mere value of around US$ 3 billion, rare earths play an essential part in downstream markets, worth US$ 5 trillion in total\textsuperscript{148}. That accounts for almost 7 percent of the global GDP in 2014\textsuperscript{149}.

\begin{itemize}
\item \textsuperscript{143} Manning, M. (2013); Polinares, (2012). p.3
\item \textsuperscript{144} China Rare Earth Holdings Limited, (2015). p.41
\item \textsuperscript{145} Molycorp Inc., and United States Securities And Exchange Commission, (2014). p.9
\item \textsuperscript{147} Porter, M. (1998). p.25
\item \textsuperscript{148} Schuessler, R. (2014).
\end{itemize}

\begin{align*}
\text{Calculation is made as following (in trillion US$): } (5.00 \times 100) / 77.00 & \approx 6.5 \text{ percent} \rightarrow \approx 7 \text{ percent}
\end{align*}
In the US and Canada alone, the rare earth metals contribute to an annual economic output of roughly US$ 350 billion and are responsible for 620,000 jobs\textsuperscript{150}. Considering the global consumption of REE’s, following table reveals the leverage power of rare earths based on the application area\textsuperscript{151}. Due to a lack of adequate data it is assumed that the financial leverage is equally distributed in each application area.

<table>
<thead>
<tr>
<th>Application Area</th>
<th>Percentage of Total Output\textsuperscript{152}</th>
<th>REE Value (in US$ billion)\textsuperscript{153}</th>
<th>Market Impact (in US$ billion)\textsuperscript{154}</th>
<th>Financial leverage in percent\textsuperscript{155}</th>
<th>End Markets\textsuperscript{156}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catalysts</td>
<td>15.50</td>
<td>0.465</td>
<td>775.00</td>
<td></td>
<td>Oil Refinery Catalysts; Automotive</td>
</tr>
<tr>
<td>Ceramics</td>
<td>5.50</td>
<td>0.165</td>
<td>275.00</td>
<td></td>
<td>Surface Coating</td>
</tr>
<tr>
<td>Glass</td>
<td>6.00</td>
<td>0.180</td>
<td>300.00</td>
<td></td>
<td>High-End Optics</td>
</tr>
<tr>
<td>Magnets</td>
<td>26.00</td>
<td>0.780</td>
<td>1300.00</td>
<td>1700.00</td>
<td>Consumer Electronics; Hybrid and Electric Vehicles</td>
</tr>
<tr>
<td>Metal Alloys</td>
<td>19.00</td>
<td>0.570</td>
<td>950.00</td>
<td></td>
<td>Green Technologies; Super alloys</td>
</tr>
<tr>
<td>Phosphors</td>
<td>6.00</td>
<td>0.180</td>
<td>300.00</td>
<td></td>
<td>Steel Additives</td>
</tr>
<tr>
<td>Polishing</td>
<td>16.50</td>
<td>0.495</td>
<td>825.00</td>
<td></td>
<td>Glass Polishing</td>
</tr>
<tr>
<td>Other</td>
<td>5.50</td>
<td>0.165</td>
<td>275.00</td>
<td></td>
<td>Water Purification; Healthcare</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
<td>3.00</td>
<td>5000.00</td>
<td>1700.00</td>
<td>\textbf{1700.00}</td>
</tr>
</tbody>
</table>


As the table above shows, the rare earths have a financial leverage of around 1700 percent. This percentage reflects the impact on rare earths according to the classified category. In other words, rare earths account for 0.0006 percent (6 x 10\textsuperscript{-4}) of the purchasing costs that companies in the affected markets are paying\textsuperscript{157}. Although REE’s represent only a very small fraction they have an enormous impact on the end-market.


\textsuperscript{152} U.S. Rare Earth Inc., And The Securities Exchange Commission, (2013), p.9

\textsuperscript{153} REE value calculated as following: US$ 3 billion x relative proportion

\textsuperscript{154} Market impact calculated as following: US$ 5 trillion x relative proportion

\textsuperscript{155} The leverage effect reflects the financial impact of rare earths on affected markets and is calculated as following (in US$ billion): 5000/3 = 1666.67 percent $\rightarrow$ \textbf{1700} percent

\textsuperscript{156} Molycorp Inc., and United States Securities And Exchange Commission, (2014). p.8

\textsuperscript{157} Calculated as following (in US$ billion): 3/5000 = 0.0006 percent = 6 x 10\textsuperscript{-4}
The estimated leverage power may deviate from the actual value because other materials add a certain value to the products as well. Nonetheless, without rare earths these goods could not provide the features they do, which reflects the strategic significance of REE’s for its end use. Products, which fall into one of the above stated application areas are summarized in the “End-Markets”-column. It can be concluded that a significant demand is created by the consumer- and industrial-end-market. These sub-areas require rare earths firstly, according to the demand of the end product in the market and secondly, the advancements of research and development (R&D). As the historical analysis reveals, especially the latter point influences the demand in compliance with the progress in R&D.

**In conclusion**, the leverage power shows that the buyer has a strong susceptibility towards rare earths although the metals occupy a minimal part of the costs.

### 3.1.4 Profit Margins

As discovered in the previous paragraph, rare earths make up only a small percentage of the costs but have large leverage effects on the sales. According to Michael Porter, profitable buyers are less price sensitive if the purchased good represents a small percentage of their costs.\(^{158}\)

The price sensitivity refers in the first place to companies whose main business is to trade with rare earths (in the following: distributors). Therefore the profit margins have to be differentiated between those firms that chiefly work with REE’s and those who buy the metals as a component of a product.\(^{159}\) Some end-user firms acquire rare earths directly from producer because of the nature of their products, which makes them equally susceptible towards price changes as in the case of distributors as Figure 7 shows.

It can be therefore concluded, that rare earth trading companies are more price sensitive and therefore suffer faster from price changes because these firms function as a link between REE mining companies and downstream consumer. This also applies to firms that buy directly from producer.

In contrast, firms with lower price sensitivity and potentially higher returns are those whose REE acquisition costs represent a fraction of the total expenditures. In addition, buyers with an efficient upstream organization will suffer less then others. This may be the chief reason for foreign firms to relocate their production to China, since that ensures a stable supply of rare earths associated with more favorable prices compared to the buyers that are not based in China.

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\(^{159}\) Molycorp Inc., and United States Securities And Exchange Commission, (2014). p.8
3.1.5 Rare Earth Varieties

This paragraph focuses on the types and varieties of rare earths that the buyer can purchase. These characteristics provide information about the degree of standardization. If the market offers predominantly undifferentiated rare earths than the bargaining power of the buyer is significantly greater while higher diversification results in a weakening.

