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MINING IN A WORLD OF INNOVATION

October 18-21, 2016 • Rio de Janeiro /RJ • Brazil

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MINERAL ECONOMICS

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Vale Institute of Technology

Created in 2009 with the purpose of stimulating innovation, competitiveness and sustainability in Vale's operations, Vale Institute of Technology (ITV) is a non-profit organization that develops research activities, with emphasis on H2 and H3 horizons as well as training of resources human at post-graduate level. ITV has two locations: one in Belém in the State of Pará, focused on matters related to Sustainable Development, and the other in Ouro Preto, MG, dedicated to Mining and Mineral processing topics.

At the ITV unit in Belém, Vale has been offering a *Master's Degree Program in the Sustainable Use of Natural Resources in Tropical Regions* since 2012. This is a unprecedented initiative in Brazil as it is the first course offered in conjunction with a company from the mineral sector to obtain certification from the Coordination for the Improvement of Higher Education Personnel (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Capes), of the Ministry of Education.

In Minas Gerais, ITV launched a pioneering partnership with Universidade Federal de Ouro Preto (UFOP) to structure the *Master's Degree Course in Instrumentation, Control and Mining Process Systems, and Master's Degree Course in Mineral Engineering*. This course has been approved by Capes in 2015 and classes began in 2016. Another innovative partnership that has been being developed is with the ISPT-Instituto Superior Profissional de Tete, Mozambique, consisting in the offer of courses for the Master's Degree Program in Mining at ISPT. These courses are supported financially and operationally by Vale and Capes.

ITV also provides Specialization courses in Mining for Vale's employees and other courses for professional qualification, as well as research activities comprising levels from scientific research to post-doctoral degree.

Luiz Mello

In partnership with Capes, Vale offers academic postdoctoral scholarships for Brazilians and foreigners to researchers who are selected to work at Vale Institute of Technology units, further bringing together the academic community and Vale, expanding the potential generation of innovation and wealth for Vale and Brazil.

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It is a pleasure for us to participate in the 24th edition of the World Mining Congress - WMC 2016, being held for the first time in Brazil, and we can introduce you to some of the technological, research and innovation solutions in the Mining Sector. It is our commitment to share knowledge, innovation and technology towards the sustainable development of the operations and processes in global mining.

I hope that everyone enjoys the most of the World Mining Congress!

Luiz Mello
CEO of Vale Institute of Technology
Technology and Innovation Executive Manager of Vale

José Fernando Coura

On behalf of the Brazilian Mining Association - IBRAM and its associates, I would like to offer a warm welcome to all the participants of the 24th edition of the World Mining Congress - WMC 2016. This is the first time that the WMC, recognized as one of the most important world mining events, is being held in Brazil. The central theme of this congress is "Mining in a World of Innovation", one of the most current and important issues in the management of mining-sector businesses.

The 24th WMC began to take shape in 2012 when representatives from businesses and entities of the mining sector, as well as the Brazilian government, joined forces to support the country's bid, before the International Organizing Committee, to host the congress (IOC). This was well-deserved, given Brazil is one of the international exponents of mining.

The presentation of the Brazilian bid was made by IBRAM's presidency in conjunction with our Director of Mineral Issues, Marcelo Ribeiro Tunes. It fell to him to deliver the speech underlining the qualities that make IBRAM suitable to organize such an event, of the city of Rio de Janeiro (RJ) to attract and host event participants, and the Brazilian mining industry; factors which proved decisive in convincing the IOC members to choose Brazil as the host of the event in 2016.

With this significant vote of confidence, we are certain that the 2016 WMC will be the stage of an intense diffusion of knowledge, of discussions on the best way forward, and deep analyses of the current and future landscape of the mining industry. Without a doubt, it will also serve as a way to strengthen relationships and enable dialogue between the most diverse actors of the sector's extensive production chain on an international level.

We know that the last few years have been challenging for the mining industry and "innovation" is the key word for new business and the future of the sector itself. The economic environment has altered the rhythm of supply and demand, impacting ore prices and making it more difficult for mining companies to outline their next steps both locally and globally. Nevertheless, this moment offers an opportunity for mining to lay the way for a return to greater productivity in the future.

This is the proposal of the 24th edition of the WMC, amongst others. We also intend to technically and scientifically promote and support cooperation to develop more stages in the sustainable development of operations and processes in the mining sector.

With an optimistic vision of the prospects of the mineral sector, I hope that IBRAM, via this grand event, can awaken the public interest to debate the future of mining and identify innovative actions to further strengthen the mining industry around the world.

We wish everybody an excellent World Mining Congress!

José Fernando Coura
CEO of the Brazilian Mining Institute

Murilo Ferreira

Brazil has a historic vocation for mineral extraction activities, and since the mid-18th century they have practically dominated the dynamics of its economy. Rich in world-class minerals, the country has emerged as one of the leading global players in the mining industry, and it is now the second largest iron ore producer and one of the most significant agents in international trading and exports of this commodity.

The mining industry has become one of the most important pillars of Brazil's development. Despite the decline in iron ore prices and demand in the international markets, especially due to the slowdown in Chinese consumption, and despite the end of the super-cycle, the mining sector has continued to play a key role in maintaining Brazil's balance of trade surplus.

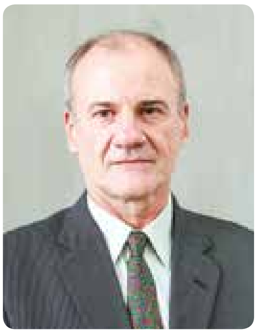
In addition to its positive impacts in the macroeconomic sphere in Brazil, mining has also become a driver of social development, particularly as it has a multiplier effect on other economic activities, contributing to the expansion of various production chains and consequently to the generation of jobs and income. It is noteworthy that in the municipalities where mining companies operate, Human Development Index ratings have been higher than the average figures for their respective states, and much higher than in non-mining municipalities.

In a country like Brazil, whose economic growth, as already mentioned, is strongly dependent upon the expansion of mining activities, the creation of the Brazilian Mining Association, which will turn 40 in December, was essential and absolutely necessary. This is a date to be celebrated, above all because IBRAM has played its role to support and strengthen mining activities with dynamism, efficiency and innovative practices. The sector's companies and organizations can count on a body that assertively and competently represents, coordinates and integrates them, defending their interests and generating conditions conducive to the sustainable development and competitiveness of their businesses.

The holding in Brazil of the 24th edition of the World Mining Congress, organized by an entity of IBRAM's quality, is a milestone and an excellent opportunity for the sector to share ideas, discuss, reflect and find stimuli and feasible ways forward at a time when we need to face the end of the mining super-cycle. The theme of the Congress could not be more appropriate, and I am sure that by its end, promising directions will have been mapped to strengthen the mining industry across the world.

Murilo Ferreira
Chief Executive Officer, Vale S.A.

Professor Jair Carlos Koppe



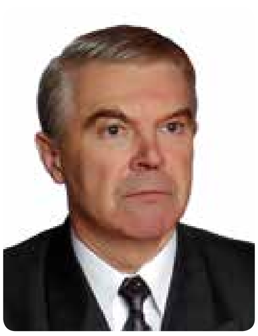
Mining has been extremely important to the World's economic growth and prosperity for centuries. The mining industry is currently facing an economic and social crises that can impact strongly the mineral production and productivity. In this scenario several challenges must be addressed, among them complex mineral deposits of low grades, water, social and environmental issues as well as declining commodity prices. Considering that the world is changing dramatically in all aspects this is the moment for innovation in mining. The WMC 2016 is under the umbrella of Mining in a World of Innovation in the proper moment. This is a nice opportunity to change our ways in mining technology considering the new evolving technologies such as automation, sensors, cloud computing, data analytics that can increase the mining production and efficiency in the entire value chain. Let's take this moment to spread our experience among academy, industries, practitioners and professionals of the mining sector focusing in the future of a world in constantly innovation.

We would like to thanks all the contributions done by the authors invited speakers and participation of delegates that will make WMC 2016 a very successful meeting. Special thanks to the members of the Scientific Committees that helped in the paper analysis ensuring the quality of the conference.

Welcome to the WMC 2016.

Professor Jair Carlos Koppe
Congress Chairperson

Józef Dubiński



Hermínio Oliveira

The 24th World Mining Congress is one of the most important mining events worldwide and is going to be held in Rio de Janeiro, Brazil, from October 18 to 21, 2016. The premiere of the World Mining Congress took place 58 years ago, in September 1958, in Warsaw, Poland. Currently, the WMC organization gathers 45 mining nations from all over the world.

Each World Mining Congress, which takes place in a different host-nation, is always a great mining occasion for the international community that represents science and industry figures involved in the exploration of mineral assets. We can assert that this congress points to the most significant directions for global mining development and determines priorities for the activities of all institutions related to mineral activity. The same approach is going to be adopted during the 24th World Mining Congress, which is going to concentrate on the theme of "Mining in a World of Innovation". Nowadays, and increasing number of countries hold great knowledge potential on mining. The challenges aforementioned demand mutual cooperation, exchange of technical knowledge and professional experience, as well as assistance to those in need. Personally, I believe that our generation of the world mining society – the heirs of our illustrious ancestors – will follow their accomplishments and guide the organization of the World Mining Congress into a new direction, to assure many more years of effective services to global mining and to the people who have taken part in this challenging activity, yet still necessary for all humankind.

Józef Dubiński
Professor and Doctor of Engineering
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Summary

ASSESSMENT OF THE OPTIMUM LEVEL OF PARTICIPATION IN MINING PROJECTS WHICH ARE SUSCEPTIBLE TO RISKS AND UNCERTAINTIES

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ASSESSMENT OF THE OPTIMUM LEVEL OF PARTICIPATION IN MINING PROJECTS WHICH ARE SUSCEPTIBLE TO RISKS AND UNCERTAINTIES.

ABSTRACT

By and large, mining projects involve uncertainties and risks, and also require huge investments, which can consume the entire budget of a company. In this context, creating partnerships can make these projects execution easier. In this study the optimal level of participation of a granite mining project was assessed. The project presents the risk of financial losses due to uncertainties related to the initial investment, the selling price and cost of of mineral production. The uncertainties were measured through Monte Carlo simulation to get the project risk. In such case, the optimal level of participation in the project is determined by maximizing the utility function. The obtained results show that the creation of partnerships can help the project accomplishment and may not require all the company's budget and consequently allowing for new investments.

KEYWORDS

Mining projects. Uncertainties. Risks. Partnerships. Financial Participation level.

INTRODUCTION

The Brazilian extractive mining industry is of great importance. After all, it accounted for 4.0% of GDP in 2013, which amounted to R$168,244 million. Add to this that 23.7% of the Brazilian exports in that year were primary mineral goods, justifying the heavy investments in sector (DNPM, 2014 - Departamento Nacional da Produção Mineral). In order to get a more accurate picture and confirmation of these reported statements, the Brazilian Institute of Mining states that between 2012 and 2016 about US$ 75 billion will be invested in the mineral industry (ALONSO, 2013).

The need for high investments is amongst the most important particularities of mining projects, which can consume the entire budget of a company. In addition, there are uncertainties in relation to production costs and selling price of mineral commodities, which imply risks of financial losses. In order to minimize them, Lima and Sulisk (2007) recommend the formation of partnerships (joint ventures) with other companies. Thus, the cash flow of each partner will be proportional to their level of participation in the project (MARGUERON, 2003).

Considering the risks and uncertainties, the challenge is to estimate what should be the optimum level participation in these projects. Souza (2005) points out that the adoption of economic valuation models based on Discounted Cash Flow (DCF) is not recommended in these circumstances because it does not capture the uncertainty of projects. Therefore, the author suggests models based on the utility theory, in which the risks and the manager's features can be incorporated.

In this context, the purpose of this study is to evaluate the optimal level of participation in mining projects subjected to uncertainties and risks, carried out through joint ventures. Specifically, the uncertainties and the risk of a granite mining project are submitted to a test model in order to determine the optimal level of participation in this business venture so to maximize its expected utility from a decision maker.

Besides this introduction, this article has four sections. the second one focuses on the characteristics of the based models on cash flow discounting and utility theory. In section three the methodological procedures to be used are presented. The discussion is conducted in section four. Finally, in section five, the final considerations are made.

THEORETICAL REFERENTIAL

Economic analysis of projects using the Discounted Cash Flow model

The main model of investment analysis is Discounted Cash Flow (DCF), defined as:

> [...] The difference between all annual cash inputs (operational revenue, non-operational revenues related to salvage value or residual value, working capital recovery, entry of third party funds, etc.) and all annual cash outflow (fixed investments, working capital injection, acquisition of mining rights, start up costs, costs of replacement and repair of equipment and other assets related to those fixed assets, tax payments, amortization and financing interest, etc. .) (SOUZA, 2005, p. 8 e 9).

In the analysis, most commonly used indicators are: net present value (NPV), Internal Rate of Return (IRR) and Payback. The NPV is the conversion of flow cash (FC) distributed over time (n) into an equivalent value at time zero, or present value (I) (FERREIRA, 2009). That is, the NPV is the difference between the values present at a rate (r) disconted, and the initial investment (SOUZA, 2005):

$$NPV = \sum_{t=1}^{t} \frac{FCt}{(1+r)^t} - I \qquad (1)$$

This way, projects with NPV greater than zero should be accepted. On the other hand, if the NPV is less than zero, they should be refused. If the NPV is equal to zero, the decision to invest in the projects is indifferent. (LIMA; SUSLICK, 2007).

The IRR of a project is the discount rate that equates the values of the future value of flow cash to the initial investment. In this case, the decision to investment in a project should be only if IRR is greater than a minimum acceptable rate of return (MARR) (PENEDO, 2005).

$$\sum_{t=1}^{t} \frac{FCt}{(1+IRR)^t} = I \qquad (2)$$

In its turn, the payback period indicates the number of periods (years, months, etc.) required to recover the expenses generated for the implementation of the project (FONTES, 2014). According to Souza (2005), by employing this method, the most viable project is the one which presents lower payback in relation to a deadline set by the manager.

Economic analysis of projects using the theory of choice under uncertainty

The presence of uncertainty in projects disqualifies the investment decision using models based on discounted flow cash. Therefore, the literature suggests the use of models based on utility theory (choice under uncertainty) (BARBOZA, 2005), incorporates the risks and the manager preferences for them: aversion, neutrality or propensity. According Margueron (2003, p. 35), “[...] quantification is performed by associating an abstract utility value for each of the possible situations.” (MARGUERON, 2003, p.35).

In this regard, the Utility of Expected Value (VEU) and Expected Monetary Value (VME) are tools that define the investor's preference on a choice and if the investment should be abandoned or not. (MARGUERON, 2003).

The utility function is used as the most appropriate for expressing a preference from the decision maker. Algebraically, the exponential utility function is more appropriate for facilitating the modeling of risk aversion coefficient (MARGUERON, 2003). The aversion coefficient will be given by the monetary portion, venture capital, the investors are willing to lose, so to conceptualize the risk tolerance.

The probability (P_i) of the occurrence of risk, regarding risk tolerance (c) may represent the willingness to abandon the project, and the amount accepted by the investor to give up his purchase and guarantee free amount of risk is called the certainty equivalent (NEPOMUCENO FILHO, SUSLICK, 2000).

$$EqC = -\frac{1}{c} * \ln[p1 * e^{-c*NPV1} + e^{-c*NPV2}] \qquad (3)$$

> The certainty equivalent of the optimum level of participation depends on the level of investment given by the investor's risk tolerance. the risk tolerance levels may vary [...] to assess the level of optimized investment and their participation in the project. (BARBOZA, 2005, p.12).

In order to maximize the certainty equivalent, investors strategically decide for creating joint ventures, in which the cash flow is divided among participants in proportion to their Financial Participation Level (FPL) in the enterprise. To determine the optimal FPL we should Maximaze the EqC:

$$Max: Eqc = -\frac{1}{c} * \ln[\sum_{i=1}^{n} Pi * e^{-FPL*NPV*c}] \qquad (4)$$
$$Limited\ to: FPL \leq FPL\ maximum$$

METHODOLOGY

As mentioned in the introductory section, this research intended to assess the optimal level of participation in a granite mining project which is susceptible to uncertainty and risk. In this way, it is an applied, quantitative and predictive research which takes into consideration the classification proposed by Ganga (2012).

Data were collected from an Economic Exploitation Plan presented by a mining company in the state of Minas Gerais to the National Department of Mineral Production (DNPM), which is the federal entity responsible for analyzing the economic feasibility of extraction projects, as well as processing and marketing of mineral reserves. It is noteworthy that, according to Article 38, chapter VII of the Mining Code. - Decree-Law No. 227 of February 28, 1967, it is mandatory the presentation of an Economic Exploitation Plan to require the mining of any mineral substance. In order to protect the confidentiality of the company, some data were changed. However, it does not harm the effectiveness of the applied methodology.

In order to obtain the economic viability of the project indicators (NPV, IRR and payback), Microsoft Excel financial functions were used. The uncertainty modeling was made with the software @RISK student version, which works in integration with Excel. 10,000 iterations were performed so that the investment, the sale price and the production costs were admitted as stochastic variables.

Then, the risk of the project was achieved, ie, the probability of loss financial (NPV lower than zero). Finally, through the Excel Solver tool the Financial Participation level (FPL) that maximizes the expected utility of the project was determined.

ANALYSIS AND RESULTS DEMONSTRATION

Analysis of the economic viability indicators

Table 1 highlights the design parameters considered in the analysis of economic viability:

Table 1- project parameters

Parameters	Value
Investment (non-recoverable)	R$5,000,000.00
Mineable Reserve	7,500 tons
Useful life	5 years
Extraction rate	1,500 tonnes/year
Sale price	R$1,000.00/ton
Variable Costs	R$300,000.00
Depreciation	20%
Income tax	15.00%
MRA (Selic Rate)	14.25% p.a.

Source: Produced by the author from the altered data in the PAE project and the adjustment of probability distribution (2015).

Table 2 shows the cash flow of the project. It’s considere that the NPV is positive, indicating that this project is feasible. This is confirmed by its IRR, (22.64% p.a.) which is greater than the MRA. In this scenario, the simple *payback* of the project is 3.82 years and discounted payback, 4.92 years.

Table 2 - project cash flow in thousands of Reais.

Year	0	1	2	3	4	5
Investment	-5,000.00					
Price		1.00	1.00	1.00	1.00	1.00
Annual revenue		1,500.00	1,500.00	1,500.00	1,500.00	1,500.00
Fixed operating cost		400.00	400.00	400.00	400.00	400.00
Variable operating cost		300.00	300.00	300.00	300.00	300.00
Profit before taxes		800.00	800.00	800.00	800.00	800.00
Before-tax cash flow	-5,000.00	1,200. 00	1,200.00	1,200.00	1,200.00	1,200.00
Depreciation		1,000.00	1,000.00	1,000.00	1,000.00	1,000.00
Taxable Profit		200.00	200.00	200.00	200.00	200.00
Income tax		30.00	30.00	30.00	30.00	30.00
Profit after the taxes		770.00	770.00	770.00	770.00	770.00
After-tax cash flow	-5,000.00	1,770.00	1,770.00	1,770.00	1,770.00	1,770.00
Discounted after-tax cash flow	-5,000.00	1,549.234	1,356.003	1,186.874	1,038.839	909.268

Source: Produced by the author (2015)

However, the uncertainty of variables influenced directly the value of NPV. Thus, it was considered the uncertainties shown in table 3.