The market evolution shows that increased R&D results in the isolation of individual rare earths, which subsequently leads to specialized and diversified applications.

Main emphasis in this paragraph is placed on the last three stages, which clearly stress the different varieties of REE’s that are sold on the market. This circumstance is due to varying needs of industries that create the supply accordingly.

The first segment “REOs to Market” serves customers that produce computers, catalytic converters, TV displays, electronic chips, etc. Demand in the “Metals & Alloys to Market”-segment is driven by the production of micro motors, sensors and further applications that require miniaturized components and strong magnetic features. Customer of the third segment “Magnet to Market” produce light emitting diodes (LED’s), turbines, solar systems and other electronic products. Each segment utilizes different types of the 17 available rare earths since each mineral provides different properties.

Summarized, diversified applications create the necessity for a larger variety of rare earths but the downside is a higher dependency on specialized supplier. Moreover, the demand is spread across several stages of the value chain. Therefore, the decentralized demand has detrimental effects for the buyer’s purchasing power.

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161 Ibid.
162 Molycorp Inc., and United States Securities And Exchange Commission, (2014). p.4
163 Ibid.
164 Ibid.
165 Ibid. p.5
3.1.6 Switching Costs

These types of costs occur when the buyer switch from one supplier to another. A buyer would only change its supplier if a significant improvement in its own supply chain or the end product were expected. Buyers in the resource market normally align themselves to the prices offered by the industry, which is also applicable for rare earths. China is the prime supplier that dictates the prices and therefore switching costs are low. However, this conception does not take export quotas into consideration, which in the case of the rare earth market impacts the price- and supply-development. An external force that is represented by China’s rare earth quotations interrupts the market mechanism, in which supplier and buyer determine quantities and prices. The historical analysis reveals that buyer purchase REE’s at any given price, which is chiefly due to the market constellation with China as the main supply source. Nonetheless, switching costs may also incur when companies aim to minimize rare earths in their products or purchase from sources that ensure environmentally friendly and sustainable production and when seeking for substitutes. One company that currently experiences switching costs is IBM. Researchers are developing alternative components to replace rare earths in certain products. This undertaking is associated with following expenses:

1. Upfront investments
2. Research, feasibility analysis
3. Product redesign and testing
4. New machines, tools
5. Realignment of supply chain (incl. contract termination with existing supplier)
6. Restructuring costs (incl. firing, hiring and retraining employees).

Summarized, as discovered switching costs are particularly low in the rare earth market that subsequently tides the buyer to Chinese supplier. However, uncertain supplies in the past years associated with extreme volatile prices result in a rearrangement of supply chains in the buyer market, which will raise switching costs subsequently.

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3.1.7 Backward Integration

Buyer of rare earths may be qualified for backward integration, which represents the upstream movement towards the source of raw material\textsuperscript{171}. Such strategic decision is associated with large investments for the acquisition of firms in order to extend the supply chain. Competitive benefits may result in synergy effects such as cost reduction because human labor and equipment can be allocated more efficiently\textsuperscript{172}. Companies that incorporate rare earths may additionally benefit from risk reductions of their own supply and lower price fluctuations.

Yet, backward integration has its limitations for the buyers. As discovered in previous paragraphs there are three types of buyer:

1. Distributors: companies whose main purpose is the sales and distribution. They purchase the REE’s straight from the mining companies
2. End-user purchase directly from mining companies
3. End-user purchase from distributors

The purchase of an entire mining company as a backward integration measure seems to be not a feasible and realistic alternative because of enormous acquisition costs. According to Infinancials.com Molycorp’s enterprise value (EV) is around US$ 1.5 billion\textsuperscript{173}. In comparison the Inner Mongolia Baotou Steel Rare-Earth Hi-Tech Co. Ltd. (REHT) has an enterprise value of almost US$ 14 billion\textsuperscript{174}.

With respect to all the buyer types, such acquisition is rather pointless considering the huge investments relative to their own company value. A more strategic sensible step for the buyers is the purchase of shares from rare earth supplying companies. That is financially and strategically more viable and leaves space for flexibility. Such backward integration is already considered by Japan and the US in the first place to ensure their supply\textsuperscript{175}. This is particularly due to the concerns of China's rare earth policies.

\textsuperscript{172} Ibid.
\textsuperscript{175} Humphries, M. (2013). p.19
3.2 The Supplier Power

The supplier power in the rare earth market derives from its ability to exert influence on quality, quantity and prices, which is in direct linkage to the profitability of any participant in the industry. The factors taken into account to assess the level of supplier power will be as follows:

3.2.1 The Supply Chain

The analysis of the supplier side will firstly examine the structure of the supply chain and within this context illuminate its strength, weaknesses and arising opportunities. A series of stages are required until rare earths are ready to be used for any application. Figure 8 (p.36) reflects exemplary the various stages of the REE supply chain management (SCM), including the upstream (extraction, processing) and the downstream industry (components, end-use).

The supplier’s strongest power can be identified in the upstream operations that involve the “Extraction” and “Processing” of REE’s. This is also known as the initial step of the “Make-Phase” in the supply chain management. However, the exploration can be carried out anywhere because it’s mainly determined by the mining ore capacities as well as technological equipment. Mining only will not be a feasible strategy to increase competitiveness because the more critical part of the upstream operations, which adds significant value to the REE, is the processing.

The downstream operations in the supply chain comprise the “Components” and “End-Use Technology”. Moreover, they are further value adding processes that are dominated by Chinese manufacturer as well. The downstream operations are in line with the demand side and can be reviewed in section 3.1.5. Rare Earth Varieties.

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Summarized, the supply chain analysis identifies its strengths that potential mining activities can be done anywhere. The weakest points are the legal issues that limit the development of the entire supply chain and thus the expansion of the market position.

### 3.2.2 Supplier Market Share

At the present days over 90 percent of the exploration takes place in China, while other mining ores in the RoW contribute to a small extend, as displayed in Table 5 (p.37)\(^{180}\). However, it has to be taken into account that the demand for rare earths in China is to a certain extend due to foreign companies that produce there for export purposes. Therefore the 70 percent has to be classified according to its ultimate end-destination\(^{181}\). In addition it must be taken into account that the current market shares of foreign suppliers remain very low due to the uncertainty of investors that are associated with heavy pre-investments as stated in section 2.5. Interim Conclusion\(^{182}\). This comes together with the limited operations of foreign REE producer that suffer from a deficiency of vertical integration, which involves specifically the value adding downstream operations\(^{183}\).

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\(^{180}\) Parthemore, C. (2011). p.8

\(^{181}\) Unfortunately, no sufficient data has been found that subdivides China's REE demand.


The analysis of the REE market evolution shows evidence that continues supply shortages along with high market prices incentivize foreign institutions to establish their own supplies. While high environmental regulations and capital requirements slow down and limit this process in the rest of the world, Chinese rare earth companies are state owned and thus benefit strongly from their advantageous market situation\textsuperscript{184}. This circumstance leads to following obstacle within the scope of market share reclamation:

The additional risk for foreign REE producer and private investors arises from the potential threat that China may stimulate its domestic production and exports to such an extent that global market prices fall significantly. Prices below a certain threshold disable foreign companies to sustain a profitable business. This could jeopardize the market share of foreign REE companies and cause a financial disaster and a long-term loss of investor’s confidence. Although this scenario is in contradiction to China's aim to motivate foreign institutions in the search for alternative supplier, it is up to the present day a feasible and realistic option taking China's market superiority into account\textsuperscript{185}.

**Concluded**, the market situation with a highly concentrated supplier side adds significant bargaining power to Chinese supplier\textsuperscript{186}. Therefore, foreign REE consumers show a stronger susceptibility to price, quality and quantity than Chinese buyer\textsuperscript{187}.

### 3.2.3 Supply Threats

The supplier power of China will be additionally evaluated through an analysis of potential supply threats stressing the availability of certain REE’s, substitutions and regulatory compliances. Specifically the less abundant and more valuable HREE’s that are used for green technologies (wind energy, electric vehicles) are subject to higher risk due to their exceptional characteristics\textsuperscript{188}. Moreover these HREE’s (esp. Dysprosium amongst other less abundant REE’s) are expected to be in short supply in the next five to 10 years\textsuperscript{189}.

\begin{table}[h]
\centering
\begin{tabular}{|l|c|c|}
\hline
 & Supply (in %) & Demand (in %) \\
\hline
China & 90 & 70 \\
RoW & 10 & 30 \\
\hline
\end{tabular}
\end{table}

\textsuperscript{185} Politi, J. (2014).
\textsuperscript{186} Porter, M. (1998). p.27
\textsuperscript{188} Humphries, M. (2013). p.13
\textsuperscript{189} Manning, M. (2013).
Although China's industries will be affected as well, potential downside risks are limited since global REE supply and demand are located in China. According to the National Research Council (NRC) there are no economic viable alternatives to rare earths that could replace them at the present days\textsuperscript{190}. A more thorough analysis of substitutes is presented in section 3.4. Threat of Substitution.

Furthermore the “Processing”, “Components” and “End-Use-Technology” threaten the supply of REE’s, as Figure 8 shows. At this stage the REE’s went through several critical refinement processes, at which large quantities of toxic and radioactive substances are released. The resulting consequences are major negative impacts on nature and all living beings\textsuperscript{191}. The legal constraints associated with environmental requirements create the barrier for suppliers around the world to establish fully integrated up- and downstream processes\textsuperscript{192}.

This constitutes a dilemma for international producer, while the extraction can be carried out domestically, foreign companies may have to ship their rare earths to China for further processing. Subsequently, the REE’s will be subject to China's REE export taxes (up to 27 percent) as soon as foreign companies reimport the metals\textsuperscript{193}. Hence, the prices for rare earths offered by companies beyond China may exceed average market prices as well as cutting down profit margins significantly.

To summarize, the lack of governmental actions, missing legal requirements and inefficient financial resources associated with the uncertainty of private investors causes predominantly a supply risk exposure for foreign firms. Considering the fact that it takes more than a decade to establish a secure end-to-end supply chain, it can be concluded that China's supplier hegemony will last at least in the medium term.

3.2.4 Profit Margins

Export restrictions, the high dependency on China's rare earth supply and the low production volumes in the RoW cause soaring prices, which temporarily increase profits for the supplier. After supply increases prices show a falling tendency to the marginal costs of production\textsuperscript{194}. Apart from that, economic instabilities across the globe affect further price declines as a result of weaker demand, which affects the profits of rare earth companies in the same way\textsuperscript{195}.

\textsuperscript{190} Humphries, M. (2013). p.13
\textsuperscript{191} Foote, B. (2014).
\textsuperscript{192} Morrison, W.M.; Tang, R. (2012). p36
\textsuperscript{193} Ibid.
\textsuperscript{194} Humphries, M. (2013). p.5
\textsuperscript{195} Bailey Grasso, V. (2013). pp.5-6
The price mechanism forces the expensive suppliers to leave the market while the more competitive ones survive \(^{196}\). Since Chinese companies possess the majority of production and supply, they benefit from the economies of scale, highly competitive production costs and the government support. Nonetheless, even Chinese producers are not exempt from the current market developments, as two of China's largest REE producer report massive drops in profits in 2014 \(^ {197}\). According to the Inner Mongolia Baotou Steel Rare-Earth Hi-Tech Co. Ltd. (REHT) profits plummeted by almost 60 percent while the operating revenue of China Minerals Rare Earth dropped 65 percent and incurred US$ 9 billion losses \(^ {198}\).

The largest foreign rare earth producer Molycorp experiences an even more precarious financial situation. The economic condition associated with recent price drops of 50 percent for most of the rare earths left the company with US$ 1.7 billion of liabilities. In 2011 the share price was at US$ 80 and fluctuates nowadays at US 0.48¢ per share, reflecting a market value of US$ 117 million \(^ {199}\). The effects of the price mechanism are reflected in a statement of Molycorp’s Chief Financial Officer \(^ {200}\):

“[...] ”We have incurred and will continue to incur operating losses due to continuing softness in product pricing, inconsistent or depressed demand for our products, and the delayed ramp-up of operations at our Mountain Pass facility,” Mr. Doolan said. [...]”

**It can be concluded** that the current economic situation affects the profits of rare earth producer dramatically. REE companies concentrate their operational activities on the manufacturing of these metals, while having co-products, such as steel. Nonetheless, the more profitable business with the REE’s is more susceptible to price and demand. This is because the REE’s represent a large fraction of the company's revenues \(^ {201}\). This condition has disadvantageous effects on the bargaining power of supplier.

However, comparing the profits respectively losses of Chinese and foreign REE companies, it can be concluded that the Chinese firms have a clear advantage, since they are state owned enterprises and thus will be backed by the government.

\(^{196}\) BusinessDictionary, (n.d.).


\(^{198}\) Ibid.


\(^{200}\) Ibid.

3.2.5 Price Influence

As discovered in the previous paragraphs the supply and demand is predominated by China. Therefore price influence on REE may be distinguished for China and for the RoW. Although China produces and consumes much of its own rare earth output, domestic quotas have been introduced within the scope of the industry consolidation\textsuperscript{202}. As a result of stronger regulations, domestic prices increased\textsuperscript{203}.