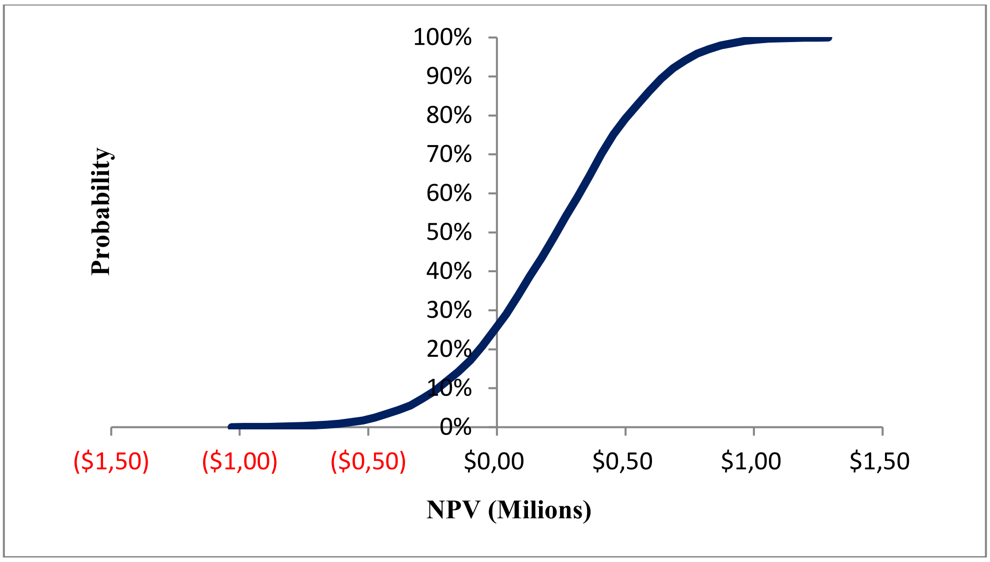
Table 3 - uncertainties in cash flow

Risk factor	Distribution	Minimum	More Likely	Maximum
Investment	Triangular	R$ 4,500,000.00	R$ 5,000,000.00	R$ 6,000,000.00

Granite price	Triangular	R$ 600.00	R$ 1,000.00	R$ 1,100.00
Variable cost	Triangular	R$ 90,000.00	R$ 300,000.00	R$ 800,000.00

Source: Produced by the author (2015).

Consequently, the NPV of the project has no single value, but a probability distribution in which the cumulative value is illustrated in graph 1. So, considering the probability of negative NPV, the risk of the project is 25,74%. In this case, the financial loss is R$ 216,968.63, on average whereas in viable scenarios, the NPV is of R$ 369,843.06.



Source: Produced by the author (2015).

Chart 1- Frequency distribution of NPV

Assessment of optimal level of financial Participation

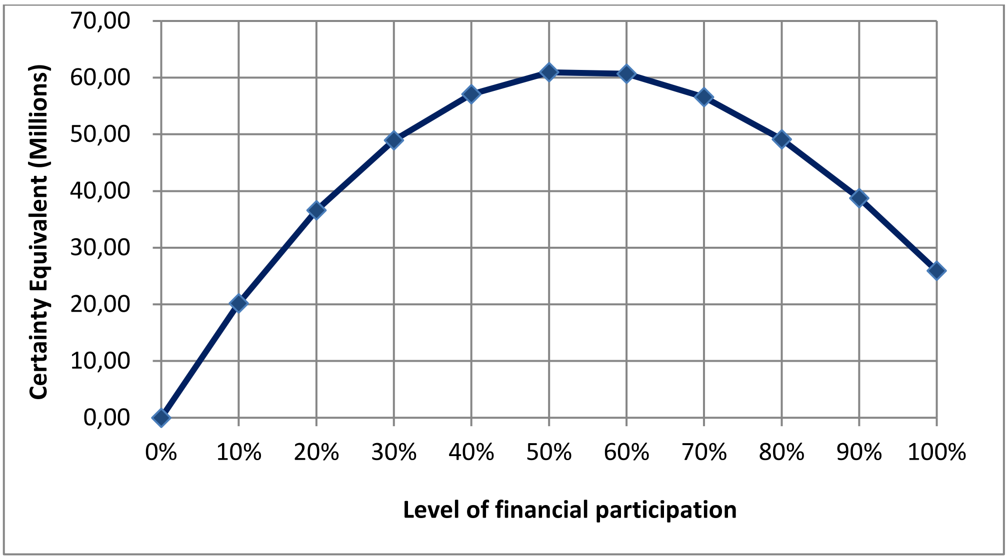
In this stage the project optimal level of financial Participation was determined. Assuming the company has R$4,000,000.00 to invest, which is not enough to required R$5,000,000.00 in order to accomplish the project. It was considered that there is no interest in taking out loan from third parties, which indicates that a partnership should be created to implement the project. The company will have maximum participation of 80% in the business. The parameters considered in this analysis are shown in table 4.

Table 4 - parameters of the analysis for the optimal level of financial participation.

Parameters	Value
Investment	R$ 5,000,000.00
Average NPV (failure)	R$-216,968.63
p (failure)	25.74%
Average NPV (success)	R$ 369,843.06
p (success)	74.26%
Budget	R$ 4,000,000.00
Coefficient of risk tolerance	0.05
Risk tolerance	R$ 200,000.00
Maximum level of financial participation	80%

Source: Prepared by the author (2015).

Chart 2 illustrates the impact of the level of financial participation on the EqC. Note that the value of the EqC assumes maximum value when the level of financial participation is between 50 and 60%.



Source: Drawn by the author (2015).

Chart 2 - The susceptibility of the certainty equivalent regarding the level of financial participation.

In fact, by solving the problem of optimization of the EqC, it was found that the level of financial participation equal to 54.29% maximizes it. That means the company must finance 54.29% of the project, which represents R$ 2,714,418.05. The company is expected to get the same NPV percentage from the project: R$ 118,781.70. These results indicate that in the formation of the joint venture the company shouldn't employ all available investment budget.

FINAL CONSIDERATIONS

In this study we assessed the optimal level of participation in a granite mining project which is susceptible to risks and uncertainties, implemented through joint venture model. It is considered the initial investment, the sales price and the cost of production of the mineral as if they were uncertainties, which involved risks of financial losses.

The investment is feasible, analyzed by the discounted cash flow (DCF) model, with positive NPV and IRR greater than MRA. However, probabilistic distributions of uncertainty factors prevent a fixed VPL value, showing, by means of simulation, high standard deviation, which makes the project susceptible to failure. The utility theory incorporates the risks and uncertainties in their analysis, being possible to calculate the level of financial participation in a partnership, does not need the investment of any budget.

The results suggest that incorporate risk factors and uncertainty in projects is a risk aversion strategy that allows for reliability under decision-making. The method of evaluation through DCF presents limitations when it comes to uncertainties and risks, which are incorporated by the utility theory. The strategic formation of a joint venture, allows investments that are considered risky made possible by the Division of cash flows in proportion to the level of financial participation each one has.

The establishment of the optimal level of participation on multiple projects susceptible to uncertainties and risks is an interesting suggestion of continuity for this research, especially because it did not show how part of uninvested budget should be applied.

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BRAZILIAN MINING INDUSTRY IN CRISIS TIMES

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ABSTRACT

The mining companies was worried with your economic health more and more, however, what is observed in the mining industry history is the difficulty that these companies face to admit the external economic impact both in the market that they are inserted and in the country that they are allocated in economic deficit period. The Brazilian mining industry is not distant from this reality, including many small and medium companies facing the economic crisis as a factor of unenforceability to a profitable deal, once they not apply the vantages for a competitive survivor. Understanding the problems, this article propose to compare activities from mining companies in crisis time. This article proposes to explain, based on the literature, the collapses that have affected the mining industry in the Brazil and their particularities. Differentiating the collapses by their origins, be it economic, environmental or legislative, therefore to reference the mitigating reactions to lessen the external impact caused by the environment received for the mining companies in periods of local economics uncertainly, denoting key competitiveness measures in hard times, since internal actions, such as financial, technologic, environmental and human resources management, to external actions, such as corporative marketing and governance.

KEYWORDS

Crisis, competitiveness, mining industry.

INTRODUCTION

The humanity is very dependent on natural resources, especially mineral resources. This dependence emerged with the advances and latest technologic products and minerals are an essential input for the manufacture of technological goods. The evolution of social structures was only possible because people knew how to use their environment and create tools that would improve their lifestyle, in addition with the technologic organization engagement; the natural resources became the base of a social and economic political structure, with the commodities. However, due to recurring failures of the economics system, even, for monitoring the global trend of economic cycles evolution, the crisis arises. These follow the primary activity, in this case, mining, in the origin of the productive activity and after, commercial, in other words, reaching significant part of the sphere of influence activity.

To understand why the influences of crisis and its various forms of occurrence is indispensable of its state of art. Propositions of Schumpeterian model about crisis explicit that they are a process by which the economy adjust to new conditions, which in fact is rating as an influence parameter for the crisis in the mining sector across the board. Worth mentioning, evidently which are not only a turning point for economic adjustment, but as stated Lerbinger (2012) that seen in the media about natural disasters, epidemics, technological mishaps, human conflicts and fault managements, and when these events are severe and threaten vital values, that comes as vectors crisis.

The same Lerbinger (2012) in his book “The Crisis Manager” mentions that term “crisis” is incorporated in everyday vocabulary. The author exemplifies saying that more people using “I have a crisis” instead of using “I have a problem”, because it seems that the problems today are more difficult to deal with. In the view of scientific researching, the crisis reached autonomy as individual object of analysis in 1960s after the numerous crisis that affected the social environment (Brecher, 1993). In this sense, Polo (2007) states in the ancient Greek, the word *krisis* reported etymologically the notion of “judgment and “decision”, in the sense of defining moment.

The Brazilian mining industry since its formation in the colonization went through periods of expansion and contraction. The Brazilian colonization started with the search for natural resources that their territory had, around 1590; the territory already had gold deposits exploited by their metropolis, Portugal. In the next century to the discovery, several expeditions to the mineral exploration and territorial expansion was carried out, which led to Brazil in the eighteenth century, an economic cycle dependent on mining, the gold cycle, occurred in the states of Minas Gerais, Goiás, São Paulo and Paraná. For Pinto (1987) and Guimarães (1981) in the period from 1752 to 1787 were extracted about 425000 kg of gold. In contrast, between 1788 and 1801 there was a sharp decrease to an estimated production to 80000 kg, resulting in the first Brazilian mining crisis, caused by the overlapping of economic cycles at the time the direction of the metropolis to the production of other products. In the same period, there was the diamond cycle; therefore, were two peaks, the 1730-1829 peak and the 1850-1889 peak, and the period between 130 and 1829 stood out as the largest colonial production, reaching the peak of 70018,8 carats in 1780 (Lins et al., 2000).

After this rich period on Brazilian history, mining was in a secondary plan, too much because of other economic cycles, as mentioned, those that were conducted by the influence of external economic policy and resource depletion. Mining returned to get significant investments, almost half a century after the last peak, even in the late nineteenth century have been implemented several schools for the training of professionals in mining. However, these investments occur only in the late 1930s, as has Gauld (1964) with the Estado Novo of Getúlio Vargas, who proposed the nationalization of companies creating the Companhia Vale do Rio Doce (CVRD, current Vale S.A.) and the Companhia Siderúrgica Nacional (CSN), strengthening the mining of iron and the steel production, and consequently the base industry and mineral processing of the Brazil. Starting as of, in the 1960s and 1970s, the Brazilian mineral exploration lived its peak with creation the Mining Code in force today, which regulates the use of schemes of mineral substances, as well as the discovery of numerous mineral wealth, most notably the discovery of iron deposit in Carajás, in state of Pará. In this way, the starting point was given to the importance of mining in the Brazilian economy, activity that now occupies about 25% of Brazilian GPD, and that the mineral or steel activity.

At the end of the 1980s, the Brazilian production and mining expansion was withdrawn, much due to the successive crisis that have occurred on the oil market. This decade has been attributed to an increase in price of crude oil barrel, in 1978 from US$9.00 to US$ 31.77 in 1981, according to the US Energy Information Administration. The Brazilian economy is another problem to the mining, which in the 1980s, according to the Índice Geral de Preços- Disponibilidade Interna (IGP-DI, General Index of Prices-Internal Availability), was 211.0% in 1983 to 1789.9% in 1989, resulting in a period of crisis and slowdown of investments, without the presence of capital for investment, whether domestic or foreign. However, the 1990s was even more critical because, although there is a revitalization plan for national economy and the recovery of global mining, the mineral area was without skilled labour, requiring a new excess work force offer and emptying the skills needed to work in the area. Only in the 2000s, it was that necessary quota has been supplied, because the graduate system housed most of the employees in which the qualifications was a real need (Furtado & Urias, 2013).

Since the beginning of the history of Brazilian mineral industry, environmental, legal, economics, financial and political (governmental) crisis have affected the progress of the activity in the country. Mainly the small and medium-sized businesses reaction to system changes, that is, crisis are unlikely and often cause the premature closure of the project. The large mining companies, likewise, are impacted by the difficult inherent in periods of crisis are not unlike those faced by smaller companies, these impediments arise because the crisis may present as cost increase factor, unenforceability of decrease in profits, damage in the company's image and operation of the enterprise. Today, no different from the history of mining industry of the country, the faced reality is considered crisis. The convergence of crisis scenarios carries one of the biggest collapses that Brazilian mining has faced and to understand what are the effects suffered by companies in each type of crisis is necessary to discuss, based on the literature and documentary collection, the behaviour of companies in crisis time, in order to obtain the related effects. Therefore, the objective is to explain the particularities of the collapse that has affected the mineral industry, comparing the sanctions and refer the mitigating reactions to the improvement of incoming changes by the external environment change stimulus mining activity, as well as expose the competitiveness measures in turbulent periods.

DISCUSSIONS

Particularities of Crisis Scenarios

By way of vectors multiplicities existence of crises and their respective influences, the current study analyzes The Brazilian mining industry in an three allied optics with the main incentives, methods, and promoting the competitiveness in times of crisis, being them: economic and financial with the comparison between statements of income, value of the shares performance of the major companies and credit availability; environmental, with case reports of impact of environmental disasters and the need for investment in safety and environmental quality; and finally, the legal with the display table comparing tax burden of the sector with other countries and in Brazil between different segments, Compensação Financeira pela Exploração de Recursos Minerais (Compensation rates for Mineral Resources Exploration, CFEM - DNPM), licenses and legal concession regimes and policies legal incentive mining..

Economic Financial Scenario

An economic financial scenario can be observed from different points of view. In traditional Marxist theory, economic crisis is defined as the interruption of capital accumulation (Fine, 1975). Already the monetarist Friedman and Schwartz (1963) connect the financial crisis to banking panics. They emphasize the importance of bank panics because of their perceptions that these are important sources of contracts which, in turn, lead severe signings in the global economic aggregate. In the opposite position, Kindelberger (1978) and Minsky (1970) have a much broader view of the subject. Affirming that financial crises involve sharp declines in asset prices, large business failures, whether financial or non-financial, deflation or inflation, disruptions in foreign stock market or a combination of these factors. Mishkin (1992) points out that the financial crisis is the perturbation of the financial markets in which adverse selection and moral hazard are problems that become increasingly worse, so that the financial market is unable to efficiently channel for those who have the most opportunities for productive investment. A financial crisis results in the inability of the financial market work efficiently, which leads to a sharp contraction in economic activity.

According to Pastore & Pinotti (2008), in the 2008 crisis, Brazil has not experienced, directly, strong impacts, due to the previous global growth that raised the prices on the international commodities market, also benefiting from China's economic growth, so that the balance Brazil's trade surplus position presented an performance with export increase, which created a stable economic environment for mining companies to work with commodities and attracted foreign investment and boosted fundraising for these companies (Abe, 2011). The Brazilian economic reality has suffered direct impacts from the 2008 crisis, as shown in Figure 1, interrupting a continuous growth sequence where, until the month of May the index of BM&F Bovespa was experiencing a sequence of continuous growth, however, affected by the impact arising from the crisis of the US housing bubble, between March and November of the same year there was a decline of 57% representing a loss of more than 40,000 points, thus being considered as the biggest decline demonstrated in the time series below.

Figure 1 - 2008 crisis: the decay of BM&F Bovespa Index (Google Indexer, 2016)

However, the question of greater value to this work can be seen in Figure 2 represents the absorption of the impact of the global crisis on the main company in the Brazilian mineral sector, in this case in particular it is observed that the value of the preferred shares of Vale S. A. got the same behavior that the Index of

BM&F Bovespa during the same time cut, further highlighting the fall with a decrease of 64.6% when going from the most high - R $ 64.62 - the amount of R $ 20.75 (this value, May 2016).

Figure 2 - 2008 Crisis: Drop value of preferred shares of Vale S. A. (Google Indexer, 2016)

When facing a crisis of this size immediate solutions such as cutting staff, mandatory vacations or reduced investment, can be taken as extreme mitigation measures. However, in these times should invest in solutions that reduce losses and optimize the results as the use of equipment (conveyor belts, renewable energy) and techniques (process reengineering, quality systems) more efficient or energy self-sustaining, fostering innovation to develop solutions (reward systems), zero waste awareness (5S program) and search for substitute products or new entrants to the market (increase marketshare).

Environmental Scenario

Although there regulatory measures imposed to operate in the environment, in the extractive nature, mining is itself cause environmental impacts. Since the initial phase of mining research until the final stage mine closure, in fact, mining induces liabilities and impacts on the environment by managing natural resources. In the recent period, there is the appreciation of environmental issues in the corporate segment, given the new legal requirements, market and society in general. The economic approach, before leading the planning, are being replaced by a broader concept of sustainable development, in which the growth targets are associated with efforts to reduce the harmful effects on environment (Strobel et al., 2004).

With intense environmental requirement promoted by frequent conferences and agendas for reducing environmental impact, concerns for the image of the mining company and its product is increasingly becoming a central issue in the integrated planning of the company's productivity. Silva (2007) reports six types of consequence left by mining in the environment. The landscape degradation by removal of native forest and movement of large amounts of soil; emission of noise and vibration, by means of machinery, equipment and blasting; vehicle traffic, spreading tailings and deteriorate the quality of soil and highways; frequent emissions of dust and gases as surplus and unused materials; water contamination, both in the improper disposal derived from mineral processing and in the production rejects that may contaminate soil, rivers and groundwater; and, finally, waste and waste: there may be leakages of irregular storage.

The disposal of waste in piles and retention of waste made by perimeter dikes that were once solutions to the bus natural drainage basins, as mentioned Sánchez (2015), now presents itself as a major risk to the formation of liabilities. In the last thirty years in Brazil, at least five disasters caused significant changes to environmental integrity of ecosystems related to the rupture of dams, as can be seen in Table 1. Not only that the damage caused to the environment by mining involved, serious damage will set of mining companies in the image are imminent. Recently, in 2015, with the breaking of the Fundão dam, which received iron mine beneficiation tailings belonging to Samarco Mineração SA brought an environmental order crisis, further aggravating the fragile mineral legislation, even with the recent bodying in National environmental Policy and resolutions, remaining in Brazil and environmental inspections applicable to federal agencies now impractical, the huge number of the needs of mining companies in relation to the environment and the attention of the media and society before the cases of mining.

By means of situations of closure risks of mineral projects, that is a deadline for losses to environmental means for Gonzaga (2005) analysis of environmental impacts and studies for the proper implementation of mitigation sustainable practices are reasonable and can elevate the concepts of mining in the social aspects, and especially to the stakeholders. In short, sustainability is positioned as a marketing strategy and competitive advantage.

Kuhndt (2004) defines the sustainability information for the managerial levels of a company, in this case, can also be applied by the mining companies need to present their activities. At the strategic level, for the strategic planning are needed the development of corporate policies, research strategies and Developing and investment in new technologies with sustainable production lines. At the tactical level: development of products, processes and services at different levels of improvement for sustainable performance. Finally, at the operational level, in communication and marketing are necessary: the decision of marketing of the product and cleaner production, and sustainability reporting for external communication; already in operational management: internal monitoring, prioritization of management opportunities, compliance with regulations, sustainable management and auditing, benchmarking and management of the chain and product portfolio are examples where decisions on sustainability information promote the company.