Apart from that, China uses export quotas, resource taxation and impose embargoes in order to create supply shortages that subsequently affect higher prices abroad\textsuperscript{204}. Foreign competitors share 10 percent of the supplier market share that puts them in an insufficient position to exert power on Chinese supplier and international buyer\textsuperscript{205}.

Hence, the influence of China on global prices is greater than its foreign competitors. It has to be taken into account that China's REE producers are more vulnerable as individual operating companies. But due to China's corporate governance structure, the state is the significant stakeholder, which creates the appearance of “one big Chinese rare earth company”\textsuperscript{206}.

3.2.6 Concentration Of Export Destinations

A drop of REE supply is due to the reduction in demand caused by the economic downturns\textsuperscript{207}. US companies in the consumer electronics sector and the military are particularly affected by China's supply. In some cases US firms draw up to 100 percent on China\textsuperscript{208}. The US receives around 10 percent of China's total exports\textsuperscript{209}. Japan accounts for 20 percent that represents about 80 percent of its entire REE consumption\textsuperscript{210}.

Both countries count for $\frac{1}{3}$ of China’s exports, which reflects a high concentration of China’s export-destinations. The circumstance may give the impression that the bargaining power of foreign companies is increased. However, it has to be born in mind that China has the strongest influence in up- and downstream processes of the REE production.

\textsuperscript{203} Ibid.
\textsuperscript{205} Porter, M. (1998). p.27
\textsuperscript{206} Morrison, W.M.; Tang, R. (2012). p13
\textsuperscript{207} Bailey Grasso, V. (2013). pp.5-6
\textsuperscript{208} Humphries, M. (2013). p.1
\textsuperscript{210} Humphries, M. (2013). p19
In addition, its domestic demand is by far the largest worldwide, which ultimately increases its bargaining power relative to its foreign counterparts. It is therefore most likely that the world will depend on China's REE exports in the medium term while China maintains a strong bargaining power.

### 3.2.7 Switching Costs

The analyses of the switching costs are in line with the buyer side. It has been illuminated that the predominant position of China tides many REE consumer to that particular source. Therefore it can be concluded that China will not face switching costs. However, the current market condition generates potential switching costs for the “rest 10 percent” of the supplier, which represent the foreign participants\(^ {211}\). The two main factors that account for the suppliers switching costs are the highly competitive prices of China and the demand. The previous chapters show in particular that this combination is an obstacle for foreign competitors. Although producer outside of China may be able to offer a diversified range of REE’s it does not provide them an advantage at the present days because China is able to offer REE’s in the same quality and larger quantities. Thus it affects as well the switching costs, which leads to the conclusion that the bargaining power of foreign supplier is too small for both, to compete with Chinese supplier and to exert bargaining power on the buyer\(^ {212}\).

### 3.2.8 Forward Integration

A forward integration is associated with the extension of operations into downstream processes, as displayed in Figure 8 (p.36). Such move requires resources, necessary skills and know-how and the volume to ensure the decisive factors for competitive operations\(^ {213}\). One major benefit for rare earth producer is the realization of synergy effects including the increased allocation efficiency for resources (labor, equipment, finance), ensuring quality and quantity and thus increase competitiveness\(^ {214}\). This strategic measure can be recognized by China's attempt to extend its value chain through the integration of downstream processes. As the previous sections reveal, there are indicators that China uses its market supremacy, quotation system and low production costs in order to attract foreign companies to relocate to China\(^ {215}\).

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\(^{212}\) Ibid.  
\(^{214}\) Ibid.  
This statement is strengthened by the policies of the National Development and Reform Commission (NDRC). Foreign companies that operate in China have to comply with following terms and conditions\textsuperscript{216}:

1. Foreigners are prohibited to operate in the REE mining
2. Foreigners may be eligible for processing (smelting, separation) but only with a Chinese partner
3. Foreigners should invest into downstream operations to develop new REE applications (which have to be patented first in China and be shared with Chinese partners\textsuperscript{217})

Many Japanese and US corporations have already moved their production to China in return for stable, sustainable and low-cost supply of rare earths\textsuperscript{218}. Moreover, China is building partnerships with foreign REE producer, including Australian based Lynas Corp. that is one of the world’s largest REE producers outside of China\textsuperscript{219}. Although this step represents a horizontal integration it is stated here because this strategic implementation aims to secure China’s downstream operations.

To sum up, China uses its position to expand its vertical operations. Foreign producer see themselves often in the situation of establishing cooperation’s with Chinese firms to access the resource under favorable conditions. However, in return they have to give up their independency and disclose patents.

In summary of the supplier side it becomes clear that not only buyer but also supplier beyond Chinese border are exposed to China's bargaining power. One potential strategy is the establishment of partnerships around the world, share production processes and costs. This would enhance the competitiveness of foreign REE producer and decrease the dependency on Chinese supply. Both, Chinese and foreign supplier have potentials for further forward integration. China takes the lead in the global comparison not least because its dominant position. Therefore Chinese supplier can exert pressure on its smaller rivals as well as its customer.

The evaluation of the eight factors above is reflected in the statement of Mr. Karl Gschneidner that gets it right to the point: \textit{China, still the biggest miner. “[There are] lot’s of companies worldwide, [however, they have] not much power”\textsuperscript{220}.}

\textsuperscript{216} State Development Planning Commission, (2002).
\textsuperscript{217} Hartmann, B. and Deutschmann, U. (2012).
\textsuperscript{218} Morrison, W.M.; Tang, R. (2012). p.18
\textsuperscript{219} Ibid. pp.20-22
\textsuperscript{220} Gschneidner, K. (2015).
3.3 Potential Entrants

The desire to enter the rare earth market is essentially to gain access to the resource and sustainable supply. The assessment of the barrier characteristics will provide indicators for the entry conditions and further the factors to a successful entry. Figure 9 below reflects the stages of the supply chain associated with the market entrance difficulty level. It is not associated with a specific country but rather with the entire REE market. The evaluation is divided into four subsections and carried out as follows:

3.3.1 Market Concentration And Opacity

At the present days the market concentration is on a high level due to China’s hegemony, as reflected in Figure 9. Thus China possesses the absolute advantage in terms of economies of scale. Adam Smith best describes this that the production of large quantities enables an efficient allocation of resources. Subsequently this impacts the development of more specific machines that meet the various needs of the industry. Given the current market structure, foreign firms can enter the market with large quantities and risking a backlash from China or small volumes and realize an overall cost handicap. As discovered previously, economies of scale may be created by partnerships with strategic focus on the sharing of intangible assets. Sharing brand names, know-how (including patents) enables foreign companies to realize economies of scale.

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224 Ibid. p.9
Intangible assets do not require storage or transportation and costs may incur once when the asset is created and for the acquisition of the rights of use. Because this reflects a relatively better opportunity for market entrance therefore the market opacity is slightly above a moderate level. However, it will be hard for foreign firms to attain economies of scale in the near future because China is investing heavily into the REE sector since the 1970’s. The advanced learning curve of Chinese manufacturer has a positive effect on declining unit costs and an accumulation of experience. This reflects an additional problem for foreign institutions. Although the largest producer outside of China, such as Molycorp and Lynas possess advanced technologies, they cannot realize economies of scale if their production volumes are not competitive with Chinese firms.

### 3.3.2 Capital Requirements

A major entrance barrier is associated with capital requirements since it impacts all areas of the operations. Considering the mere value of rare earths of around US$ 3 billion, capital costs of up to US$ 1 billion represent a risky undertaking for investors. Sufficient financial resources are particularly important for the junior miners because they are often underfunded, which is a principal reason for Mr. Gschneidner’s forecast about the downfall of the majority of REE producer.

There is a higher chance that the large rare earth producer will survive because of their ability to better allocate financial resources and thus diversify into several production processes. Since the mere REE mining is at the lower end of the value creation, large producer rather prefer to shift their operations to the more lucrative processes.

Secondly, the exploitation process of each mine is unique and cannot be implemented in other mines since each deposit has different natural characteristics. Low prospects for high profits associated with extensive capital costs make the market entry more difficult. Figure 9 reflects the aggravated market entry conditions that are associated with the necessary capital requirements. Almost each process of the supply chain involves moderate to high capital investments.

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229 Gschneidner, K. (2015); Radon, J. (n.d.). p.18
230 Radon, J. (n.d.). p.18
231 Ibid.
3.3.3 Regulatory Requirements

Legal requirements represent a particularly sensitive entry barrier for potential REE producer because national and international regulations have a direct impact on the operations. One specific example that represents such governmental impacts is the light bulb industry, in which domestic legislative measures of the US impacted the entire industry dramatically\textsuperscript{232}. From this date on Compact Fluorescent Light bulbs (CFL) were not allowed to trade on the market, thus virtually eliminating the supply and demand for fluorescence. In return the supply and demand for the so-called Triband Phosphors (used for LED’s) increased\textsuperscript{233}. This affected the rare earths in the same way since they are an integral part of replacement substance. Therefore it can be concluded that governments should reform the legal basis in order to support the market entrance.

According to the interview with Mr. Gschneidner, such regulatory changes can be executed on federal, state and local level and may include loan guarantees, tax incentives and the support of the vertical integration beyond the mining of rare earths\textsuperscript{234}. Especially these steps reflect a significant market entrance difficulty as displayed in Figure 9.

3.3.4 Intellectual Property Rights (IPR)

A possible roadblock for the market entrance is the ownership of strategic patents, represented in Figure 9 as “Knowledge/Technical Requirements”. The IPR’s involve human capital as well as technical expertise in the various stages of the supply chain\textsuperscript{235}. The R&D enables various industries to utilize new rare earths for further applications. As a consequence, more experts and further developed equipment will be needed in order to sustain the supply of REE’s\textsuperscript{236}. This is because education and training leads to the development of new technologies that subsequently contribute to the creation of new patents for the REE production\textsuperscript{237}.

“Knowledge/Technical Requirements” in Figure 9 is associated with the separation, metal making, alloying and magnet manufacturing, which represent the highest entry barrier. Specifically these steps require perhaps the most significant IPR’s for the permanent magnet (NdFeB) manufacturing\textsuperscript{238}.

\textsuperscript{233} Ibid.
\textsuperscript{234} Gschneidner, K. (2015).
\textsuperscript{236} Ibid.
\textsuperscript{237} Gschneidner, K. (2015).
\textsuperscript{238} Ibid.
These particular stages create most of the value and therefore are associated with higher profits as discovered in the supplier side analysis. At the present days the Japanese company Hitachi owns more than 600 patents for the manufacturing of NdFeB magnets\textsuperscript{239}. Five licensees are in China, three in Japan and two in Germany while the US has no licenses\textsuperscript{240}. This is a disadvantage for US rare earth corporations taking into account that the US is the second largest rare earth consumer worldwide.

Mr. Gschneidner states in the interview that IPR’s are one of the main problems that cause the REE market crisis in the RoW\textsuperscript{241}. This is due to the fact that irrespective of the production location, the ownership of IPR’s allows to keep the control of certain value chain processes, despite the hegemony of China in the rare earth market\textsuperscript{242}. Nevertheless, China’s highly competitive production costs act as a countervailing force to the IPR’s of foreign companies.

**Summarized**, the potential entrants have to cope with several properties of the entry barriers. Firstly, the availability of liquid assets and government actions lead to an increased efficiency of economies of scale and the development of new intellectual property rights. Secondly, China’s influence on the prices will affect the market entry since existing and expected entry deterring price will increase the threat of market entrance\textsuperscript{243}. This condition will remain as long as foreign competitors have not accumulated the necessary expertise\textsuperscript{244}. This problem can be resolved through tighter cooperation of foreign companies that could be the solution for the short-term with possibly positive long-term effects. According to Mr. Gschneidner “There are lots of junior miners - worldwide several hundred, but maybe only ten will make it”\textsuperscript{245}. This will become a self fulfilling prophecy if potential entrants will not succeed in entering the REE market and become serious competitors.

### 3.4 Threat Of Substitution

This section analyses the feasibility of potential substitutes and within this context presents a selected range of affected industries\textsuperscript{246}. The assessment emphasizes the development, improvement and redesign of alternative materials and systems that achieve equal or superior properties to eliminate the need of rare earths while retaining the functionality and cost efficiency.

\textsuperscript{239} U.S. Department of Energy, (2011). p.56  
\textsuperscript{240} Ibid.  
\textsuperscript{242} U.S. Department of Energy, (2011). p.28  
\textsuperscript{244} Ibid. pp.15-17  
\textsuperscript{245} Gschneidner, K. (2015).  
The assessment is limited to six key industries with high earning potentials that suffer mostly from rare earth shortages\(^{247}\). The represented selection includes magnets, motors, generators, photovoltaic, batteries and phosphors\(^{248}\). In addition, the rare earth recycling will be considered as well although it may not be a substitute in the traditional way but it represents an alternative supply channel.

### 3.4.1 Substitutability Through Materials And Systems

At the present days substitutions for permanent magnets are researched particularly since they affect several key industries worldwide\(^{249}\). According to Mr. Gschneidner there are currently no marketable substitutes that replace any rare earths\(^{250}\).