Table 1 - Major environmental disasters and liabilities associated with Brazilian mining activity

Occurrence	Accident and Place	Socio-environmental Impacts
1984	Methane Gas explosion, Mina Santana, the former Companhia Carbonífera Urussanga, Urussanga/SC	- Death of 31 workers.
1986	Dam Breaching of Itaminas Group, in Itabirito/MG	- Death of seven people.
1999	Dam Breaching of Mining Mata Virgem, located in the municipality of Gente Grande/MG	- Contamination of the drainage network.
2001	Dam break in Mining Rio Verde, in Nova Lima/MG	- Death of five people; - Devastation of 79 hectares of Atlantic Forest; - 600mil m³of waste reached the Taquaras stream and 30 hectares of protected area.
2006-2007	Dam break in Mining Rio Pomba Cataguases, Miraí/MG	- 2 million of m³ of mud leaked; - Silting, pollution of soil and of the local water system.
2008	Dam break, Companhia Siderúrgica Nacional, Congonhas/MG	- Town of Congonhas was flooded with mud.
2014	Dam break, Mine do Retiro do Sapecado, explored by Herculano Mineração, Itabirito/MG	- Death of three workers; - Damage to the streams of the river basins of the Rio das Velhas.
2015	Fundão dam break, Mine of Germano, Samarco, Mariana/MG	- 1200 homeless; - 70 million of m³ of rejection pulp; - 17 deaths e 2 missing; - Burial of springs and contamination of the basin of Rio Doce; - 663,2 km of water bodies directly affected; - It has reached areas of indigenous communities; - Ecosystems (devastated fish populations) and affected biodiversity.

Samarco Mineração S. A., responsible for the environmental disaster in Mariana/MG, seeking to mitigate the effects of the environmental crisis traced reduction impacts of strategies that promote social and environmental sustainability and promotion plan and image change the market level. The main observed measures ranging from social recovery programs, as devastated communities resettlement of the and cultural programs to those affected, and environmental remediation, as the map of actions to recover the affected areas, environmental quality monitoring and early works recovery. Figure 3 shows the company's website that has almost exclusively focused campaigns to environmental disaster, which is noticeable to a green marketing, in this case, selling a sustainable image of the company.

Figure 3 - Samarco site with the enterprise promotion and green marketing (Samarco, n.d.)

Therefore, for corporate sustainability methods are needed, as recommended by Jappur (2004), for a pinch organization toward sustainability, the main ones being: environmental responsibility, corporate governance, eco-efficiency, life cycle analysis, zero emission system certifiable management, cleaner production and, as already mentioned, the reporting corporate sustainability.

Legal Scenario

The Brazilian legal scenario determines and regulates government intervention of legal and political questions about the mining activity. The Brazilian tax situation is among the most incidents taxes and taxes levied on a mining project compared to other countries, for example, can take the application of corporate income tax, IRPJ, (Imposto de Renda para Pessoa Jurídica - Income Tax for Legal Entities) for mining companies this rate is 35 % of profit (Brazilian Ministry of Mines and Energy, 2013). Among some minerals producers, only Argentina, Democratic Republic of Congo, Ghana, India and the United States have higher or equal indices for the aforementioned tax, Brazil is the sixth largest incident in charges in the mining industry among the twenty-one producing countries analyzed PwC (2012).

Making a comparison of mining to other sectors of the economy, taxes, levies and fees for mining is low, assimilated, for other areas to compare with these other sectors, we adopt the most appropriate in terms of comparison, COFINS (Contribuição para o Financiamento da Seguridade Social - Contribution to Social Security Financing), since it is charged to all sectors of the economy. As can be seen in Table 2 Brazilian mining has one of the lowest taxes in all domestic sectors, even in the external environment is highlighted by having a heavy tax burden, other taxes also focus on mining, such as PIS (Programa de Integração Social -Integration Social Program) and IPI (Imposto sobre Produtos Industrializados -Tax on Industrialized Products) (FIESP, 2011).

Table 2 - COFINS aliquot collected in each industrial sector in the state of São Paulo (FIESP, 2011)

Segment	Mining	Steel industries	Plastic	Extraction of Oil and Gas	Electronic	Cosmetics and Pharmaceuticals	Petrochemistry
Aliquot (in %)	7,7	9,8	7,3	6,0	6,3	6,9	7,2

A tax imposed exclusively for mining is CFEM (Compensação Financeira pela Exploração de Recursos Minerais - Financial Compensation for Exploration of Mineral Resources), which although established in the Constitution, was only procedures within one year from the Law No. 7.990/89, determining the fate of this recipe on the resulting net revenues from the sale of mineral products through value associated with the exploited ore type. According to Law No. 8876/94, the authorization and jurisdiction to supervise and collect the CFEM responsibility of the DNPM (Departamento Nacional de Produção Mineral - National Department of Mineral Production). All tax revenues should be reinvested for the benefit of the local community, through improvement in infrastructure, environmental quality, health and education (Ministério de Minas e Energia, 2013).

The ICMS (Imposto sobre Operações Relativas à Circulação de Mercadorias e Prestação de Serviços de Transporte Interestadual e Intermunicipal e Comunicação-Tax on the Circulation of Goods and Transportation Services Delivery Interstate and Intermunicipal and Communication) is a state tax, with the same non-cumulative, but also focuses on mining. Collected through all intercity or interstate transport activity (in the specific case, the ICMS is charged at the origin and destination of the product), or communication (tax levied on the value added). Regarding the rates of operations and internal services, in general, correspond to 17%, with variation margin in each state. Following sample aliquots connected mining:

- São Paulo: 12% gravel productions, sand, ornamental stones, iron, steel and ceramics; 18% for construction goods in other states; 25% for explosives and consumption of electricity in mining operations.

Table 3 - Aliquot parts of CFEM (Law No. 7.990/89)

Mineral Resources	**%**		
	Aliquot	**States**	**Counties**
Ore of aluminum, manganese, rock salt and potassium	3,00	23,00	65,00
Iron, fertilizers, coal and other minerals	2,00		
Precious stones, stoned colored stones, noble metals and carbonates	0,20		
Gold (When extracted by mining companies)	1,00		
Gold (Other hypotheses of mining)	0,20		

Regarding operations and interstate services, the general rate is 12%, according to No. 22/89 resolution of the Senate. For operations and services originating in the Southeast Region and South destined to the Northeast, North, Midwest and Espírito Santo, this rate is reduced to 7%. For imports, the rate is 17% and exports of mineral products are tax-free (Ministério de Minas e Energia, 2013).

The concession areas scheme for mining in Brazil is another situation that comes away from the gaze of investors for Brazilian areas. The New Regulatory Mark, controversy generated in the operating area appears as a key factor in changes in the investment framework, as proposed changes in the scheme, which in turn is in place and is the mining concession act linked as a result of the obligations required by the Exploration Permit. That is, once met all the requirements for the current Mining Code, the entrepreneur does not have the guarantee that you will receive the award. The biggest disadvantage is related to maintenance of the area indefinitely, only for fulfilling the requirements described by the concession, even if there is no operation or activity. Consequently, prevents actuation of another applicant for mineral exploration.

The new regulatory mark for mining suggests that there is a concession granted preceded by public notice or competitive bidding process in which the dealer will sign a membership contract and will compete in a bid to make the phases of exploration and exploitation, preventing the application of an area to be inactive because the bidding will stimulate activity and productivity of a given area, because the entrepreneur will be bound to the adhesion contract. The mark not only proposes changes to the concession regime also serves other charges, the first need of revitalization constitutes to update the current regime, dated 1967, completely different reality of today's national mining, with many technological advances, new social, environmental and political demands from the proposition of the Mining Code, so urgent implementation of the new regulation. Another insurgent need in the current market is the higher participation of private key players taking these agents effective participation in the research and mining activities. The possibility to occur a successful enterprise with higher return for the government and society is well regarded. In addition, one of the justifications for use of this system is the possibility of increasing the selectivity of private agents in technical and economic qualitative questions, and access to a large number of areas and producing in areas with high mineral potential, translating in reality the mineral potential social development for the country.

CONCLUDING CONSIDERATIONS

Although Brazil get through situations of change in the economic cycle with the crises faced by the mining industry segment, it is undeniable the existing geological potential for exploration in the country, beyond the technical capacity and training of qualified professionals in the field. In the current conjuncture, the nation undergoes inversion cycles in several influencers areas of mining, this study sought to conduct a review of the current crisis in order to seek solutions to intermediation of such, although each one has its own particularities the keys of competitiveness to she pervade tenuous lines.

To culminate in Brazil, the subprime economic crisis not only affected the index of BM&F Bovespa, but rather the enterprises of mining branch for working voluminously with export suffered by easily absorb that impact. In those moments, there are opportunities to develop entrepreneurial profiles in order to seek solutions to minimize costs and maximize profits. The main effects related environmental crises in the Brazilian mineral industry are concentrated in the degradation of mined area, through tailings disposal, use of explosives and destruction of ecosystems (fauna and flora) sites. Such situations lead to pressure of media, society, non-governmental organizations, trade unions and government by significant promotional materials in social background for environmental risks to environmental quality, environmental responsibility and cleaner production. Mining companies assuming environmental liabilities, through monitoring, increase significantly its costs, but at the same time, promote their images and their relationship with the social actors, as well as themselves against possible incidents, prepare for them or even heading them. The Brazilian mineral sector, in particular, takes imposing advantage when dealing _ tax in relation to export, because in many situations receive full exemption. In the country, can also see that among the rates of COFINS, as the example seen in the state of São Paulo, mining has similar value to other industries. On the other hand, the international scenario, counts on one of the largest tax charges imposed on the mining industry, a fact that is due to archaic legal structure and regiment represented by a code dated approximately to fifty years. As hope to times of crisis caused by legal terms, there are possibilities to mining promoted by the emergence of new bills that will change the framework of concession schemes and ownership of areas for mining.

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CONSIDERATIONS ON THE QUALITY OF COAL PRODUCTION IN THE COAL-MINING DEPOSIT OLTENIA, ROMANIA

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ABSTRACT

The medium content of energy of the coal in a deposit can be established exactly by mining specialists. The exploitation of the coal deposit involves the extraction of a mining product (the coal) with a medium content of energy lower than that of the coal in the deposit. The exploitation, transportation, loading, and unloading contribute to the continuous diminution of the energy content of the coal production. This paper will establish the values of the energy content diminution per product unit, as well as the causes of this reduction from the moment of the coal extraction from the deposit to its burning in the furnaces of thermal power plants. The research presented in this paper was conducted on the coal deposit in Oltenia, Romania.

KEYWORDS

Quality features, correlation and regression methods, calorific power, statistical parameters, energy coal.

OVERVIEW OF THE JILȚ DEPOSIT

From an administrative viewpoint, the Jilț mining deposit is located in North-Western Oltenia, in the South-Western county of Gorj, on the territory of Mătăsari, Runcurel, Dragotești, Croici and Miculești towns.

The various settlements in the area are linked by county local roads and the nearest railway station is in Dragotești town.

From a hydrographic and morphological viewpoint, the Jilț mining deposit is located on the interfluve between the Jiu river and the Motru river, being part of the Getic Plateau geomorphological unit.

From a structural viewpoint, the Jilț mining deposit is part of the Getic Depression, with the role of a foredeep in front of the Carpathians between the Paleocene and the Pliocene.

In the Jilț mining basin extraction activity is conducted through two open-pit mines, Jilț North and Jilț South.

The Jilț North open-pit mine has a hilly relief, less rugged than the Jilț South perimeter, having a 170 m level difference between the grade elevations. Among the peaks that dominate the landscape stand Runcurelu Peak (390 m), Brădeţelului Peak (395 m) and Cerchezului Hill (353 m). The minimum grade elevations are situated on the southern and eastern sides of the perimeter, in the Runcurelu and Jilțul Mare valleys going up both to the north and to the longitudinal axis of the perimeter. The hydrogeology of the area is determined by the Runcurelu, Valea Largă and Brădeţel valleys that traverse the area from west to east and hydrographically feeding the Jilțul Mare river.

Description of the coal strata from the Jilț North open-pit mine

The drillings in the Jilț North area have investigated the whole deposit, both the part located in the Lower Pleistocene (villafranchian), which contains the lignite strata XIII - XV, and the one in the Romanian, which contains the VIII - XII layers and the Dacian, containing the I – VII layers.

Although the deposit is continuous throughout the perimeter, the thickness of the layers is reduced. The layers are located in an area with difficult hydrogeological conditions and only layers V sup. – X. are relevant from an economic viewpoint. Layers I, III, IV and V inf. Layers XI - XV are generally thicker than 1 m, but their surface is small.

THE BENEFICIARY'S REQUIREMENTS REGARDING THE QUALITATIVE CHARACTERISTICS OF THE COAL [12-21]

Humidity [16, 18] - is considered to be ballast, because it requires an additional quantity of heat in order to evaporate and, together with the ash, it decreases the calorific power of the coal.

The humidity or the water content varies depending on the type of coal and on the deposit's conditions. Lignite can contain 35%-60% water.

The research of coal behavior with a view to determining its use requires the settling of the three types of humidity: the imbibed moisture, the hygroscopic moisture, and the total humidity.

The imbibition moisture (W_i) of the coal is the humidity of the coal that has just been extracted. This moisture is lost by storing the coal at the surface, in open space. This humidity is the amount of water resulted from drying the coal by bringing it up to the surface.

The hygroscopic humidity (W_h) is represented by the amount of water that is still left in the coal after the imbibition moisture has been lost. This type of humidity is eliminated by drying the sample in the autoclave at 105°C. The hygroscopic humidity, also called internal humidity, is retained in the pores of the coal by capillary forces. The thinner the capillaries of the coal and the lesser the amount of organic colloidal substances (humic acids) in the coal, the higher the content of hygroscopic humidity (W_h).

The total humidity (W_t) is defined by the total amount of water in the coal. It can be calculated by adding the value of the imbibition moisture to the value of the hygroscopic humidity or by using another method. The lignite from Oltenia has a total humidity of 40% on the average.

The volatile matters (V) represent the total amount of products leaked by heating the coal in certain conditions, setting aside the moisture content analysis. The leakage process takes place when the coal is heated at 850°C for 7 minutes under anaerobic conditions. The difference between the initial mass and the residue resulted after the heating process and the moisture content W_a^a, is represented by the volatile matters V^a. The content of volatile matters can be calculated using the following formula:

$$V^a = \frac{100 \times \Delta G}{G_i} - W_a^a \ [\%]$$

where :

- G_i is the initial mass (in grams) of the coal that was heated.
- ΔG is the mass (in grams) loss of the coal through heating in the absence of air.
- W_a^a is the moisture content of the sample used for analysis in the anhydous state (%).

The ash content (A) [19, 20] is the solid residue resulting from the process of burning of the amount of coal resulted from the calcination of the coal at $815^0 \pm 25^0$C to a constant mass value. The ash content is composed of inorganic materials.

The ash content is calculated using the ratio in percentage between the mass of the resulted residue after calcination and the mass of the analysis sample. Part of the ash content are remains from the original plants, therefore it is primary ash.

The calorific power (Q) [21] is the main feature of the coal used as fuel. The calorific power represents the amount of heat that is generated by the combustion of the fuel unit and the cooling of the burning gases to 298^0 K (25^0C) [28]. The laboratory analysis has revealed the connection between the calorific power and the chemical composition of the coal. Therefore, the value of the calorific power is generally directly proportional with the carbon content and inversely proportional with the ballast percentage (humidity + ash). This explains the high calorific power of superior coal.

THE QUALITY PARAMETERS OF THE COAL DELIVERED TO THE CUSTOMER [13, 15, 16, 21]

The coal extracted from the Jilţ deposit is used as fuel by the Turceni thermal power station, located at 30 km from the deposit. The coal is delivered on railroad, using hopper cars that are daily loaded with 1000-3000 tons of coal.

The average duration of the storage of coal is mentioned for every fully loaded hopper car. Samples of coal are also taken in order to determine the following quality parameters:

- the duration of the storage of the coal;
- the ash content;
- the moisture content;
- the calorific power.

The storage duration, the content of ash and the moisture content are the independent quality parameters, which don't influence one another. Nevertheless, these parameters influence negatively the quality of the mining product: the higher are the values of these parameters, the poorer is the quality of the extracted coal.

The calorific power is a quality parameter that depends on the other three parameters (the duration of the storage of the coal, the ash content and the moisture content). The value of this parameter increases when the quality of the extracted coal is better.

In the next section, we will present how the duration of the coal storage, the ash content and the moisture content parameters influence the calorific power, both individually and as a group.

The influence of the duration of the storage time on the calorific power [1, 6, 7, 10, 11]

The duration of the coal storage influences negatively the calorific power parameter. Thus, higher values of storage time lower the quality of the extracted coal.

The loss of calorific power during storage is caused by:

- the amount of time when the coal is exposed to air, which leads to the oxidation of the organic substances in the coal;
- the leakage of volatile substances from the mass of stored coal.

The six-month research on these issues has highlighted the following results:

- the series of data for the first months of 2015 (January - June) show insignificant differences;
- for every month and for the entire analyzed period, the value of the calorific power decreases as the duration of the storage time increases.

To determine the formula for the calculation of the amount of lost heat depending on the storage time period, we use the "regression analysis" model [1], [6], [7], [10], [11].

The regression analysis uses a model to determine the value of a feature depending on the values of other features. If we note with y the dependent feature, and with x_i the factorial (independent) features, where i = 1, 2,..., m, then, the dependence between y and x_i will be determined using the following formula:

$y=f(x_1,x_2,\ldots,x_m)$.

The less complex model which presents the connection between two or more quality features is the linear model, where the dependence between y and x_i appears as a linear expression:

$y=f(x)=a_0+a_1x_i$.

It is necessary to determine the values of the a_0 and a_1 coefficients.

The value of these coefficients can be determined using the least squares method.

Consider $\delta = \hat{y}_i - y_i = a_0 + a_1 x_i - y_i$,

where δ is the difference between the ordinate calculated using the adjustment formula, corresponding to x_i abscissa of the experimental point and the determined y_i ordinate.

$$\min\{\sum_{i=1}^{n}\delta_i^2\} = \min\{\sum_{i=1}^{n}(a_0 + a_1 x_i - y_i)^2\}.$$

The minimum value of the sum is reached for those values of a and b that cancel the first derivative of the sum with respect to the unknown values of a and b, i.e.:

$$\frac{\delta}{\delta a_0}\sum_{i=1}^{n}(a_0 + a_1 x_i - y_i)^2 = 2\sum_{i=1}^{n}(a_0 + a_1 x_i - y_i) = 0$$

$$\frac{\delta}{\delta a_1}\sum_{i=1}^{n}(a_0 + a_1 x_i - y_i)^2 = 2\sum_{i=1}^{n}(a_0 + a_1 x_i - y_i)\cdot x_i = 0.$$

After calculating, we get the following system:

$$\begin{cases} na_0 + \sum a_1 x_i - \sum y_i = 0 \\ a_0 \sum x_i + a_1 \sum x_i^2 - \sum x_i y_i = 0 \end{cases}$$

from which we obtain:

$$a_0 = \frac{\sum y}{n} - \frac{n\sum xy - \sum x \sum y}{n\sum x^2 - (\sum x)^2}\cdot\frac{\sum x}{n};\ a_1 = \frac{n\sum xy - \sum x\sum y}{n\sum x^2 - (\sum x)^2}.$$

Using the coefficients a_0 and a_1, we determine the value of the regression equation for every x. These values of the regression equation are also known as theoretical values of the y feature depending on x, and the operation of replacing the real y factors with the values of the regression equation is known as adjustment.

In table 1 we present the values of the coefficients of the linear regression of a line in plane, as well as the equations of the linear regression lines for every month and for the entire period of time analyzed.

Table no 1

Month	a_0	a_1	Regression line
January	2107.049	-10.4311	y=2107.049-10.4311x
February	2134.705	-14.1362	y=2134.705-14.1362x
March	2115.911	-14.3641	y=2115.911-14.3641x
April	2093.494	-13.8836	y=2093.494-13.8836x
Mai	2096.033	-13.3534	y=2096.033-13.3534x
June	2126.034	-16.6261	y=2126.034-16.6261x
Total	2078.25331	-11.4313	y=2078.25331-11.4313x

From the analysis of these regression lines we see that the storage time influences negatively the calorific power of the mining production. The loss of calorific power resulted from a day of storage is:

- a day of storage leads to a loss of 10.4311 Kcal/Kg of coal, i.e., 0.5% in January, and in June we get the highest loss of calorific power per day of storage, 16.6261 Kcal/Kg of coal, i.e. 0,782%;
- an average storage day in the analyzed period of time leads to a loss of 11.4313 Kcal/Kg of stored coal, i.e., 0,55%.