Nonetheless, the U.S. Department of Energy (DoE) in cooperation with the Ames Laboratory (under the leadership of Mr. Gschneidner) reported a breakthrough in the research of a substitute for Dysprosium\(^{251}\). This rare earth is known to be the scarcest and one of the most expensive amongst its peers. Partially because the supply is below its demand, hence putting upward pressure on prices\(^{252}\). This metal is used for the magnets for green technologies. Ultimately hybrid cars, generators, wind turbines will benefit from this alternative material\(^{253}\). However, the substitute for the Dysprosium, the so-called Cerium is a rare earth itself. The two advantageous over the other REE’s are its abundance and the production is known to be less burdensome\(^{254}\). Therefore it can be produced much easier elsewhere and does not depend highly on China.

Additionally, the Nanotechnology is considered as a potential substitute\(^{255}\). These materials function on a nanometer scale that can provide superior performance compared to rare earths. However, from an economic standpoint, it has not reached a commercial feasibility to produce this alternative and it may take several years to make it market ready.

The third option that may completely replace rare earths is Graphene, which can provide significantly higher performances than rare earths. This material has the potential to impact and transform more industries and has higher commercial leverage power than REE’s.

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\(^{248}\) Ibid. pp.125-128  
\(^{250}\) Ibid.  
\(^{252}\) Ibid.  
\(^{254}\) Ibid.  
Despite the potential wide range applications of Graphene, only a few companies worldwide have access to this mineral. About 70 percent of the global supply of Graphene is controlled by China and 25 percent by the US. China has already implemented export charges of 20 percent and value added tax (VAT) of 17 percent. Prices for Graphene increased between 2006 and 2013 already more than 100 percent due to steadily rising demand and further technological innovations.

The commodity supercycle follows a similar trend as the REE’s with one exception: China already introduced export restrictions in the early stage of the Graphene life cycle, whereas the quotas for REE’s came 15 years after China achieved its supply hegemony. While these actions force up prices for Graphene, foreign countries take advantage of that and aim for a faster market entrance.

3.4.2 REE Recycling

An increase in recycling results in a demand decrease for newly produced rare earths and thus minimizes the dependency on China. Particularly large scaled magnets are currently in the main focus of REE recycling companies since they are larger and easier to extract from the metal scrap.

Japan develops the “urban mining” in other words recovering metals from used electronic devices, e.g. laptops, smartphones and batteries. The country is even importing electronic scrap in order to boost this plan. It is estimated that 300,000 tons of REE’s are available in used electronics, with a rising tendency. However, less than 1 percent is recycled at the present days due to insufficiently established infrastructures that support the recycling process.

Major challenges that these companies are facing include the development of automated technologies and processes to ensure an economically viable and environmentally friendly recovery. Furthermore, innovative product redesigns could support the easier access and thus the extraction of rare earth components, which encourages the recycling process additionally.


259 Ibid.

260 Ibid.


263 Ibid.
The various stages of the REE supply chain management (Figure 8, p.36) reflect the recycling cycle of REE’s. Rare earth recovery through recycling goes through the same stages as the recovery through mining. The major difference is that the recycling process involves already mined and processed REE’s. Although this minimizes the environmental degradation significantly, 30 percent of the recycled rare earths are lost in this process due to insufficient systems and machines. While this reduces the actual recovery rate, it has also major effects on the productivity and profitability and thus the economic competitiveness of recycling with alternative REE productions.

Summarized, if one substitute establishes itself in the market it will subsequently limit the potential threats of China. REE consumer would have to bear one-time switching costs but in return detach from China’s supply. However, market prices for rare earths could be sealed temporarily because China possesses high competitiveness and a well-developed workforce.

That already incentivized the Chinese to enter the (Graphene) substitute market with a strategy as it already implemented for the REE’s. Many sources advice to reduce the usage of REE’s but such a measure does not break the dependence on rare earths. A simple substitution of rare earths is very difficult due to the complex technologies nowadays. Therefore experts advise to seek for functional substitutions, where new technology completely replaces another one, while avoiding the usage of rare earths.

The major challenge will be to identify viable substitutes, required technologies and infrastructures that contribute to a decentralized control of strategic commodities. As Mr. Gschneidner comments on this: “A lot work is going on but only some substitutes may be successful.”

3.5 The Competitive Rivalry

Despite the reduced industry growth at the present days, it is expected that REE demand will increase on average by 10 percent annually in the next five years. This motivates producer beyond China to establish independent respectively alternative supplies. Such undertaking is associated with high requirements, i.a. government actions and financial funding’s that could boost the competitiveness of firms in the rest of the world.

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265 Ibid. p.57
269 Ibid.
In addition, the analysis of the previous chapters reveals an unequally balanced supply and demand associated with a poor diversification amongst competitors, a difficult situation for potential entrants and substitutions that are currently in the development phase. Furthermore, as a consequence to the lacking differentiation there are virtually no switching costs for the buyer but exist chiefly for foreign supplier. The circumstance puts pressure and limits the operation capabilities of market participants in the RoW.

These factors are in direct linkage with China's predominant market position and the prices for rare earths that determine whether foreign producer operate feasible or not. A sudden surge of cheap Chinese REE supplies may cause market prices to fall below the threshold, thus disabling foreign companies to compete on the market profitably. The stimulus threshold cannot be determined at this point because it is different for every country since it depends on several input factors including labor, capital and the quantitative availability of rare earths. Moreover, China's large price influence reflects a permanent potential risk exposure that additionally adds to its competitive market position.

China's supremacy associated with government control, inflow of large investments and well-developed infrastructures in the rare earth market enables the country to dominate strategic value chains. This creates a high entry as well as exit barrier, which put China in the position to realize higher profits relative to its smaller foreign competitors. While this situation is beneficial for China it is associated with an increased risk exposure for both, foreign buyer and supplier. The sum of all individual aspects creates in addition a psychological entry barrier due to the uncertainty of foreign market participants.

A major hurdle that affects all miners worldwide is the processing of rare earths. The extraction process has to be applied to all REE’s irrespective of their market value while the chance exists that each production might not provide higher valued metals. This circumstance creates a reverse economy of scale because the more producers mine the higher the chance of unprofitable results. The possession of several mines, diversified and specialized manufacturing, low production costs associated with a large market share enables China to overcome this hurdle better than its foreign competitors.

A ray of hope for foreign companies is the maturing industry that entails declining growth rates, smaller profits that eventually increase the rivalry over the long-term. The current market development may be considered as an inflection point where disruptions create new opportunities for competitors to become an equal counterforce in the market.

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3.6 The Competitive Strategy

The purpose of this chapter is to present a framework for foreign rare earth market participants to compete against China's leadership. An implementation of the external benchmarking with the airline industry takes place because of the similar market structure. In this comparison the foreign REE producer are compared with the airlines in the aviation industry as stated in Figure 10. The Input factors indicate the upstream- and the output factors the downstream market. The arrow pointing to the top right reflects the desired market condition. Box B represents the greatest chances to make high profits due to the combination of a highly competitive input market and a monopolistic output market. This condition offers high bargaining power since the firm has a large choice of input factors while it is the principal seller in the market where it can determine the price.

Examining the REE market from the perspective of the RoW it can be concluded that it faces a quasi-monopoly led by China in the input market, which comprises the acquisition of labor, REE’s and capital\textsuperscript{273}. Many firms, ranging from steel, green-tech to high-tech applications, dominate the output market, where firms are selling REE containing products. A quasi-monopolistic input market associated with a competitive output market locates the international producer in the center of box C.

The input factors of the airline industry are airplanes, landing rights and pilots. Both, Airbus and Boeing are the two major aircraft producer representing an oligopolistic structure. Most cities have one airport, forcing the airlines to accept the airports terms of condition in order to operate there. Pilots are difficult to replace due to their special education. In addition they are expensive and unionized, therefore reflecting a quasi-monopoly of labor supply\textsuperscript{274}. The output market is characterized by a large group of ticket seller represented by travel agencies and the Internet.

\textsuperscript{274} Ibid.
Customers choose the airline according to the cheapest ticket offered for the given travel dates between two cities\textsuperscript{275}. The output market indicates high competition, which positions the airline industry as well in box C.

The strategic steps that airlines take to enhance their competitiveness in the market is to engage in alliances, which allows them to realize the Code Sharing that involves to share passengers\textsuperscript{276}. Subsequently the competition in the output market is reduced and moves the airlines towards the desired box B. Furthermore, the airlines exchange landing rights, share the pilot and crew trainings as well as place joint airplane orders in order to realize bulk discounts. This measure increases the bargaining power of airlines and gives them some control over the input prices, thus shifting the airlines further towards box B\textsuperscript{277}.

The second competitive situation is amongst short- and long-distance airlines. Short-distance operators fly point-to-point between specific routes that others do not serve. Therefore these airlines have a higher profitability since they are often the only ones flying between certain destinations, thus creating a monopoly supply. In contrast, the long-distance operators are less profitable because of several others that serve the same route. This increases the price competition because the buyers tend to select the one with the best prices\textsuperscript{278}. Therefore these airlines take advantage of the hub-and-spoke strategy. Long-distance airlines share their passengers and thus are able to fill the planes more efficiently\textsuperscript{279}.

The lessons learned from the aviation industry can be applied straightforward to the REE market. In other words, foreign rare earth producer aim for box B as displayed in Figure 10. In order to recapture the necessary value chains, foreign companies should implement the code-sharing operations. The aim should be to develop the vertical integration with main focus on the down-stream operations\textsuperscript{280}. As discovered, the mining operations reflect the very beginning of the entire value chain process. The processes afterwards are associated with very advanced technologies to create the needed property of each rare earth\textsuperscript{281}.

Code Sharing would involve the sharing of production facilities, labor and patents. This could be realized amongst REE companies around the globe and is not limited to a specific location, thus enhancing each firm's capacities and possibilities. Sharing these input factors minimizes the limitations of one company by utilizing the resources of the other partner.

\textsuperscript{276} Ibid.
\textsuperscript{277} Ibid. p.120
\textsuperscript{278} Begg, D. and Ward, D. (2009). p.120
\textsuperscript{279} Ibid.
\textsuperscript{280} Conclusion is based on the findings of the foregoing analysis.
Taking David Ricardo’s theory of comparative advantage into account, each REE producing partner may specialize into that specific area with the most efficient output. This strategy lowers costs, which has positive effects on the prices that foreign firms can offer for their rare earths.

The revenues are determined by the price a company offers for its products while the costs are a result of labor-, capital- and raw material prices. This enables the costs reduction on the one hand and incentivizes closer cooperation due to the mutual interactions on the other hand. Moreover, by appearing as one alliance they influence the market structure and therefore the prices for rare earths. Thus foreign firms can realize economies of scope, hence moving them closer towards box B.

The establishment of a competitive strategy requires actions on international government and corporate level. The agreement on common goals should involve the synchronization of intergovernmental trade arrangements, including import and export relieves as well as raw material policies. Ultimately, the coordination of resources is necessary to create a positive sum game.

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3.7 Economic Consequences Until 2025

According to a McKinsey report from 2013, technological innovations have experienced a rapid development in the past 3 decades\(^{285}\). With further innovations the industries will be able to diversify their product lines and services. In 2025 it is predicted that the global GDP related to the “Internet of Things” will be affected by US$ 36 trillion\(^{286}\).

The vast growing high-tech industry is reflected in the sales figures of smartphones and tablets that have already increased 7 times within the past years\(^{287}\). Nevertheless, the mobile computing devices represent a fractional amount of technologies that utilize the potentials of REE’s.

A shortage of these elements will affect economies, enterprises and consumer from several perspectives. Those interest groups depend on technologies on the daily basis at the workplace and in their private life. Cutting off the supply of critical elements in technologies will disable the innovation process and production of new technologies and the related services. Specifically Japan and the US will experience major impacts, since they count amongst the largest economies globally and consume most of China's REE exports\(^{288}\).

They have a vast interest to invest and further ensure the supply of rare earth metals. Therefore a mitigation of the US’s and Japan’s economy may have disruptive consequences on the global scale. The rare earth elements are key components in nowadays and future innovations. Ranging from the high-tech industry to the green-technologies, all industries are predicted to increase and contribute significantly to the GDP and thus to the wealth of nations\(^{289}\). The shift towards the usage of more REE depending products may result in sales growth but the downside is the increasing need for rare earths.

The scenarios analyzed in the McKinsey report match with the predictions of Mr. Gschneidner, that particularly the downstream REE consumption will grow on average 10 percent annually\(^{290}\). If China continues to determine market prices in the long run, foreign corporations will face a difficult periods to establish feasible supply chains and to meet their own demand.

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\(^{286}\) Ibid. pp.4-5

\(^{287}\) Ibid.


\(^{289}\) Manyika, J., Chui, M., Bughin, J., Dobbs, R., Bisson, P. and Marrs, A. (2013). p.3

4 Conclusion

This thesis examined China's rare earth strategy and the impact on its own market position as well as on foreign institutions. The historical analysis reveals China's competitive strength that is associated with low environmental regulations, government substitutions, low labor costs and a concentration of rare earths. Higher requirements and production costs elsewhere enable thereby China to expand its market leadership in the supply and demand. The implementation of Hotelling's Theory shows that a pure examination of quantitative metrics distorts the outcome of the market evaluation.