The influence of the content of ash on the calorific power [1, 6, 7, 10, 11]

The content of ash from the mining production has great influence on the calorific power of the coal extracted from a stratum.

The percentage of ash from the extracted coal is determined by:

- the percentage of ash from the coal in the stratum. This value can be constant for the entire stratum;
- the percentage of ash resulted from the dilution of the extracted coal containing waste from the roof and floor of the coal stratum. This percentage of ash is variable, increasing as the value of the dilution of the extracted coal containing waste is higher.

In table no 2 we present the values of the coefficients of the linear regression lines, as well as the equations of the linear regression lines for every month and for the entire period of time that was analyzed for the loss of heat due to the loss of ash content.

Table no 2

Month	a_0	a_1	The regression line	The value of the calorific power for 35% ash content	The value of the calorific power for 36% ash content	Δ=5-6
1	2	3	4	5	6	7
January	2934.027	-3087.18	y=2934.027-3087.18x	1853.514	1822.642	30.872
February	2577.035	-1847.44	y=2577.033-1847.44x	1930.429	1911.955	18.474
Martch	3280.974	3871.04	y=3280.974-3871.04x	1926.11	1887.4	38.71
April	2706.174	-2220.26	y=2706.174-2220.26x	1929.083	1906.88	22.203
Mai	2730.145	-2200.18	y=2730.145-2200.18x	1960.082	1938.08	22.002
June	2803.07	7069.179	Y=2803.07-2421.89x	1955.409	1931.19	24.219
Total gen	2814.887	-2547.96	y=2141.97-2547.96x	1923.104	1897.624	25.48

From the data in table 2 it follows that if the percentage of ash increases, then the calorifc power decreases.

The equations of the regression lines we have presented in column 4 from table 2 show that if the percentage of ash increases, the calorific power decreases. The loss of calorific power resulted from the increase of the content of ash by one percentage is:

- a growth of the coal content by one percent leads to a loss of the calorific power of 38.71 to 18.474 Kcal/Kg of coal;

- for the analyzed period of time, a growth of 1% of the content of ash results in a calorific power loss of 25.48 Kcal/Kg of coal.

The influence of humidity on the calorific power [1, 6, 7, 10, 11]

The research regarding the coal behavior with a view to determine its use requires the determination of three types of moisture: the imbibition moisture, the hygroscopic humidity and the total humidity.

The hygroscopic humidity is a constant value for the coal extracted from a layer. The imbibition humidity is a dynamic variable dependent on the water in the rocks surrounding the coal layer and the amount of precipitations.

The coal moisture resulting from the exploitation of a deposit consists of the following types of humidity: imbibition and hygroscopic.

In Table 3 we present the values of the linear regression coefficients, as well as the equations of the regression lines for each month and for the entire period of time under review, for the heat loss caused by moisture.

Table no 3

Month	a_0	a_1	The regression line	41%	42%	Δ=col. 5-col.6
1	2	3	4	5	6	7
January	4503.95	-6371.97	y=4503.95 - 6371.97x	1955.162	1891.442	63.7197
Februarye	2343.069	-857.389	y=2343.069 - 857.389x	2000.113	1991.54	8.57389
March	2184.629	-623.305	y=2184.629 - 623.305x	1935.307	1929.074	6.23305
April	-9206.77	26756.11	y=-9206.77+26756.11x	1495.674	1763.235	-267.561
Mai	1325.696	647.8846	y=1325.696+647.8846x	1584.85	1591.329	-6.47885
June	-164.167	5078.675	y=-164.167+5078.675x	1584.85	1591.329	-6.47885
Total	1876.121	97.8219	y=1876.121+97.8219x	1867.303	1918.09	-50.7867

The data from table 3 show that if the percentage of moisture increases by 1%, the situation is as follows:

- in the first 3 months, the calorific power decreases by 63.7, 8.57, 6.23 kcal / kg coal;

- in the next months and during the entire period of time under review, we can see that the calorific power increases by the following amounts: 267 561, 6.47885, 6.47885, 50.7867 kcal / kg coal.

The influence of the production factors on the calorific power [1, 6, 7, 10, 11]

The data shown above highlight the individual influence of the three parameters (storage time, ash content, water content) on the quality parameter, the "calorific value". In reality, these three parameters do not influence the "calorific value" parameter of the coal production independently, but as a group. To emphasize the dependence of the action of these three quality parameters on the quality parameter "calorific value" of the mining production, we will use multiple linear regression.

To study the multiple link between a quality feature and other two or more production features, we use the following expression:

$y=f(x_1,x_2,\ldots,x_n)$

where x1, x2, ..., xn represent factorial characteristics.

The simplest link between the quality features is the linear one:

$$\hat{y} = a_0 + a_1 x_1 + a_2 x_2 + \ldots + a_p x_p$$

The regression coefficients are obtained by applying the least squares method. Let's consider:

$$S = \sum (y - \hat{y})^2 = \sum (y - a_0 - a_1 x_1 - a_2 x_2 - \ldots - a_p x_p)^2 = \min .$$

Deriving S with respect to each of the a_i (i = 0, 1, 2, ..., n) coefficients, we get a system of (n + 1) equations with (n + 1) unknowns, i.e.:

$$\begin{cases} a_0 N + a_1 \sum_{v=1}^{N} x_{1v} + a_2 \sum_{v=1}^{N} x_{2v} + \ldots + a_p \sum_{v=1}^{N} x_{pv} = \sum_{v=1}^{N} y_v \\ a_0 \sum_{v=1}^{N} x_{1v} + a_1 \sum_{v=1}^{N} x_{1v}^2 + a_2 \sum_{v=1}^{N} x_{1v} x_{2v} + \ldots + a_p \sum_{v=1}^{N} x_{1v} x_{pv} = \sum_{v=1}^{N} y_v \cdot x_{1v} \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ a_0 \sum_{v=1}^{N} x_{pv} + a_1 \sum_{v=1}^{N} x_{pv} \cdot x_{1v} + a_2 \sum_{v=1}^{N} x_{pv} \cdot x_{2v} + \ldots + a_p \sum_{v=1}^{N} x_{pv}^2 = \sum_{v=1}^{N} y_v \cdot x_{pv} \end{cases}$$

where N is the number of observed variables.

We solve this system of linear equations using one of the known methods.

In table 5 we present the coefficients of the regression multiple linear regression lines and the multiple linear regression equations for the analyzed months and for the entire period of time under review,

The significance of the coefficients is:

- a_0 – constant term, which shows the influence of other factors that are not considered here as they don't influence the "calorific power";

- a_1- the value of the influence coefficient given by the water content;

- a_2 – the value of the influence coefficient given by the ashes content;

- a_3 – the value of the influence coefficient given by the storage time.

In table 4 we present the results of the processing of the data for each month and the entire period of time under review:

Table no. 4

No	Month	a_0	a1	a_2	a_3	The regression equation
1	January	4810.751	-38.762	-35.5639	-0.386	$Y=4810.751-38.762x_1-35.5639x_2-0.386x_3$
2	February	5469.922	-62.4142	-16.9976	-14.945	$Y=5469.922-62.4142x_1-16.9976x_2-14.945x_3$
3	March	3157.145	-14.272	-15.247	-7.66	$Y=3157.145-14.272x_1-15.247x_2-7.66x_3$
4	April	3366.902	-18.0354	-16.73	-7.796	$Y=3366.902-18.0354x_1-16.73x_2-7.796x_3$
5	Mai	4988.207	-41.802	-36.506	-0.8913	$Y=4988.207-41.802x_1-36.506x_2-0.8913x_3$
6	June	3736.834	-23.295	-21.04	-7.900	$Y=3736.834-23.295x_1-21.04x_2-7.9x_3$
7	Total genera	4139.153	-29.013	-27.039	-2.971	$Y=4139.153-29.0130x_1-27.039x_2-2.971x_3$

Analyzing the results in table 4, we see that the three factors of production influence negatively the "calorific power" of the exploitable coal.

Observations:

- these three factors of production together influence negatively the "calorific power" of the mining production.

- the amounts x, y are calculated as a percentage.

Example:

For the set of values presented in table 5, we calculate the value of the calorific power in the given situation and for the case when the value of these parameters is increased by 1, using the regression equations for the month of May and the overall total.

Table no. 5

Units of hopper cars	Data	Humidity [%]	Ash [%]	Days	Determined PC [Kcal/Kg]	Calculated PC [Kcak/Kg]	
						The equation of the regression lines - May	The equation of the regression lines, - T. gen.
34	20-May	41.6	34	5	2000	2003.583	1998.031
		42.6	35	6	-	1924.384	1939.008

If we compare the calculated values of the calorific powers calculated with the two equations of the regression line for the data set we have considered, we can see that the calculated values are within the range of 2000 Kcal/Kg.

Increasing the values of the given parameters with value 1, we can see that the values we obtained using the two equations of the regression lines are smaller than in the first case, which demonstrates that the calorific power decreases as the values of these parameters increase.

DETERMINING THE INTENSITIES OF THE LINEAR LINKS BETWEEN A GROUP OF FACTORS AND THE RESULT [1, 6, 7, 10, 11]

To highlight the intensity of the links between a group of factors and the results we will use the correlation method. The linear correlation method will be applied in the following versions: simple and multiple.

Determining the intensities of the linear links between a factor and the result

To measure the intensity of the link, we use two main indicators: the correlation ratio and the correlation coefficient.

The correlation ratio is an indicator that allows the measuring of the intensity degree of the connections between the feature that is considered a mitigating factor and the resultant feature. To calculate this, we will use the following formula:

$$\eta = \sqrt{1 - \frac{\sigma_r^2}{\sigma_y^2}} = \sqrt{1 - \frac{\sum (y_i - \hat{y}_i)^2}{\sum (y_i - \bar{y})^2}} = \sqrt{\frac{a\sum y_i + b\sum x_i y_i - \frac{(\sum y_i)^2}{n}}{\sum y_i^2 - \frac{(\sum y_i)^2}{n}}}$$

where σ_r^2 is the dispersion of the values of the y feature around the regression line $\hat{y}$ and it results from the following formula: $\sigma_r^2 = \frac{1}{n}\sum_1^n (y_i - \hat{y}_i)^2$

σ_y^2 is the general (total) dispersion of the feature y with respect to the mean: $\sigma_y^2 = \frac{1}{n}\sum_{i=1}^n (y_i - \bar{y})^2$

Remark. The correlation ratio varies in the range (0,1): $0 \leq \eta \leq 1$, therefore it has only positive values. It is shown that in the case of the linear correlation, the correlation ratio is converted to the correlation coefficient.

The correlation coefficient shows the intensity of the interdependences between two quality characteristics, x and y. This coefficient can be obtained using the following formula:

$$r_{xy} = \frac{\sum (x_i - \bar{x})(y_i - \bar{x})}{n\sigma_x\sigma_y} = \frac{n\sum xy - \sum x \cdot \sum y}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Remark. The correlation coefficient can range between -1 and +1. The sign of the correlation coefficient shows the direction of the connection. If it has a "+" sign, the correlation is direct, and if it is '-', we have an inverse correlation.

When r = + 1, y_x and x_y regression equations coincide, which means that the correlation between variables is a functional type, i.e., for each value of data X we have only one Y correspondent. The link between all type variables is also a functional type and it is called a positive (direct) perfect correlation.

If r = -1, the pairs of correlated values x1 and y1 belong to a straight line as in the previous case. The difference is that for the highest values of x we have the smallest values of y and vice versa. The link between the variables is also a functional type and it is called negative (inverse) perfect correlation [7].

In practice it is considered that if:

$0 \leq |r_{xy}| < 0,2$ – there is no connection;

$0,2 \leq |r_{xy}| < 0,5$ – there is a weak connection;

$0,5 \leq |r_{xy}| < 0,75$ – there is a medium intensity connection;

$0,75 \leq |r_{xy}| < 0,95$ – there is a strong connection;

$095 \leq |r_{xy}| < 1$ – there is a strong relative deterministic connection.

It is known that the interdependence connections between the quality features and their determining factors are complex, which leads to the study of the degree of influence of several factorial features on the resulting features. For this purpose, the multiple correlation is used together with the multiple regression.

In table no. 6 we present the simple linear correlation coefficients for moisture, ash and time, calculated for each month and for the entire period under review.

Table no. 6

Nr.crt	The correlation coefficient	January	February	March	April	Mai	June	Total Period of Time
1	r_{yu}	-0.04495	-0.16477	-0.09316	0.255	0.11849	0.279069	0.0205
2	r_{yc}	-0.89911	-0.68852	-0.83106	-0.82	-0.79057	-0.84839	-0.8317
3	r_{yt}	-0.76304	-0.8689	-0.93388	-0.943	-0.83667	-0.94951	-0.8423

Where: r_{yu}, r_{yc}, r_{yt} are the correlation coefficients between the resulting feature (the calorific power) and the functional characteristics: moisture content, ash content and the number of coal storage days of in the warehouse.

Analyzing the values of the correlation coefficients, we see the following:

- the correlation coefficient between the moisture content and the calorific value parameter for the first three months shows a weak but negative connection, due to the rainfall in January, February and March. During the months of April, May, June, the connections are positive but of low intensity. Therefore, between the humidity and calorific value parameters there is a weak connection, with contrary signs;
- the correlation coefficient between the ash content and the calorific value parameters has a strongly negative connection for each of the months of the period of time under review and for the entire period of time;
- the correlation coefficient between the time and the calorific value parameters has a strong, negative connection for each of the months of the period of time under review and for the entire period of time.

Determining the intensity of multiple links between a series of factors and the result

When a factorial variable acts alone in an experiment, it can have the following behavior with respect to a resulting variable: to have no influence, to exert weak influence, or have a very strong influence.

If, besides the analyzed factorial variable, there are other variables that can also have an impact, there is a possibility that the factorial variable will alter considerably its way of influencing the resulting variable.

Also, a group of factorial variables could act in a certain way on the resulting variable.

To highlight the type of impact of a group of factorial variables on a resulting variable, we use the partial and multiple correlation.

The partial correlation

In the case of the simple correlation, we analyze the linear link between two factors, without considering the influence of other factors that act simultaneously on the resulting variable Y, whereas in the case of multiple linear correlation we study the simultaneous influence of two or more of the factorial features on the representative feature.

A problem that can be solved using the regression and correlation method is how to determine the influence of an independent variable on the dependent variable, assuming that the other independent variables remain at a constant level. The indicator of the intensity of this type of correlation is called the partial correlation coefficient.

The formulas used to calculate the partial correlation coefficient are:

1. Y between X_1 and X_2 neglecting its influence:

$$r_{yx_1 \cdot x_2} = \frac{r_{yx_1} - r_{yx_2} r_{x_1 x_2}}{\sqrt{(1 - r_{yx_2}^2)(1 - r_{x_1 x_2}^2)}}$$

2. between Y şi X_1, without considering the influence of X_2 and X_3:

$$r_{yx_1 \cdot x_2 x_3} = \frac{r_{yx_1 \cdot x_2} - r_{yx_3 \cdot x_2} r_{x_1 x_3 \cdot x_2}}{\sqrt{(1 - r_{yx_3 \cdot x_2}^2)(1 - r_{x_1 x_3 \cdot x_2}^2)}}$$

3. for the general case:

$$r_{yx_1\cdot x_2x_3...x_n} = \frac{r_{yx_1\cdot x_2x_3...x_{n-1}} - r_{yx_n\cdot x_2x_3...x_{n-1}} \cdot r_{x_1x_n\cdot x_2x_3...x_{n-1}}}{\sqrt{(1-r^2_{yx_n\cdot x_2x_3...x_{n-1}})(1-r^2_{x_1x_n\cdot x_2x_3...x_{n-1}})}}.$$

For the situations 1 and 2:

Table no. 7

No	The partial correlation coefficient	Value	The partial correlation coefficient	Value	The partial correlation coefficient	Value
0	1	2	3	4	5	6
1	r_{yx1}	0.0205	$r_{yx1\cdot x2}$	-0.83182	$r_{yx1\cdot x2x3}$	-0.78046
2	r_{yx2}	-0.8317	$r_{yx1\cdot x3}$	0.074307		
3	r_{yx3}	-0.8423	$r_{yx2\cdot x1}$	-0.95131	$r_{yx2\cdot x1x3}$	-0.86313
4	r_{x1x2}	-0.5042	$r_{yx2\cdot x3}$	-0.66454		
5	r_{x1x3}	0.0232	$r_{yx3\cdot x1}$	-0.84318	$r_{yx3\cdot x1x2}$	-0.55044
6	r_{x2x3}	0.6728	$r_{yx3\cdot x2}$	-0.8234		
			$r_{x1x2\cdot x3}=r_{x2x1\cdot x3}$	-0.7028		
			$r_{x1x3\cdot x2}=r_{x3x1\cdot x2}$	0.567263		
			$r_{x2x3\cdot x1}=r_{x3x2\cdot x1}$	0.792835		

The values of the regression coefficients that were calculated between the dependent variable "calorific power" and the independent variables, for the three situations presented in table 7, show a negative connection. The interval of the connections intensities ranges from weak negative links to strong negative links.

The multiple linear correlation

To measure the intensity of the correlation between a resulting variable y and more factorial variables x_1, x_2, …, x_n , we use the multiple correlation coefficient, which is given by the following formulas:

$$R_{y\cdot x_1,x_2,...,x_n} = \sqrt{1-\frac{\sum(y-\hat{y})^2}{\sum(y-\bar{y})^2}} \text{ ; or}$$

$$R_{y\cdot x_1,x_2,...,x_n} = \sqrt{\frac{a_0\sum y + a_1\sum x_1 y + ... + a_n \cdot \sum x_n y - \frac{(\sum y)^2}{n}}{\sum y^2 - \frac{(\sum y)^2}{n}}}$$

This coefficient is always positive.

The multiple correlation coefficient can be calculated using the simple correlation coefficient between features:

$$R_{y\cdot x_1,x_2} = \sqrt{\frac{r^2_{yx_1}+r^2_{yx_2}-2r_{x_1x_2}\cdot r_{yx_1}\cdot r_{yx_2}}{1-r^2_{x_1x_2}}} \quad \text{or} \quad R_{y\cdot x_1,x_2,x_3} = \sqrt{1-\frac{\sum_{i=1}^{n}(y_i-\hat{y}_i)^2}{\sum_{i=1}^{n}(y_i-\bar{y}_i)^2}}$$

The square of the correlation coefficient is called coefficient of multiple determinations and it shows the weight with which the factorial characteristics influence simultaneously the resulting features. We can say that the difference between unit and the multiple determination coefficient is the weight with which the other factors that were not included in the project influence on the resulting characteristics.

If we calculate the value of the multiple correlation coefficient for the period of time under review, we get: $R_{y\cdot a1,a2,a3}$=0.962657994.

The value of this coefficient indicates a strong link between the quality feature "calorific power" and its quality independent characteristics (the moisture content, the ash content of coal and the number of days of coal storage).

CONCLUSIONS

The quality of coal extracted by surface mining workings is largely influenced by the following qualitative characteristics: moisture content, ash content, storage time and calorific power.

The calorific value is dependent on the first three quality features.

The influence and of the quality characteristics (time of storage, moisture content and ash content) on the calorific power is pointed out using the method of correlation and regression.

The processing of data regarding the three parameters for a period of six months (January-June) using the simple regression method highlights the following:

1. The influence of the storage time [2, 3, 4, 5]

-one day of storage leads to a loss of 10.4311 kcal / kg coal, i.e. 0.5% in January; the greatest loss of calorific power for a storage day, i.e. 16.6261 kcal / kg coal , namely 0.782% was reached in June;

-for an average storage day in the period under review, the loss was of 11.4313Kcl / Kg of coal stored, namely 0.55%.

2. The influence of ash content [5]

-for a one percent increase of the ash content, the calorific power of coal decreases by values between 38.71 and 18.474 Kcal / Kg coal;

-in the analyzed period, for an increase of ash content by 1%, the calorific power will decrease by 25.48 kcal / kg coal.

3. The influence of moisture content

-in the first 3 months, the calorific power decreases by 63.7, 8.57, and 6.23 kcal / kg coal;

-in the coming months and in the entire analyzed period, it can be noticed that the calorific power increases by the following amounts: 267.561, 6.47885, 6.47885, 50.7867 kcal / kg coal.

Regarding the influence of the moisture content on the calorific power, conflicting results were obtained, namely decreases and increases of calorific power alongside with the increases of the moisture content by 1%. We believe that this contradictory outcome requires further research in this area to determine the influences of moisture content in the two seasons:

- In winter, when average temperatures are around 0°C;
- In spring, when the average temperatures are around 20°C.

The individual influences of the three independent features on the calorific power are highlighted through correlation analysis, namely:

-the correlation coefficient between the moisture content and the calorific power in the first three months shows a weak but negative link, due to the rainfall in January, February and March. In April, May, June, the links are positive, but of low intensity. Therefore, between the moisture content and the calorific power there is a weak link of opposite signs;

-the correlation coefficient between the ash content and the calorific power in the analyzed months and in the entire analyzed period shows a strong negative relation;

-the correlation coefficient between the time parameter and the calorific power parameter shows in the analyzed months and in the entire analyzed period a strong negative link.

The values of calculated regression coefficients between the dependent variable "calorific power" and the independent variables for the three situations presented in Table no 7 shows a negative link. The interval of intensities of links range from weak negative links up to strong negative links.

The link between the quality feature "calorific power" and the group of independent quality characteristics (moisture content, ash content and days of coal storage) for the entire analyzed period is strong, having the value of 0.96.

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CREDIT LEVERAGE PROBLEMS FACED BY SMALL BUSINESSES IN THE MINING INDUSTRY

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CREDIT LEVERAGE PROBLEMS FACED BY SMALL BUSINESSES IN THE MINING INDUSTRY

ABSTRACT

This paper aims at showing the problems faced by small mining businesses in Brazil to leverage credit by detailing currently financing options available and the natural ease larger companies have to access such credit tools. Because of that, these credit dynamics will unavoidably foster opening toward internationalization of mining in Brazil, considering foreign investments in that segment are significant, added to the fact that, in other countries, that kind of financing to small mining businesses is both more common and more broadly available. Finally, how the Brazilian government is dealing with the matter and what innovations in the New Mining Framework may help change that scenario. The methodology employed was based on a systemic approach together with multivariate analysis, where analyzing recent discussions about the issue was of great importance.

KEYWORDS

Junior Companies, Financing, Mining, Credit.

FOREWORD

A major difficulty all small businesses face is doubtlessly the need of financing for their activities, especially during their early years. Dynamics are the same for the mining industry. However, the stakes are even higher, thanks to uncertainties of the business and the natural demand for intensive capital investment.

Because of that, it is vital to discuss this issue, so society can better understand the difficulties faced when companies from that niche and industry are looking for credit, because they have many specificities, like: location rigidity, draining of resources, sensitiveness to economies of scale, and barriers to the entry of new competitors due to the prevalence of large businesses.

In order to familiarize the reader with the matter, we can explain how junior companies – those with annual revenues between zero and 3,600,000.00 BRL (three million six hundred thousand Reais) and that are usually in the mineral survey stage – are responsible for the discovery of most ore beds in the industry they belong to. In the view of BNDES – Brazilian National Bank for Economic and Social Development, small businesses belong to a range from 2.4 million BRL and 16 million BRL in annual gross operating revenue. Also, these small businesses are typically listed in the Australian, British or Canadian Stock Exchanges.

It is well known that the size of a company may depend on the number of its employees or the size of its gross annual revenue. A junior company will hardly have any revenue during its survey stage, which makes credit analysis focused on that business segment even more specific.

These companies are the ones that hire and employ most professionals working in mineral survey. They also invest a considerable amount of financial resources in survey and drilling campaigns. These campaigns are technical studies to prospect for economically-feasible mines. They are characterized by being projects with very high chances of loss, as not everything that is surveyed – despite positive evidences – ends up having a favorable result.

Currently, discussing the matter of credit in Brazil is not a very complex task, considering the countless incentives provided by the Federal Government during the past few years for credit extension. However, these are geared to the consumer class.

When we restrict the issue to businesses, we realize that these incentives were not widely extended to that category. Also, when we focus on the mining industry – mainly on small businesses in that industry – we become convinced that credit scarcity is even more evident.

Therefore, this discussion intends to show the credit scenario of the mining industry in Brazil in the past few years. We also want to expose the problem of credit leverage by small businesses in the industry and its limitations by showing some credit tools available in the domestic and international market exemplified by some successful cases. We also want to show opening to internationalization is, in part, due to these financial difficulties, and also point out how recent talks about legal standards for the industry by Agencies relevant for mining are helping improve the scenario.

This paper does not intend to exhaust the whole subject, much less draft a standard model for obtaining credit.

The Credit Scenario in the Mining Industry

Credit lines offered to the mining industry are the same ones offered to other businesses segments, even though the mining industry has a very specific characteristic, namely, the need for high investments during a project pre-operational stage and the high risk associated to that, arising from uncertainties around surveys required by the projects.

As soon as a company starts its activities, there immediately arises the need for investments in machinery and equipment – the so-called fixed assets. In the case of mining industry small businesses, there is also a need for investments in mineral survey to find and/or expand the project's mineral reserves.

There are two major sources to obtain these resources. The first is shareholders' equity, the second is creditors' equity.

Cash flow pressures at the beginning of mining projects are very severe and also, the use of retained earnings is a very limited option for capitalization of these small businesses. For, in most instances profits are non-existent and a new input by shareholders with not enough future profitability data is unfeasible. Therefore, obtaining new resources via creditors' equity becomes the option these companies consider the most.

Due to that, those companies with large cash assets have the capability of ensuring financing operations from Brazilian financing institutions. Small businesses, which do not have such resources to provide the collaterals required, end up looking for financing from other sources, mostly foreign ones.

It is important for financial resources coming from the credit system to include a grace period for payment to liquidate the principal and interest. Otherwise, obtaining funds this way would not be justified.

It is in this context that the Brazilian Domestic Financial System comes into play to provide alternatives and tools for credit leverage.

According to Lucato & Júnior:

> [...] to qualify for BNDES credit lines, companies are asked to meet some requirements: having discharged all their tax and social security obligations, present a satisfactory track, be capable of meeting payments by showing a consistent business plan and have enough collateral to cover the

risk of the transaction (BNDES, 2004b). Likewise, the other official banks lay down their own requirements for granting long term credit that, in general, are very similar to those laid down by BNDES (Lucato & Júnior, 2006).

Regarding the good behavior companies need to evidence, solid revenues for a 12-month period prior to the credit line request is one of them. This goes against the profile of junior mining companies, which will only have revenues after initial investments in survey and establishment of the processing plant for then selling the ore.

Sometimes, tax maneuvers are adopted to help companies' balance sheets to become more attractive to financing banks. Sometimes, this is done via a new shareholders' capitalization, which would show an improvement in companies' equity.

Another requirement from the Bank Financing System to back long-term financing are security interests, together with fixed assets, or also an accommodation by an individual representing the company statutory board.

The fact is that most investors in the mining industry belong to countries like Canada, Australia and England, and laws ruling on companies in these countries do not always match Brazilian laws. This makes it difficult to produce the documents required by the banks.

Another determining factor in acquisition of credit is that small businesses should comply with standards and guidelines pertaining to international agreements, such as the Equator Principles and the International Cyanide Management Code for mining of gold, which financial institutions are signatory to. Most of these agreements include a risk management structure that determines, assesses and manages a project environmental and social risks. They are considered as a minimum standard for due diligence and support responsible risk-taking decision-making.

From what has been said it can be seen how hard it is for junior companies to meet all the above-mentioned prerequisites.

It is in that regard that the following chapters discuss some of the instruments both in Brazil and abroad to obtain credit and successful cases in the financial journey followed by mining companies.

Some Sources of Financing

Credit instruments presented below are some examples of what is currently available to help junior companies obtain financing.

Brazilian National Bank for Economic and Social Development – BNDES

Brazilian National Bank for Economic and Social Development (BNDES) is considered a federal public company and is currently the major long-term financing institution for all segments in Brazilian economy.

Recently, BNDES CEO Luciano Coutinho said the bank provides support to small and medium businesses, and that the quality of its credit portfolio ensures the lowest level of nonperformance in all the Domestic Financial System.

It must be stressed that enterprises that cannot be supported by BNDES are those connected to mining that include rudimentary mining or prospecting.

However, access to credit via this path is not as simple as it seems. Chart 1 shows a good example of that. It presents disbursements for the mining industry made by BNDES between years 2008 and 2014.

	2008	2009	2010	2011	2012	2013	2014
TOTAL MINING	4.540.559.290	3.375.892.122	1.127.489.765	3.001.195.945	1.581.916.616	2.784.455.000	2.083.958.000
JUNIORS COMPANIES	0	0	0	0	106.000.000	202.000.000	55.000.000

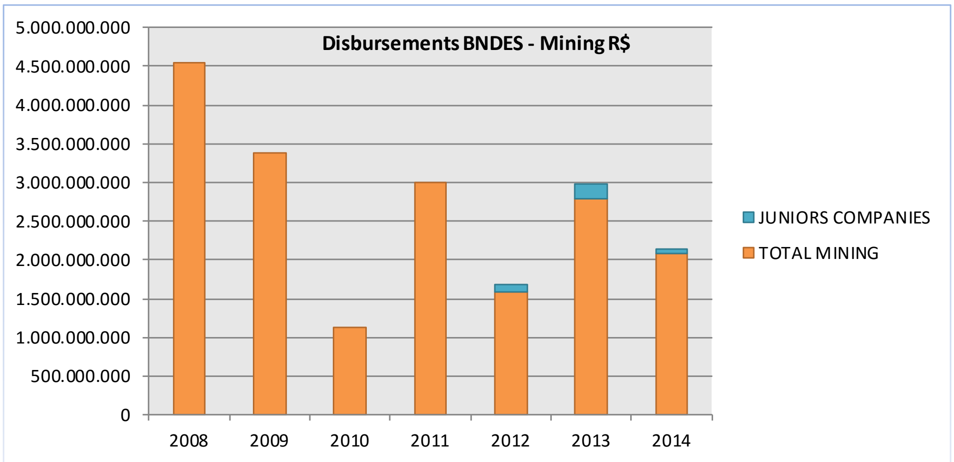

Chart 1 – BNDES Disbursements – Mining years 2008 to 2014
Source: BNDES/2015

Based on data made available by BNDES, it is possible to see the small amount of funds lent to junior companies when compared to the total amounts transferred to companies in the mining industry.

BNDES has a financial product called Finame. This is mainly geared toward the acquisition of new domestic machinery and equipment for micro, small and medium businesses. However, the best known transactions are those where Finame was obtained by large mining companies, such as the BRL 7.3 billion granted as credit limit to Vale S/A company, which invested the funds in expanding and upgrading its production capacity and also in logistics during the years 2008 to 2012.

The bank itself considers companies of the size of Vale as “traditional BNDES clients.”

Brazilian Stock Exchange – BM&FBovespa

Unlike foreign stock exchanges, the Brazilian stock exchange lists only large-size mining companies, as shown on Table 1, which displays financial data for 2014:

Table 1 – Companies listed at BM&FBovespa

Company Name	Trading Name	Segment	Shareholders' Equity (R$ Thousand)	Gross Operating Revenue (R$ Thousand)
CCX Carvão da Colômbia S.A.	CCX CARVAO	Minerais Não Metálicos	205.566	-
Litel Participações S.A.	LITEL	Minerais Metálicos	27.161.161	-
Manabi S.A.	MANABI	Minerais Metálicos	608.627	-
MMX Mineração e Metálicos S.A.	MMX MINER	Minerais Metálicos	(828.291)	329.046
VALE S.A.	VALE	Minerais Metálicos	149.601.623	88.274.564

Source: BMF&Bovespa, October/2015

Data provided by BM&FBovespa Department of Relationship with Companies and Institutions show the amount of funds obtained by large mining companies:

Since 2006, companies in the sector raised R$ 26 billion in the capital market

MMX's IPO in july/2006
100% primary offer
R$ 1.12 billion funding

Vale debentures in december/2006
100% primary offer
R$ 5.5 billion funding

Follow-on Vale in August/2008
100% primary offer
R$ 19.43 billion funding

The mining sector is 9.35% (R$ 231.73 billion) and 16% (R$ 19.82 billion) in market value and trading volume total listed companies in april/2012

Figure 1 – Borrowing by mining companies at BM&FBovespa
Source: BM&FBovespa, 2012

The program that best fits small businesses funding requirements provided by the Brazilian stock exchange is Bovespa Mais:

> Conceived for companies that wish to gradually enter the market, this segment aims at helping small and medium businesses to grow using the capital market. The gradual access strategy allows your company to properly prepare, at the same time "showcasing" it to the market, making it more visible to investors.
> Bovespa Mais allows for obtaining smaller funds when compared to New Market, but which are enough to finance your growth plan. Companies listed in Bovespa Mais tend to bring in investors that view your business as having a more acute growth potential.
>
> As stressed above, Bovespa Mais allows for listing without offer, that is, you can list your company at the Stock Exchange and have up to 7 years to do the IPO. This possibility is ideal for companies wishing to enter the market gradually.
>
> Companies listed in Bovespa Mais do not have to pay a register fee (a fee charged by BM&FBOVESPA for company listing) and get a stepwise discount in the listing maintenance fee, which is 100% in the first year" (BM&FBovespa, website retrieved in October 2015).
>
> No small mining company has been admitted in that program, so far.

Canadian Stock Exchange

The Toronto stock exchange is known worldwide for being the best-structured and providing the best incentives for the mining industry.

In order to gain access to this financing channel, the small mining business needs to meet some requirements. These include sufficient working capital or mine life, proven management and experience in the field, mineral survey and exploitation requirements meeting those of relevant Bodies, together with qualification for the *National Instrument 43-101 – NI 43-101*, which is a set of standards and guidelines for preparing reports and producing information related to mining projects, which provide a standard for advertising at stock exchanges within Canada.

At a presentation on 25 May 2012, during an event held by the Mining and Steelmaking Business Council in a partnership with the Business Council for Legal Matters, both from ACMinas – Minas Commercial and Business Association called Panel: Investments in Mining Project, guest speaker Mrs. Orlee Wertheim clarified the importance of the Canadian stock exchange in financing for mining.

In 2011 the largest financing figures were connected to trading at the Canadian stock exchange, according to data from the *Toronto Stock Exchange* presented in Figure 2:

Figure 2 – The importance of the Canadian stock exchange

Also, that stock exchange strong liquidity is also an ally for small businesses that need greater working capital for their financial resources.

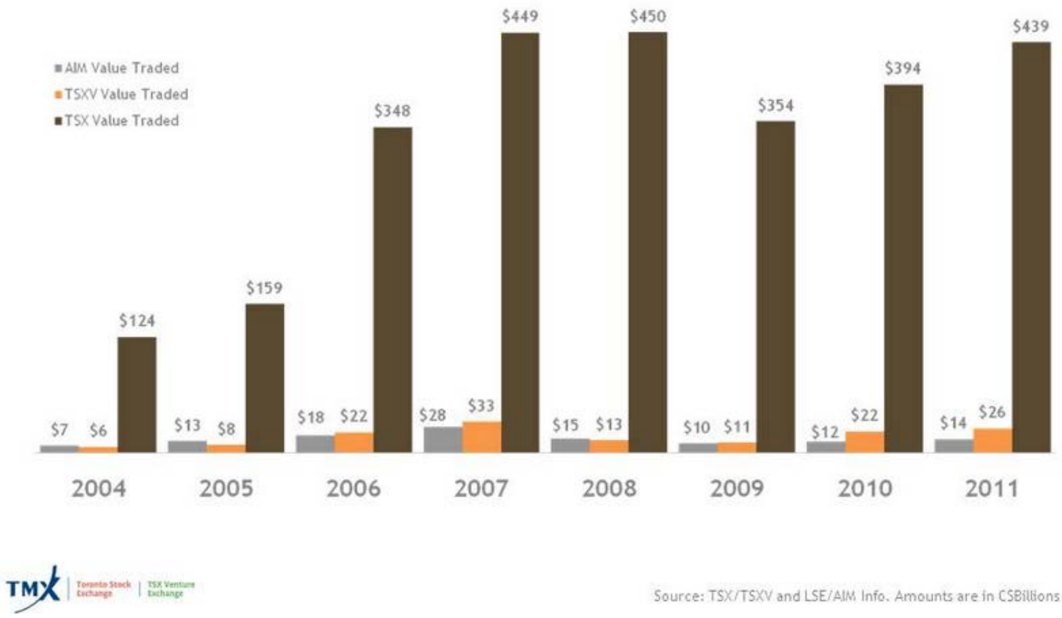

Figure 3 – Transaction Values between 2004 and 2011

The importance of that financing channel is clear when we analyze the stages mining companies listed in that stock exchange are at. Figure 4 shows their rating by stages in early 2012:

Figure 4 – Number of companies and the point their projects are at

South America was strongly linked to that financing channel, with over 280 mining companies listed in that stock exchange at the end of December 2011.

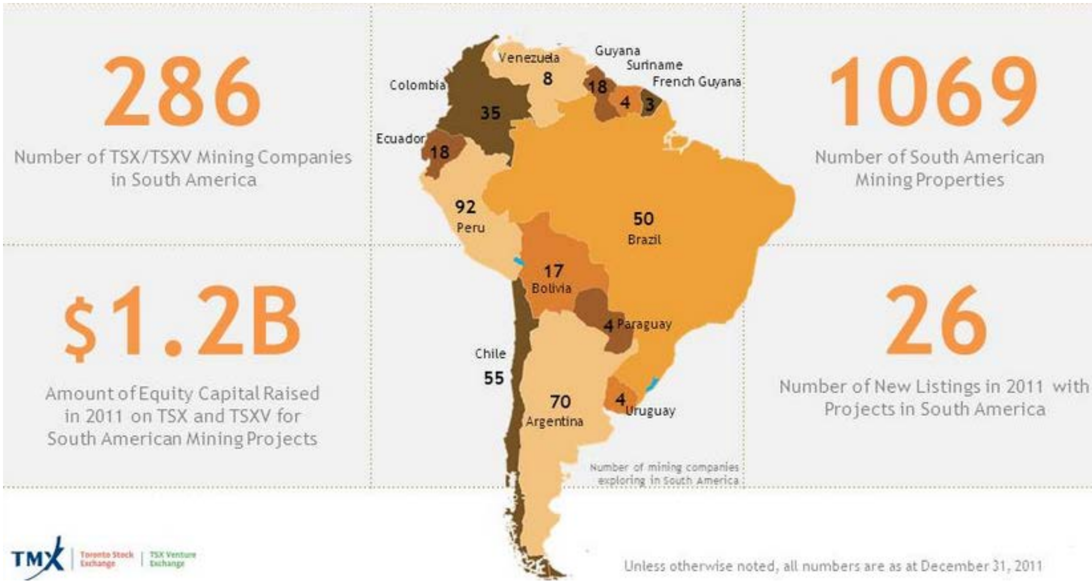

Figure 5 – Number of listed companies – South America

However, to make the scenario for small mining businesses more difficult, a negative behavior regarding the Toronto stock exchange index has been noticed, both regarding the number of negotiations and the Initial Public Offering – IPO. According to studies from consulting firm Deloitte:

> For the first time in ten years, the Toronto Stock Exchange did not have initial public offerings of mining shares in the whole first quarter of 2013, and financing in the Australia Stock Exchange plummeted (Góes, 2013).

On analyzing TSX *Venture* – which represents the primary risk capital market in Canada – for the past few years, the negative behavior of the index becomes clear. A capital flight into United States and the need for technological innovation of the stock exchange trading platform are some of the reasons given by TSX for the decline.