Moreover, the five forces analysis uncovers the qualitative characteristics that shape the contemporary market structure. The analysis shows clearly that the price mechanism is the decisive lever for other market factors. Specifically, the stimulus threshold is mostly significant that either encourages or discourages the expansion of activities in the REE market. Besides the price, it is the uncertainty about China's potential actions that could lead to repeated supply shortages in several key industries. This circumstance stimulates alternative and innovative supply approaches in the market as well. Nevertheless, the price as a market-influencing factor is considered as the top parameter.

China possesses up to the present days the strongest price influence and the power to cause far-reaching effects on multiple industries. Therefore it can be concluded that the evidence found in the analysis of the market forces strengthen the affirmation of the thesis question.

China's motivation for its strategic realignment is firstly the consolidation of its REE sector that will be controlled by a few large state-owned enterprises in order to combat illegal mining and unauthorized exports. Secondly, the stronger concentration on its domestic market growth leads additionally to the slowdown of the mining activities in order to ensure a sustainable domestic supply and adequate prices. These measures may be considered as part of China's economic transformation process. The economy of China went through decades of double-digit growth and now is expected to level off at around 7.3 percent.

In fact, Japan and South Korea went through such economic development until they eventually established themselves. Nonetheless, due to the decade-long dependence on China's supply, the sudden reorientation has deleterious consequences particularly for foreign buyers.

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291 Bailey Grasso, V. (2013). p.18
293 Bailey Grasso, V. (2013). p.18
Therefore it can be acknowledged that China's rare earth policies are strategic improvement measures for its domestic sector, yet at the same time disrupts global supply.

The rest of the world realizes that a sustainable supply cannot function through the reliance on one source. Therefore foreign companies focus specifically on the expansion of downstream REE operations. As it has been discovered, the mining itself will not ensure the supply but rather the more strategic and value adding steps including the processing and components production are significant.

The current economic-political condition is insufficient to improve the market environment, which creates a long lead-time that is associated with high capital expenditures. Moreover, primarily high market prices stimulate alternative supply approaches. In order to establish competitive operations, foreign firms have to overcome this mechanism because the REE prices do not remain at a high level as the analysis shows.

**Summarized,** China's strategic refocus impacts global prices and supply of rare earths. This incentivizes institutions with strategic interests in these metals to take advantage of the contemporary market situation. Their chief reason is to ensure steady supply and solid prices for current and future demand. The analysis of the thesis concludes that the question *“Does China’s rare earth strategy disrupt its quasi-monopoly and thereby stimulate innovative supply approaches in the global rare earth market?”* is logically consistent and can be admitted as correct.

Certainly, all attempts to detach from China's supply hegemony open up new opportunities. Deeply interesting remains how foreign institutions will ultimately solve the situation.
5 References


## 6 Appendix

### 6.1 Rare Earths Statistics

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### Notes
1. Price change relative to previous year
2. Mean excluding outlier
3. Output relative to previous year
Appendix | A

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Average in %: 26.88 24.62 4.92 14.95 4.63

Formula for the calculation of the “Output relative to previous year”:

\[
\frac{T_{n-1}}{T} = K
\]

T = unit value of actual year
T_{n-1} = unit value of previous year
K = relativ change to the previous year

Formula for the calculation of the “Price change relative to previous year”:

\[
\frac{P_{n-1}}{P} = P_R
\]

P = price of actual year
P_{n-1} = price of previous year
P_R = relativ price change to the previous year

Formula for the mean:

\[
\frac{(K_1 + K_2 + ... + K_n)}{n} = K_M
\]

K_M = Mean (Average)

Note:

- This statistic is used for Figure 3 (p.10), Figure 4 (p.13), Table 1 (p.11).

Source:

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Note:
- This statistic is primarily used for the visualization of Figure 3 (p.10).

Source:

### 6.3 US Three Month Treasury Bills Interest Rate (Secondary Market)

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**Average in %** 4.19

**Note:**
- Values of the secondary market are chosen, because of the extensive availability of data.
- This statistic is primarily used for the scenario modeling in 2.4 Hotelling’s Theory Of Non-Renewable Resources (pp.22-24).

**Source:**

### 6.4 Market Entrance Characteristics And Entry Level Difficulty

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<tr>
<td><strong>Knowledge/ Technical Requirements</strong></td>
<td>Low to Moderate</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td><strong>Regulatory/ Requirements</strong></td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Moderate</td>
<td>Low to Moderate</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Intellectual Property Entry Barriers</strong></td>
<td>Low</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

#### Translation of Nominal Values into ordinal (scale: 10 - 1)

<table>
<thead>
<tr>
<th>Nominal Value</th>
<th>Ordinal Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>10</td>
</tr>
<tr>
<td>Moderate to High</td>
<td>7.5</td>
</tr>
<tr>
<td>Moderate</td>
<td>5</td>
</tr>
<tr>
<td>Low to Moderate</td>
<td>2.5</td>
</tr>
<tr>
<td>Low</td>
<td>1</td>
</tr>
</tbody>
</table>

Nominal values have been given a numerical value in order to visualize the market entrance characteristics associated with the entrance difficulty level in each stage of the supply chain. This statistic is primarily used for the visualization of Figure 9 (p.43).

#### Nominal Values Table

<table>
<thead>
<tr>
<th></th>
<th>Mining/ Milling/ Concentration</th>
<th>Separation (Oxides)</th>
<th>Metal Making</th>
<th>Alloying/ Powder Production</th>
<th>Magnet Manufacturing</th>
<th>Motors and Generators</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Market Concentration</strong></td>
<td>7.5</td>
<td>7.5</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td><strong>Market Opacity</strong></td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td><strong>Capital Requirements</strong></td>
<td>7.5</td>
<td>10</td>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>Knowledge/ Technical Requirements</strong></td>
<td>2.5</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td><strong>Regulatory/ Requirements</strong></td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>2.5</td>
<td>1</td>
</tr>
<tr>
<td><strong>Intellectual Property Entry Barrier</strong></td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>10</td>
<td>10</td>
<td>1</td>
</tr>
</tbody>
</table>

**Note:**
- This statistic is primarily used for the visualization of Figure 9 (p.43).

**Source:**

6.5 Declaration Of Originality (Eigenständigkeitserklärung)

Die Arbeit muss folgende, unterzeichnete Erklärung enthalten:

Eigenständigkeitserklärung


Ort/Datum: ........................................................................................................

Unterschrift: ........................................................................................................