Chart 2 – TSX Venture Index Evolution
Source: www.tmxmoney.com

As in Canada the mechanisms for small investors participating in the stock market are well-developed, this facilitates the growth of the index over time, thus also strengthening this financing channel for small mining businesses. However, with the increase of trading by large banks in that market and the resulting improvement in the US economy that historically has both a large advantage and financial stability, the index proved fragile, also due to the smaller number of listed companies. This partly accounts for the high cost linked to the performance of companies listed in that index, as in average USD 200,000 a year are required to meet regulations and pay for legal fees alone. It is a very high cost for junior mining companies.

Decline in the prices of commodities, whose quotations more recently peaked between 2011 and 2013 – and hardly would be sustainable in the face of the increasing growth of production above consumption, including the lower appetite from China that, despite the growth of its economy from 7 to 7.5 %, has been slowing down its demand for mineral goods, which makes investment via the Toronto Stock Exchange not as attractive as before.

According to Valor Econômico newspaper issue of 06 February 2014:

> Part of the money that used go to the cash of the so-called 'junior companies' (survey companies or those with projects in their early stages) is now being invested in other businesses or into financial products. (...) Investors have kept their resources in the industry – many of them because they did not want to sell already written-down shares – and avoided making new investments.
> Only projects in more advanced stages are now able to obtain funding. As an alternative, many companies are trying to present their projects and seek for funds in other markets, like the London Stock Exchange. Or else they are looking for partners overseas, like in China, for instance (Alonso, 2014).

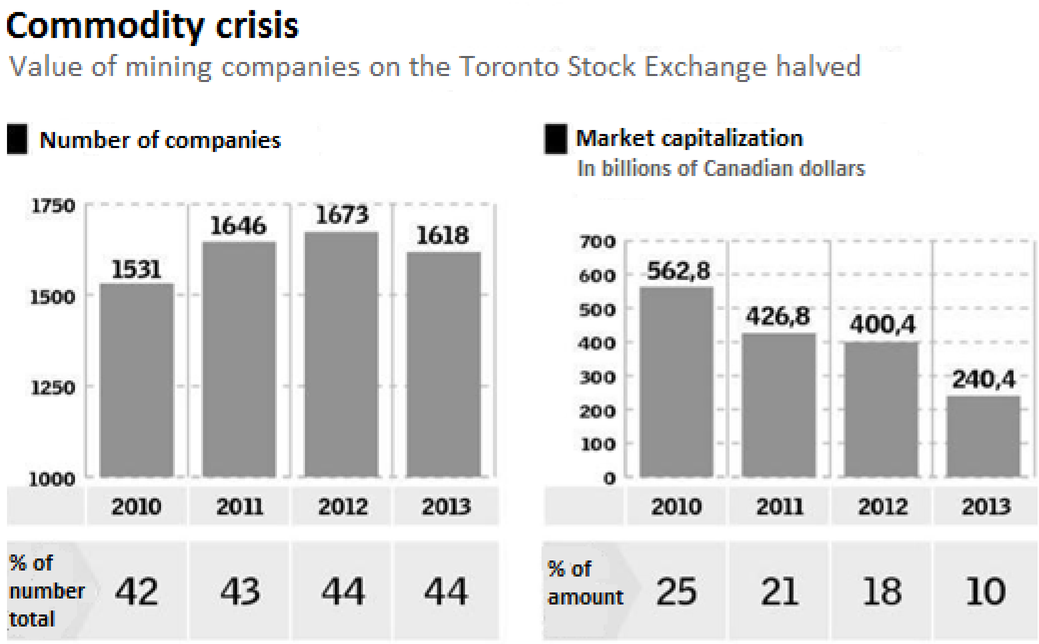

Figure 6 – The commodities crisis and its impact in trading at the Canadian stock exchange
Source: Valor Econômico, February/2014

Showing the decline in commodities prices, Chart 3 displays the evolution of the IC-Br Index from the Central Bank of Brazil, which provides a summary of the price of commodities in the agribusiness, mining and energy industries, the mining industry being represented by aluminum, iron ore, copper, tin, zinc, lead and nickel.

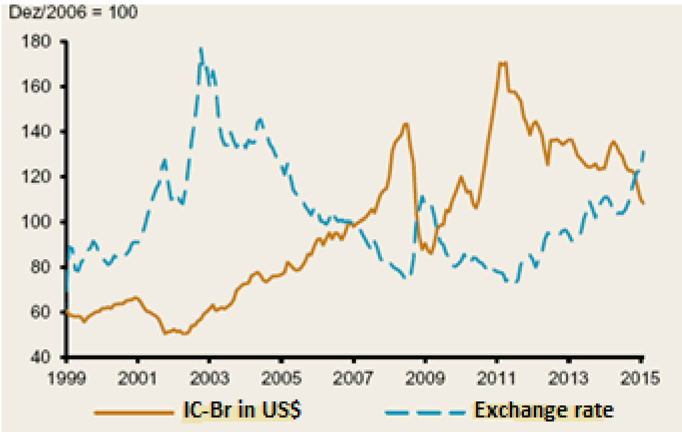

Chart 3 – Commodities and exchange rates
Source: Central Bank of Brazil, March/2015

Private Equity Funds

Private equity funds are those that directly invest in companies, whether they are listed in stock exchanges or not, in order to manage them and exit financing on the long term.

These investments coming from private equity funds are mostly geared to large companies in the mining industry, according to data collected by Jesse Riseborough and Firat Kayakiran in February 2015:

> The funds spent a small part of the money they had available last year. In total, 50 transactions were notified for over USD 2 billion made by private stakeholders in the mining industry, according to an analysis of law firm Berwin Leighton Paisner (...). Gold was the most popular commodity for those looking for transactions, totaling 15 of those concluded, followed by coke coal, with 6 transactions, as shown by the analysis. Average investment was USD 43.8 million. Davis' X2 raised about USD 4.8 billion in equity investments and has been looking for assets to buy from the largest mining companies in the world, like Vale SA, BHP Billiton Ltd. And Anglo American Plc. Its financiers include Noble Group Ltd., the largest raw material trader in Asia, TPG Capital private equity fund and sovereign wealth and pension funds.
>
> Pengilly's QKR is financed by Qatar's sovereign wealth fund and by the wealthiest man in Poland, Jan Kulczyk. They concluded their first transaction last year, namely the acquisition of the Navachab mine in Namibia from AngloGold Ashanti Ltd. for USD 110 million in July. The fund is also considering placing a bid of about USD 1 billion for Nevsun Resources Ltd. from Canada, as stated by sources in the industry in November (Riseborough and Kayakiran, 2015).

Even with evidence that most funds are allocated to large companies in the industry, even so resources from private equity funds are a good option for small businesses.

According to a report from JP Morgan Bank based on analyses about the *Denver Gold Forum*, held in September 2015 in th US, while investment funds have been shirking investments in the mining industry, private equity funds have been using the chance provided by devaluation of the currency of some countries like Australia and Brazil to support investments from junior companies, including merges and acquisitions.

Recently, DuSolo junior company, a fertilizer manufacturer, managed a on-year USD 750 thousand loan from *Tembo Capital* private equity fund. The company will invest some of the funds obtained to advance its mineral surveys in the São Roque project, located in the town of Piumhi, Minas Gerais state, Brazil. As *Tembo Capital Group* is one of DuSolo's shareholders, this confirms that the commonest path for leveraging resources at small miners is via their shareholders, who are mostly investment and/or private equity funds.

Financier of Studies and Projects – FINEP

Finep was established to foster research projects connected to technological innovation. It is directly linked to the Ministry of Science and Technology – MCT – and can help research institutes, private and public companies, investors, tertiary sector organizations, and also international bodies.

To apply for financing, an interested company needs to present a project where technological innovation stands out. This project will go through a screening process where the following technical criteria provided by Finep will be assessed:

- The intrinsic merit of the proposal, assessed based on strategic guidelines, operational guidelines and criteria for each action;
- The merit of the proposal against the others – this happens when there are proposals competing among themselves;
- Economic and financial sustainability of the applicant.

In order to discuss with society and companies the opportunities and routes for the latter technological development, Finep, in a partnership with BNDES, has put together a workshop called Opportunities for Development and Innovation in Mining and Metals in October 2015. The matters discussed included articulation of a new plan to support the mining and metal industry, called Inova Mineral. This includes fostering density and value-adding in the mineral base production chains, fostering technological development and innovation in the industry and overcoming technical challenges in the frontier of the mining industry in a sustainable way.

Some minerals are preferred by this program, due to its strategic position in economy. These are called "future-bearing minerals" by Finep, and include cobalt, graphite, lithium, metals in the platinum group, thallium, titanium, molybdenum, tantalum, silicon, rare earths, vanadium and niobium. Other minerals with investment incentive are phosphate and potassium, with a high level of external dependency.

According to Brazilian Metallurgy, Materials and Mining Association – ABM, fields for possible innovations in the mining industry may include decrease in new water consumption in processes, development of logistics systems for transportation in mines, together with improvement of mining software.

Credit instruments are released via bid notice launching and publication. These include details on financial support instruments, such as availability of funds and eligibility criteria for interested companies, together with analyzed business plans with deadlines and screening process stages.

So, another major option comes up within Brazilian economy to help small mining businesses to access the credit market. It is evident that they need to be well supported so technological innovation to be implemented in the projects can be characterized. This will also help provide a possible competitive advantage to that small mining business.

Companies that declare their investments in Research & Development may obtain tax benefits via Lei do Bem (Asset Act), no. 11196, from 2005.

According to data provided by MCT, during the 2006 to 2009 period, 23 companies belonging to the mining and steelmaking benefited by that Act were identified. All of them are large-sized, like: Alcoa Alumínio S/A, Anglo American Brasil Ltda., Companhia Brasileira de Alumínio, Vale S/A, Villares Metals S/A and Votorantim Metais Zinco S/A.

Evidences, successful cases and comments

The credit tools shown demonstrate how low are the chances of getting financing domestically.

Another example of how a large mining company finds it easier to access credit is the partnership between Bradesco Bank and Bank of Brazil, together with a private company, Vale S/A. This resulted in the Inove financing line, geared at funding small and large suppliers for the larger mining company. Goals of the company include having available for these suppliers about BRL 120 million per year, as per data from 2009.

According to Vale company, by acceding to InoveCapital, suppliers are expected to have a greater credit line offer, lower interest rates offered, simplicity, safety and speed in obtaining funds and strengthening of their working capital.

An alternative achieved by Mineradora Mirabela, located in the State of Bahia, Brazil, was obtaining with Bradesco Bank a USD 50 million credit line, backed up by an advance 7-year sales agreement for nickel concentrate. This kind of agreement is called an offtake.

An evidence of success in a junior mining company's financial stability is in the formation of a join venture, which is the association of two or more exiting companies in order to start or carry out a joint economic activity for a given period of time, with a view – among other things – at obtaining profits. That is what Miranda Gold Corp. has been able to establish to fund its activities. The company strategy involves keeping enough cash resources to support the more critical stages. This includes geological exploration and the way found by Ken Cunningham, the company CEO, is getting investors for these joint ventures.

We can see that, even considering the controversial world economic scenario, related to the mining downturn cycle, private initiative is even so able to promote investment meetings where mining companies and potential investors gather in a common space to discuss market trends, prices and best practices in the industry. The *121 Mining Investment Conference* held in London in April 2015 is an example of one such incentive. This conference is also held in Hong Kong and Cape Town.

In 2015, even in face of the world crisis, there is evidence of funds raised by Brazilian junior companies, like: in order to fund their activities, Avanco Resources opted for two different ways of getting financial resources. One of them is a royalties binding agreement on the production of copper and other metals by the company with *Black Rock World Mining Trust*, which is also a shareholder in the business. This agreement provides for an investment by the trust of USD 12 million as a counterpart for royalties net smelter return of 2% on copper, 25% on gold and 2% on other metals produced in the areas of Antas North and Pedra Branca, belonging to Avanco and located in the State of Pará, Brazil.

The other initiative to leverage resources was the execution of an non-binding agreement with Votarantim Bank, which granted the company a credit of USD 30 million.

Evolution of Avanco share prices, as well as the amount of its grading in the Australia Stock Exchange (ASX) can be seen on Chart 4.

Chart 4 – AVB – Avanco Resources Limited
Source: ASX, November/2015

Another example is Orinoco Gold Limited, an Australian mining company focused on gold production and located in the State of Goiás, Brazil. Orinoco is also listed in the Australian stock exchange, which uses the code JORC – Joint Ore Reserves Committee – to standardize publication of information listed companies have to provide to their investors.

In 2014 the company raised USD 1.1 million via the issue of 15.7 million shares. In 2015, the mining company executed a financing package with an investment group from the mining sector of *Singapore Chancery Asset Management*, thereby obtaining about USD 8 million. The counterpart for the investment group will be a share in the gold production. In Chart 5 we can see the evolution of the company prices, as well as the amount traded in the Australian stock exchange.

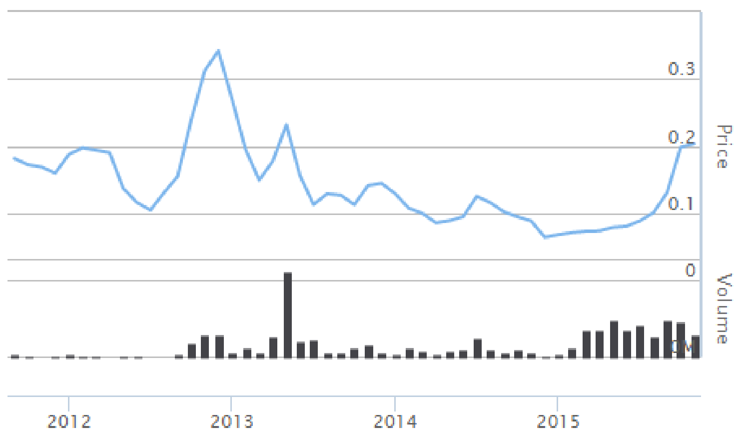

Chart 5 – GOX – Orinco Gold Limited
Source: ASX, November/2015

From the options for credit and also the cases of success detailed above, it can be concluded that there are not enough credit instruments for the sustainable development of the activities of small businesses from the mining industry, and priority given to larger mining companies is clear. Even BMF&Bovespa being much larger than the Canadian TSX, the latter finances more than half the mineral exploration in the world. As junior companies answer for most discoveries of new ore beds and basically depend on the capital market to leverage their projects, we suggest that Brazilian institutions – which typically shirk risks

– should take the successful cases from abroad as examples and apply these practices in a manner better fitting the domestic situation. That way, they would provide greater maturity to processes.

Opening up to Internationalization

Internationalization can be seen as a process where companies trade their products or services outside the local market by directing their sales to the international market.

It is well known that the mining industry is characterized by long-term investments, widespread geographic location and intensive use of capital. This, naturally, motivates internationalization with a stress on expansion based on a search for increasing production volumes, finding new markets to strengthen the business, and for maximizing investment made in the ore bed survey and development.

As per the definition provided by Mathias Heider in an article for InTheMine magazine:

The process of internationalization of Brazilian mining companies is characterized by a search for assets (in all stages) and mining projects capable of being consolidated in a sustainable and competitive way, as well as supplementing strategies for the domestic market, thus decreasing vulnerabilities (foreign exchange, demand, etc.). (Heider, M., 2012).

Difficulties to obtain financing in the domestic credit market end up providing an opening for internationalization of mining in Brazil, as foreign investments in that segment are significant for, abroad, that kind of investment is commonplace. This movement can be defined as a reverse internationalization, since foreign influence prevails, at least in that financial area of the company.

There are several factors that contribute for realizing foreign investments in Brazil. One of them is the trend in commodities prices. An investor will only invest their funds in a business in Brazil if they are convinced that, in the long run, prices will tend to go up and that the demand for a given mineral will also show signs of future increase.

According to a story in América Economia:

As the wealth of mineral resources in Brazil is significant and there are many business opportunities, domestic investments and investments by foreign groups – especially Canadians, Australians and Chinese – are increasing. Ibram (Brazilian Mining Institute) runs studies on companies' investment plans within a five-year term. In 2007, investments added up to USD 25 billion (2007-2011) and have been gradually rising until the current forecast of USD 75 billion for the 2012-2016 period. (Rocha, D., 2012).

Recently there came up in the businesses environment the so-called angel investor, which appoints those that deposit their funds in startups and share with them the uncertainties of the business, always with an eye toward the high return potential these startups have.

The counterpart of the foreign investment mostly implies in the financing institution becoming the junior company major shareholder and/or a return in royalties.

This trend toward reverse internationalization will hardly decrease, considering the growing globalization and the excellent opportunities for mineral deals in the Brazilian territory.

New Mining Regulatory Framework

As mining is an activity involving much risk and, conversely, has a high rate of return, it is extremely important for the industry to be ruled by norms and laws that provide confidence to that businesses segment of international scope. A coherent regulatory framework capable of inspiring confidence is vital.

In Brazil, the mining industry is regulated by an old, oftentimes outdated code from 28-Feb-1967.

Unlike what happens in countries like Chile, Peru and Portugal, mining companies find it difficult to offer their survey and exploration mining rights as collateral for financing. Should the financing institutions accept that kind of collateral and should the mining company that is being funded not meet its obligations, the mining right cannot be transferred to the financing bank, since ownership returns, in that case, to the Federal Government.

Mining rights each company has are rated as an asset in their balance sheets. This, in a way, should make it easier to mortgage these intangible assets when acquiring a loan. But, even so, there are difficulties.

A sign that the Government would change the norms ruling the industry always reaises mining companies expectations for renewal and improvement of several aspects, including regarding a better and easier access to financing for mining projects.

Originally, the text of Bill 5807/2013, annexed to Bill no. 37/2011, did not provide anything on a permit for the use of mining grants, authorizations and permits as collaterals to obtain credit lines in Brazil.

However, the interest mining companies and investors have in having their mineral reserves available as collaterals in loans is widely known.

A sign that these claims are included in the agenda is the interest displayed by the rapporteur of the Bill, Federal Congressman Leonardo Quintão, who stood for the importance of the matter after presenting the demands for use of mining authorizations and permits as financing collateral made by the Brazilian Cooperative Organization (OCB) via Amendment no. 268, filed by Congressman Eduardo Sciarra (PR). Also, during meetings held by the Government on 20-Aug-2013 and 25-Sep-2013, where issues of "Guarantee of financial resources in the new institutional model for the mining industry" and "Financing of investments in surveying and mining," respectively, were discussed, shows the interest displayed by representatives of various entities, like General Economic and Fiscal Analysis Coordinator of the National Treasury Secretariat Mr. Hailton Madureira de Almeida, BM&FBovespa representative Mr. Roberto Ricardo Barbosa Machado and Rio Grande Mineração S.A. CEO Luiz Bizzi in updating this aspect of the Mining Code pending in the Brazilian National Congress.

In its latest version presented by the Special Committee and intended to provide an opinion on Bill no. 37/2011, whose rapporteur is Federal Congressman Leonardo Quintão, we find some important mentions to the possible use of mining rights as financing collaterals for the mining industry:

> Regarding financing of survey and mining activities, important instruments have been introduced, such as mineral survey and mining credit bills, mortgage and trust ownership. These bills may cause a true revolution in the mining industry, like what happened with Brazilian agribusiness.
>
> It must also be stressed that mining rights may be encumbered for the purposes of obtaining financing of activities related to mine development via mortgage or trust ownership supported by collaterals (...)
>
> Art. 6 of mining rights establish rights in real estate that are different and independent from the surface property, binding to third parties, transferable and that can be offered as collateral (Quintão, 2014).

Another thing that shows progress regarding regulation standards is Brazil having joined CRIRSCO – Committee for Mineral Reserves International Reporting Standards in May 2015, an initiative from ADIMB – Agency for Technological Development of the Brazilian Mining Industry – and ABPM –

Brazilian Association of Mineral Survey Companies that includes development and implementation of Brazilian standards in line with international procedures already adopted by other mining countries for the proper reporting of their mineral resources and reserves.

The new Mining Code is pending for vote in the Brazilian Congress sine 2013, but the vote went back to the agenda thanks to the recent environmental disasters caused by the breaching of a tailings dam in the State of Minas Gerais.

CONCLUSIONS

Considering the aspects discussed above, we concluded that, despite small business trying to obtain credit, most of them do not meet the requirements of our Domestic Financial System, whether because the companies themselves are not aware of existing credit tools, whether because financing agencies are not ready to match their credit instruments to the mining business reality.

It is clear that globalization is a process that intensifies trading and investments in mining. However, Brazilian economy traditional aversion to risk and a discouraging economic scenario involving high inflation and interest rates – which make investment in government bonds with assured profitability into a safe harbor for investors – make if very difficult for credit to be channeled and serve as a tool to foster mining enterprises.

It is also clear that the stereotypical view of the mining industry as harmful to the environment is an obstacle in leveraging financing. We must keep in mind that one should look at the countless benefits mining provides society with. Also, it is not enough to just contemplate the present, where we see temporary degradation of part of Nature to obtain mineral resources, but cast our eyes out to the size of the planet and the billions of years it took for it to form. If we consider that global scale, we will see that even mineral resources are renewable, it is only a matter of time.

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DOES MINING SECTOR IMPROVES OR RETARDS GROWTH AND DEVELOPMENT? CASE STUDY OF BOTSWANA AND AUSTRALIA

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DOES MINING SECTOR IMPROVES OR RETARDS GROWTH AND DEVELOPMENT? CASE STUDY OF BOTSWANA AND AUSTRALIA

ABSTRACT

There is an ongoing debate surrounding the impact of mineral resources on nation's economic wellbeing. Mineral resources are expected to be a blessing, a gift of nature available to be developed, sold and used to better citizens of the host country. Yet often minerals are linked to curse. Nations blessed with abundant mineral resources have not performed as well as mineral resource-scarce economies. This resulted in some observers suggesting that mineral resource endowed economies are better off leaving the resources untapped. However, others opine that there is nothing inevitable about the poor performance. The study attempt to examine the impact of mineral resource sector on the economy of Botswana and Australia based on the Dutch Disease hypothesis. The aim of the study is to examine the dynamic relationship between mining GDP, manufacturing GDP, services GDP, inflation and exchange rate. Vector autoregressive approach is employed to examine the dynamic relationship between mining sector, exchange rate, inflation, manufacturing sector and services sector. The method consists of impulse response function to trace the adjustment of variables to shocks in the system, variance decomposition to indicate the contribution of each variable to the forecast error of another and vector error correction analysis for Botswana and Australia respectively. The study covers the period of 1975-2010. Overall the results suggest that macroeconomic policies are principal for resource-based economies because mining boom tend to impact the structure of the economy.

KEYWORDS

Dutch disease, Inflation, Exchange-rate, mining GDP

INTRODUCTION

The notion that natural resource oriented economies are destined for retarded or incomplete development has been around for quite some time. According to this perspective, the windfall associated with resource abundance has brought in its wake societal, policy and economic restraints on development. Sachs and Warner conceptualised this perspective into what is known as the 'resource curse' hypothesis. The hypothesis has been supported by cross country study and panel regression analysis revealing an inverse relationship between resource intensity and indicators of economic performance such as rates of growth, investment and human capital. Substantial number of papers have since considered the natural resource curse hypothesis from different points of view.

Recent work has provided something of a counterbalance by indicating that the curse is not inevitable and by investigating what resource-based economies can do to mitigate it. The presence of natural resources does not cause economic stagnation, rather induces certain distortions in the economy which then serve as transmission channels, which in turn, affect economic growth. Some transmission mechanisms include, the Dutch disease, rent-seeking, government mismanagement and low levels of human capital. Some resource-based economies have performed positively through a long economic development period despite having some symptoms of resource curse such as Dutch disease. Our focus is on Australia and Botswana as case in point of resourced based economies that have experienced economic growth and modern economy more particularly Australia. However, these countries are cited as having suffered the Dutch disease and it is therefore the aim of this paper to re-examine the dynamic relationship between inflation rate, exchange-rate, manufacturing output, mining output and services output in both countries. The contribution of this paper is to apply time series econometric method to examine the structure and adjustment of the concerned variables to mining shocks in Botswana and Australia. Although these countries differs in terms of economic development stage, geographical location, population size and historical development process, they both evolved and evolve as resource-based economies and have almost similar economic structure. Mineral resources have dominated Australia exports throughout the last century and Botswana still does export more than 80% of mineral commodities and mining sector account for more than one third of the nation GDP. Therefore Australia and Botswana may be described as resource-based economies both in history and current condition. Therefore the interaction of mining sector and the rest of the economy in these countries are used to point out that retarded economic growth and development is not a by-product of resource-based economies.

Theoretical framework of Dutch disease

Dutch disease denotes an economy that features coexistence of growing sector and lagging sector that are tradable. The growing sector or booming sector as is usually referred is the resource extractive and the lagging sectors are manufacturing and agriculture (Corden and Neary, 1982, p.825). This term was coined to explain the negative effects that North Sea Oil and gas revenues had on Dutch industrial production. The Dutch disease result from currency inflows associated with increasing resource exports resulting in appreciation of the real exchange rate. This coincides with reallocation of factors of production, capital and labor drawn away from agriculture and manufacturing to the resource extractive sector. Moreover, the prices of non-tradable sector goods such as construction and other services rise leading to uncompetitive agricultural and manufacturing goods. Natural resource booms, in effect, crowd out other important sectors of the economy and render them uncompetitive. This results in countries with resource-dependent economies that are vulnerable to the inherent volatility of commodity prices (Davis and Tilton, 2005; Leite and Weidmann, 1999; Mogotsi, 2002). The Dutch disease operate through two different paths. The resource movement referring to mobile factors of production transferring to the booming sector. The spending effect occurs as the extra income is spent on non-traded sector thus raising prices of the non-traded sector as compared to the non-booming traded sector (manufacturing).

Botswana and Dutch disease

The argument that Botswana has suffered the Dutch disease or not is not settled. According to Iimi (2006) the country has benefitted from the coexistence of good governance and abundant mineral resources, diamonds to be particular. There is no clear evidence of Dutch disease hypothesis. IMF (2007), point out that the resource movement effect is limited considering the capital-intensive nature of diamond mining. The spending effect has been limited, first because a large percentage of goods consumed in Botswana are sourced from South Africa thus reducing the effects on the non-tradable sector. To add to IMF point of view, Norberg and Blomstrom 1993 argue that revenues from the diamonds are kept in foreign capital markets rather than invested or consumed at home and this policy has largely reduced the spending effect thus find little evidence of either a resource movement or spending effect in Botswana. Hillbom, 2008 opine that Botswana does not suffer from typical Dutch disease but the pre-conditions are present.

Contrary to the previous views, Mogotsi 2002 put forward that Botswana has suffered a mild form of Dutch disease. Unlike the typical Dutch disease paths, resource movement effect and spending effect, Botswana had high unemployment at the start of its mineral boom. According to Mogotsi, the mining sector took skilled labor from agriculture and manufacturing and replaced them by less skilled manpower thus lowering productivity in such sectors. Mogotsi also argue that mining boom resulted in significant real appreciation of exchange rate and major spending increases. With focus on agriculture Love (1994) argue that diamond mining affected agriculture through rise in Botswana currency pula against South African rand.

Australia and Dutch disease

Australia has a history of mining booms dating back to 1850s gold rush to the current episode of both mineral and energy boom (Battellino, 2010). The country's mining industry grew by 85% (gross value added) and this was measured in Australian dollar from 2005 to 2011 (Corden, 2012). The core of the boom is centred on large expansion in the iron, coal and gas industries, which grew by 100% in value reflecting to a significant extent increases in prices. The boom has been to a great extent fuelled by demand for resources by emerging developing economies such as China and India. This resulted in the value of Australia's GDP growth by 41% from year 2005 to 2011. Therefore, minerals and energy boom in Australia has been prime because of this considerable growth (Gregory and Sheehan, 2011: Gregory, 2012).

Increased capital inflow caused by the rapid rise of commodity prices strengthened Australian dollar. According to TRA (2012b) Australia's strong ties to Asia's demand for resources have played a key role in the long term rise of Australian dollar against other leading currencies, which reached historic records in mid-2012. Corden (2012) argue that, mining exports of Australia grow at the cost of part of agriculture, manufacturing sector and international education. Moreover, output and employment in the construction industry have grown reflecting strong demand for mining-related infrastructure, also there have been a shift in the composition of the manufacturing industry towards mining-related manufacturing and away from import-competing manufacture (Connolly and Orsmond 2011). These works highlight that commodity exports boom tend to result in appreciation of real exchange rate, thus weakening the performance of other sectors in the economy such as manufacturing.

It is clear from the above literature review that that the evidence regarding Dutch Disease hypothesis is mixed especially for Botswana. Therefore, this paper is an attempt to re-investigate the Dutch Disease for both countries considering the dynamic relationship of the concerned variables in order to examine the structure and adjustments of the variables. As noted by Hutchison (1990, 1994), the rate of occurrence of deindustrialisation vary between economies based on underlying structural parameters.

The econometric methodology

Data

In the present study time series data has been considered to explore the dynamic relationship among the variables. Annual data on mining GDP, Service GDP, and manufacturing GDP sourced from Australia Bureau of Statistics, inflation and exchange rate sourced from world development indicators for Australia. For Botswana the data is sourced from Bank of Botswana annual reports for mining GDP, service GDP and manufacturing GDP while inflation and exchange rate are sourced from World development indicators. The observation spans are from 1975-2010. The data for Australia is expressed in chain volume measures in Australian dollar while the data for Botswana is in growth percentages. The variable specifications for empirical analysis are as follows:

- MIN: mining GDP
- SERV: service GDP
- MANUF: manufacturing GDP
- INF: inflation
- EX: exchange rate

Methodology

Before applying any econometric techniques, the statistical properties of the time series variables are needed to be verified. The basic testing procedure requires three steps. The first step is to test for unit root to confirm the stationarity of each variable (Engle and Yoo, 1987). The Augmented Dickey-Fuller tests and Philips-Perron (PP) tests (1988) are used to perform the unit root testing. The second step is to test for the long-run cointegrating relationship between variables and this is done through the use of Johansen cointegration method. Finally if all variables are I (1) (integrated of order one) and cointegrated, vector error correction model (VECM) suggested by (Engle and Yoo, 1987) will be performed. In this case, an error correction mechanism occurs by which changes in the dependent variables are modelled as a function of the level of the disequilibrium in the cointegrating relationship, captured by the error-correction term. However, if all the variables are integrate of order one I (1) and not cointegrated, an unrestricted vector autoregressive (VAR) model is suggested (Sims, 1980). The VAR model provides a multivariate framework where changes in a particular variable (mining output) are related to changes in its own lags and to changes in other variables and the lags of those variables. This model consists of impulse response functions and variance decomposition. To verify the causal relationship between the variables, Granger Causality test is used. According to Granger (1969), X is said to granger cause Y, if past and present values of X helps to predict Y.

Empirical results

Unit Root Test

We used Augmented Dickey-Fuller unit root tests to test for non-stationarity in our data series. Considering the low power of the ADF test we used also the Phillips-Perron test as an alternative test which takes into account the serial correlation and heteroscedasticity. The data for Botswana is stationary at level except for exchange rate making it qualify for unrestricted vector autoregressive analysis. While the time series data for Australia is non-stationary and cointegrated therefore analysed using vector error correction model. The results are presented in Table 1 below.

Table 1: Unit root test results for Botswana case study

Variable	Type	Level		
		Test statistics	Test critical at 5%	Integration order
MIN	ADF	-5.29	-2.94	I(0)
	PP	-5.29	-2.94	
MANUF	ADF	-8.97	-2.94	I(0)
	PP	-8.86	-2.94	
AGRIC	ADF	-6.15	-2.94	I(0)
	PP	-6.15	-2.94	
SERV	ADF	-5.22	-2.94	I(0)
	PP	-5.21	-2.94	
INF	ADF	-3.42	-2.94	I(0)
	PP	-3.44	-2.94	
EX	ADF	0.182	-2.94	I(1)
	PP	0.48	-2.94	

Table 1.1: Unit root test for Australia case study

Variable	Type	Level		First difference		
		Test statistics	Test critical	Test statistic	Test critical	Integration order
LMIN	ADF	1.704216	-2.948404	-5.881179	-2.948404	I(1)
	PP	2.058292	-2.948404	-5.88153	-2.948404	
LMANUF	ADF	-0.676467	-2.948404	-5.306046	-2.948404	I(1)
	PP	-0.61289	-2.948404	-5.489941	-2.948404	
LSERV	ADF	2.399858	-2.945842	-4.136716	-2.948404	I(1)
	PP	2.749069	-2.948404	-4.121993	-2.948404	
EX	ADF	-2.034328	-2.948404	-4.148262	-3.6329	I(1)
	PP	-1.879424	-2.945842	-4.185375	-2.948404	

INF	ADF	-2.655088	-2.945842	-6.175575	-2.948404	I(1)
	PP	-2.6825	-2.945842	-7.806611	-2.948404	

Cointegration Test

The cointegration tests based on multivariate Johansen approach (1988) uses two statistical tests namely: Trace test and Max-Eigen value. The results of the Johansen cointegration tests for Australia are displayed in Table 2 below. The Trace test and Max-Eigen value suggest the existence of one cointegrating vectors at 5% significance level. The existence of cointegration signifies that there is at least one long-run equilibrium relationship among the variables.

Table 2: Johansen's Cointegration Test results

Hypothesized number of cointegrating equations	Eigen Value	Trace Statistics	Critical value at 5% (p-value)	Max-Eigen statistics	Critical Value at 5% (p-value)
None*	0.661	79.5	69.8(0.0069)	33.88	33.9 (0.016)
At most 1	0.45	41.7	47.9 (0.167)	27.6	27.6 (0.282)

* denotes rejection of the hypothesis at the 0.05 level

Main Results

Figure A1 reports the impulse response functions, IRFs, of the estimated stationary VAR for Botswana case study. The IRFs show the magnitude and the directions of how a variable respond to shocks within the model. The reported results indicate that the response of manufacturing, services, exchange-rate and inflation to a one standard deviation shock to mining is positive. However the effect of the shock is minimal and lasted for a short time. The results indicate that for a short-run the economy of Botswana did not experienced severe inflationary pressure and exchange rate appreciation from the mining boom that could cause distortions. This indicate prudent macroeconomic policies adopted by the country such as inflation target and de-linking mineral resource revenue and the government spending to avoid currency appreciation.

Variance decomposition shows the contribution of each variable to the variations of a variable within the estimated VAR model. Table A1 reports the variance decomposition of the estimated multivariate VAR model. The results show that mining contribute 32% to the variation in manufacturing followed by exchange-rate and inflation rate by 15% and 14% respectively. Variation in exchange rate is explained mostly by itself and manufacturing by 11.7% in the tenth year and 5.3% by mining. While the variation of inflation is explained by 22% of exchange rate followed by 10.8% of mining. The IRFs and variance decomposition results indicate that the economy of Botswana did not suffer high currency appreciation and inflationary pressure that are associated with mining boom.

The case of Australia was empirically tested using VECM to correct the disequilibrium in the cointegration relationship and to test for long and short-run causality among cointegrated variables. The results of the long-run equilibrium relationship and causality are presented in Table A2. It shows that the error correction for inflation as the dependent variable is negative and significant indicating long-run relationship between inflation and all other variables in the model. Moreover, the results indicate that manufacturing granger cause inflation. However, the results indicate that there is no long-run relationship or causation between other variables in the model. The results do not show evidence of inflationary or appreciation of exchange rate as a result of mining boom in Australia. For consistency of the analysis we performed diagnostic tests including normality test, serial correlation and heteroscedastic distribution. The normal distribution of residual has been examined using Jarque-Bera statistic and corresponding probability value in the histogram method. The diagnostic results indicate that all are normally distributed except manufacturing. To test for the presence of heteroscedasticity we used ARCH test and the test does not reveal heteroscedasticity effect. Serial correlation was tested using Breusch-Godfrey serial correlation test and it has been found that there is no evidence of serial correlation in the model. The results are presented in Table A3.

CONCLUSION

This paper investigates the dynamic relationship between inflation, exchange-rate, mining, manufacturing and services GDP for Botswana and Australia using unrestricted and restricted VAR. The results does not indicate evidence of inflationary pressure and currency appreciation caused by mining GDP. The results indicate minimal response of other variables in the model to a one standard deviation shock to mining. Moreover, the results indicate that mining does not contribute much to the exchange rate and inflation in Botswana thus positing that if Botswana experienced Dutch Disease is not through exchange rate and inflation transmission channel and the results are consistent with (Iimi, 2006a; Norberg and Blomstrom, 1993). The results for Australia case also do not provide any evidence of real exchange appreciation associated with mining boom. This is indicated by lack of long-run and short-run and causal relationship between exchange-rate and mining output. The results for both countries imply sound macroeconomic policies adopted by the two countries. This provide a lesson for developing resource based economies to put in place sound macroeconomic policies to ensure that they benefit from natural resource endowments.

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APPENDIX

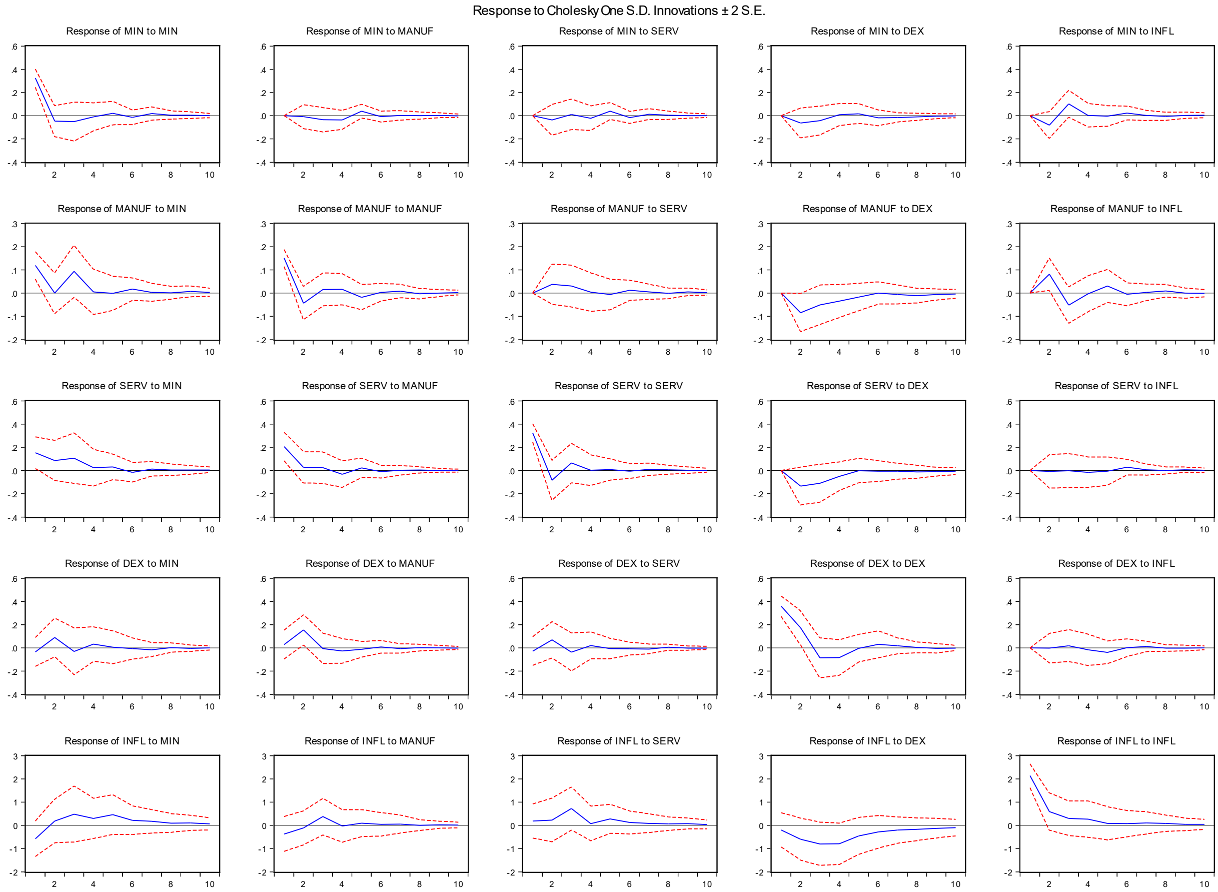

Figure A1: Shows the impulse response function results for Botswana case.

Table A1: Variance decomposition for Botswana case study

Variance decomposition of EX

Period	S.E.	MIN	MANUF	SERV	DEX	INFL
1	0.362	0.896	0.624	0.572	97.9	0.00
2	0.445	4.69	12.6	2.81	79.9	0.0035
3	0.456	4.92	12.0	3.29	79.6	0.18
4	0.466	5.21	11.8	3.33	79.4	0.305
5	0.468	5.18	11.8	3.32	78.7	1.002
6	0.469	5.17	11.8	3.33	78.7	0.998
7	0.470	5.25	11.7	3.36	78.6	1.073
8	0.470	5.25	11.7	3.37	78.6	1.07
9	0.471	5.26	11.7	3.37	78.6	1.08
10	0.4701	5.26	11.7	3.37	78.6	1.08

Variance decomposition if INFL

Period	S.E.	MIN	MANUF	SERV	DEXRATE	INFL
1	2.26	6.51	2.70	0.675	0.768	89.3
2	2.43	6.19	2.54	1.458	6.73	83.1
3	2.74	7.963	3.85	8.05	13.8	66.4
4	2.88	8.24	3.49	7.35	20.1	60.9
5	2.98	10.2	3.39	7.77	21.3	57.4
6	2.99	10.5	3.35	7.80	21.8	56.5
7	3.01	10.7	3.34	7.80	22.1	56.1
8	3.02	10.8	3.32	7.80	22.3	55.8
9	3.03	10.9	3.32	7.83	22.4	55.6
10	3.03	10.9	3.31	7.83	22.4	55.6

Table A2: VECM Granger causality results for Australia case study

Dependent variable	**INF**	**EX**	**SERV**	**MANUF**	**MIN**	**Joint significance**	**ECM**
INF	-	0.703 (0.402)	1.22 (0.267)	8.06 (0.005)	0.0814 (0.775)	8.17 (0.0856)	-0.304 (0.0083)
EX	3.45 (0.063)		0.574 (0.449)	0.626 (0.429)	1.54E-05 (0.997)	3.93 (0.415)	0.00434 (0.554)
SERV	0.664 (0.415)	0.024 (0.877)		0.114 (0.736)	0.0363 (0.849)	0.734 (0.947)	-75.0 (0.666)
MANUF	2.50 (0.114)	3.06E-05 (0.183)	1.79 (0.184)	-	0.181 (0.671)	4.28 (0.369)	160.4 (0.2807)
MIN	0.157 (0.692)	0.68 (0.409)	0.536 (0.464)	0.247 (0.619)		2.75 (0.6002)	-373.83 (0.0063)

(1)* Indicate significant at 5% level.

(2) Number in parentheses are probability value.

Table A3: Residual diagnostic check Australia case study

Dependent variables	Normality test	ARCH test	LM test
INF	1.91 (0.385)	1.28 (0.258)	2.38 (0.123)
EX	0.96 (0.62)	2.33 (0.127)	1.51 (0.22)
SERV	0.015 (0.993)	0.0507 (0.822)	0.17 (0.679)
MANUF	15.10 (0.00052)	0.59 (0.44)	0.87 (0.351)
MIN	0.958 (0.619)	0.696 (0.404)	1.36(0.507)

(1) Estimated figures under the column Normality test are Jarque-Bera statistic and figure inside parenthesis are corresponding probability values.

(2) Estimated figures under the column ARCH test are observed R-squared values and figure inside parenthesis are probability chi-square values.

3. Estimated figures under the column LM test are observed R-squared values and figure inside parenthesis are probability chi-square values.

DYNAMIC-COGNITION OF STRATEGIC MINERAL COMMODITY PRICES, AN EMPIRICAL ASSESSMENT

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DYNAMIC-COGNITION OF STRATEGIC MINERAL COMMODITY PRICES, AN EMPIRICAL ASSESSMENT

ABSTRACT

Strategic mineral commodities (SMC), encompassing energy, metallic and non-metallic have been fundamental for human development. A strong correlation exists between the mineral resources industry and society's development, whereby the supply of primary raw material is a significant driver of economic growth. Thus, a proper understanding of the SMC behaviour has become crucial due to its significance for the economy. SMC price fluctuations are interpreted through cognition and depend on economic, geopolitical, environmental, technological and psychological issues. Cognition is defined as the capacity to store information in memory, processing and decision making for problem-solving; therefore, has a significant role in systems that exhibit dynamic equilibrium, such as economic growth. Cognition allows the comprehension of past behaviours and trends in the markets. It also supports prices, demand and supply expectations in the market where speculations are unavoidable. Technological development may also be defined as a cognitive system. Since the Industrial Revolution, technological developments have exerted significant influences on SMC production costs and pricing.

Econometric and Gaussian-probabilistic models have been commonly used to forecast SCM prices. Nevertheless, the assumption of random behaviour and normal distribution could be unrealistic as it does not take into account the sudden emergence and evolution of market events and underestimate pricing fluctuations. A proper understanding of SMC price dynamics that takes into account the historical-cognitive relationship between economic, technological and psychological factors over time is fundamental before any meaningful attempt at simulation of pricing can occur. The aim of this paper is to discuss the SMC market cognition hypothesis and empirically demonstrate its dynamic-cognitive capacity. To assess the psychological, technological and economic conditions of cognition, oil, copper and gold markets will be assessed by investigating the effect of historical events on market pricing.

KEYWORDS

Mineral economics, dynamic systems, cognition, learning market process, strategic mineral commodities.

INTRODUCTION

Strategic Mineral Commodities (SMC) are defined as non-renewable resources classified into three main groups: metallic; non-metallic and energy commodities. Metallic and non-metallic commodities have been exploited since the Stone Age. (Hong, Candelone, Soutif, & Boutron, 1996; Ma, 2013; Radetzki, 2009; Thompson, 2006). Metallic commodities have been the oldest SMC exploited mainly used for construction, fabrication of domestic goods and as a reservoir of value. Non-metallic commodities have been used as a raw material in the construction, chemical and agrochemical industries. The extraction of energy commodities rose sharply in the 18th century forming the pillars that supported the Industrial Revolution. The technological development triggered by the Industrial Revolution has considerable increased the demand for metals and energy sources (Arezki, Loungani, van der Ploeg, & Venables, 2014; Bogatyrev, 2008; Dong, Li, & Lin, 2010; Hong et al., 1996; Kononov, 2009; Kulshreshtha & Parikh, 2000; Ma, 2013; Miller & Ni, 2011; Radetzki, 2009; Thompson, 2006; WEC, 2013).

The large amount of SMC required to sustain the vast quantity of infrastructure, consumer goods and energy is evidence of the close relationship between economic growth and the mineral resources industry. This relationship highlights the significant influence that the SMC market also has on technological and social development (Ayres & van den Bergh, 2005; Gargano & Timmermann, 2014; Gordon & Tilton, 2008; Krzak, 2012; Pierdzioch, Rülke, & Stadtmann, 2013). The mineral resources industry provides financial benefits for companies and governments, and social benefits for community. This benefits have a direct relationship with SMC pricing, which is fundamentally determined by supply and demand (Ayres and van den Bergh, 2005; Darling, 2011; Gordon and Tilton, 2008; Ricardo, 1817; Smith, 1776; Tapia Cortez et al., 2015). While the supply is driven by pricing, technology, productivity and cost, the demand is driven by pricing, income level, the price of substitute products, complementary goods and primarily by customer preferences (Boyes & Melvin, 2012; Darling, 2011; Gordon & Tilton, 2008; Pindyck & Rubinfeld, 2009; Smith, 1776; Tapia Cortez et al., 2015).

Customer preferences, desires and expectations are fundamental for the demand. They are driven by human psychological states based on cognition, which is the capacity to store and process information for decision making for problem solving. (Keynes, 1930; Simon, 1959; Smith, 1776; Tapia Cortez et al., 2015; Thelen, 2005). For more than two centuries, distinguished economists have investigated the influence of the complex human behaviour into the market. Smith (1776) noted that customer preferences split the demand into effectual and absolute. Ricardo (1817) noted that customer desires determine commodities demand based on its utility. Keynes (1930) identified the relationship between market expectations and commodity prices establishing the risk premium theory known as backwardation. Schumpeter (1934) contrasted the belief of continuous behaviour of the economy against its fluctuating pattern resulting from social, political or economic events affecting the market over the time (Fort & Quirk, 1988; Keynes, 1930; Ricardo, 1817; Schumpeter, 1934; Smith, 1776). The temporal relationship between the human psychological states and its consequences for future events and behaviours revealed and helped to form the concept of sensitive dependence on initial conditions. It means that minimal causes may have significant effects over time. This concept has long been used to explain or describe important historical events and their effects through time (Gleick, 1988; Tapia Cortez et al., 2015).

There is a wide belief that SMC markets and its price fluctuations exhibit random behaviour (Dechert, 1996; Lee, List, & Strazicich, 2006; Shafiee & Topal, 2010). However, the relationship that SMC prices have with economic, social and technological development, in addition to the cognitive nature of the decision-making process, appears inconsistent with this assumption. For instance, oil price fluctuations have been historically related to geopolitical events and consequent speculations. The economic and financial environment, mainly in the U.S., influences gold price volatility, and copper price fluctuations have been mainly influenced by the technological development of the mineral extraction, construction and the transformation industries. (Alexander, Alexander, & Ilya, 2013; Baldursson, 1999; Dooley & Lenihan, 2005; FED, 2013; Koutsoyiannis, 1983; Ma, 2013; Nappi, 2013; OPEC, 2014; Parker & Whaples, 2013; Sukagawa, 2010; Svedberg & Tilton, 2006; Tully & Lucey, 2007; U.S. Department of Historical Treasury, 2016; C. Watkins & McAleer, 2004).

MARKET CONFIGURATION

Crude Oil

The oil market is characterised by a sort of oligopoly led by the Organization of the Petroleum Exporting Countries (OPEC) that detent about 70% of the global reserves and produce more than 40% of crude oil worldwide (British Petroleum, 2015; Dooley & Lenihan, 2005; OPEC, 2014). As the predominant 'firm' in the market, the OPEC has actively influenced oil prices having the power to set prices, from production to distribution, until 1974. For instance, in 1971 a price increasing was established in the Tehran agreement and, by threatening of an embargo, the Libyan government further increase oil prices during the same year (Yergin, 2011). In 1973, the Arab members of OPEC imposed an embargo against the U.S. in response to the decision of the U.S. to re-supply the Israeli army during the Arab-Israeli War (1973), that resulted in the U.S. oil crisis (1973 – 1974) (OAPEC, 2014; U.S. Department of State - Office of the Historian, 2013).

Geopolitical events in the Middle East such as wars, coups or rebellions in the OPEC countries and their associated effects (expectation and speculation) have been key factors for pricing in the oil industry. (Abdullah & Zeng, 2010; Dooley & Lenihan, 2005; Makridakis, Hogarth, & Gaba, 2009). The Iran-Iraq war (1980-1988) triggered a dramatic decrease in the global oil production reducing the market share of the OPEC to its lowest level (~30%). Despite the production cuts oil prices fell because of the conflict coincided with the economic recession in the U.S. that reduced oil consumption (British Petroleum, 2015; The World Bank, 2015). Oil prices suddenly rose before the First Gulf War (1991), the bombing of Afghanistan (2001), the subsequent Iraqi War (2003-2011) and the Arab Spring (2010), which is attributed not only to the supply loss but also to anticipation of the conflict. (Freedman, Karsh, Karsh, & Karsh, 1993; Thussu & Freedman, 2003; Yergin, 2011). During all the conflicts, oil prices decline steadily and once again rise suddenly due to the emergence of a new conflict. The Iraqi War is the only exception when oil prices increase until 2008 influenced by the economic growing of China and other Asia-pacific countries. This atypical trend was interrupted by the Subprime mortgage crisis (2007 – 2009) that resulted in a significant falling in oil prices (British Petroleum, 2015; FED History, 2013).

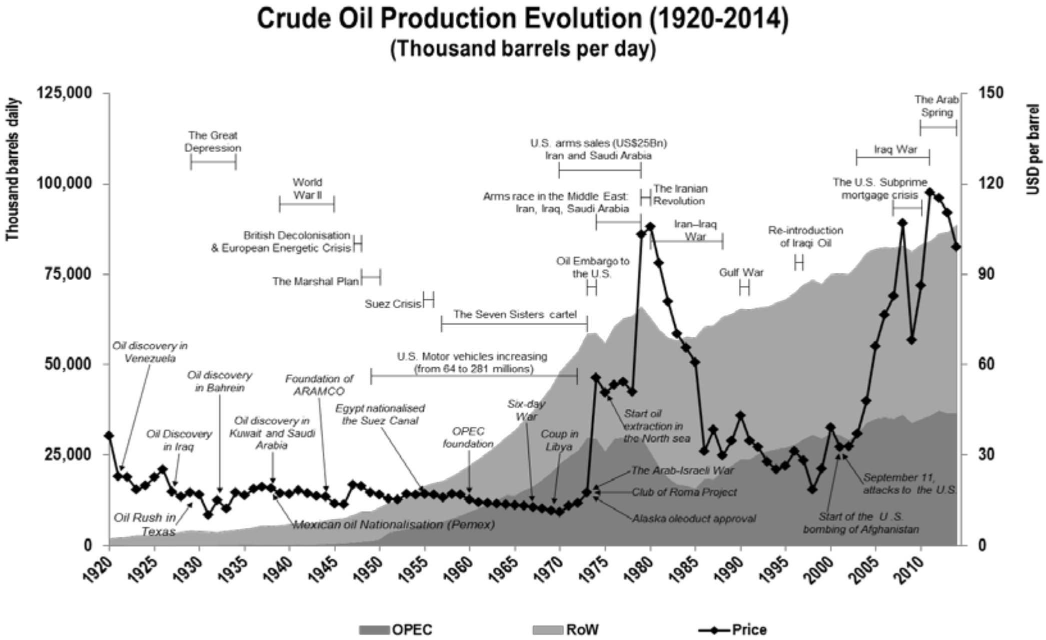

Figure 1 - Crude Oil production evolution1920-2014
(Adapted from Bakhtiari, 1999; British Petroleum, 1951, 2015; Bullock, 1985; Cairncross, 2013; Campante & Chor, 2012; FED History, 2013; Freedman et al., 1993; Hamilton, 1983; Jones, 2012; Streifel, 1995; Swearingen, 1988; Thussu & Freedman, 2003; U.S. Department of State - Office of the Historian, 2013; Yergin, 2011)

The persistent pattern exhibited by oil prices during war periods involving large producer countries is noticeable. Thus, the memory of the market to face the same type of events based on expectation, speculation and anxiety (psychological states) configures its cognitive behaviour through the time. Figure 1 shows oil prices, production and consumption evolution and its relation to major global geopolitical events during the last century.

Gold

The use of gold and influences on its market pricing have not suffered many changes over time, and a significant participation of “recycled” metal is a notable feature. The demand for gold has been historically driven by jewellery fabrication and its use as a reservoir of value. Due to the technological development in the modern times, its demand has also been extended to industrial applications; however, in a small proportion. (Aye et al., 2015; Mutafoglu et al., 2012; Schofield, 2012; Shafiee and Topal, 2010; Tully and Lucey, 2007; World Gold Council, 2015).

Because of its strategic financial features, gold prices have been largely influenced by the geopolitical and economic state of the U.S., where inflation, interest rates and the U.S. Dollar quotation are the primary variables (Koutsoyiannis, 1983). Gold has been an essential hedge during times of financial or political crisis. Speculations and expectations regarding the U.S. monetary policy, interest rate, inflation or U.S. Dollar depreciation threats generates extensive changes in the gold demand; and therefore, price volatility. The use of gold as a financial hedge sets up an inverse relationship between gold prices and the quotation of U.S. Dollar (FED, 2013; Tully & Lucey, 2007; U.S. Department of Historical Treasury, 2016). Gold has a high correlation with the equity market being used as a market hedge also classified as a monetary asset. Figure 2 shows gold prices, production evolution, and its relation to significant financial and economic events in the World and during the last century.

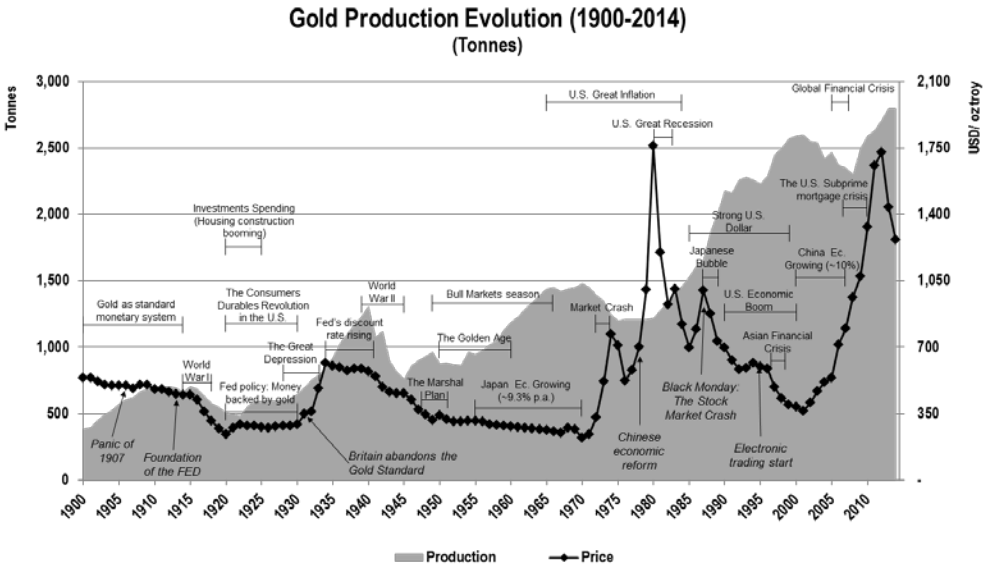

Figure 2 - Gold prices and production evolution 1900-2014
(Adapted from Barro & Ursúa, 2009; Barsky & Long, 1990; Bernhardt & Eckblad, 2013; Carlson, 2007; Carson & Clark, 2013; FED History, 2013; FED, 2016; Friedman & Schwartz, 2008; Hunter, Kaufman, & Krueger, 2012; Meltzer, 2005; Oxford Economics, 2011; Parker & Whaples, 2013; The World Bank, 2015; USGS, 2015; T. Watkins, 2013; Yergin, 2011)

Due to the global financial use of gold, geopolitical events involving oil reserves and oil production also have significant implication for its price fluctuations. Between 1968 and 2008 gold and oil real prices exhibited a close correlation and similar rising trend, increasing four and seven times respectively. The increasing trend in the price of both commodities is mainly influenced by the wars carried out in Iraq (1980-1988 and 2003-2011) and Afghanistan (2001) that shocked the oil industry and destabilised the global market.

Technological development of online gold trading platforms (Exchange Traded Funds (ETFs)) and mine production shrinking also influenced the gold prices increasing trend until 2013 (Shafiee & Topal, 2010; Tully & Lucey, 2007). Since this year, gold prices exhibited a decreasing trend largely influenced by the U.S. economy. Speculation about the financial stimulus reduction, expectations of monetary policy and the low-interest rate between 2013 and 2015 removed gold necessity as an inflation hedge (FED, 2013; U.S. Department of Historical Treasury, 2016). Figure 3 shows the real price evolution of gold and crude oil during the last century.

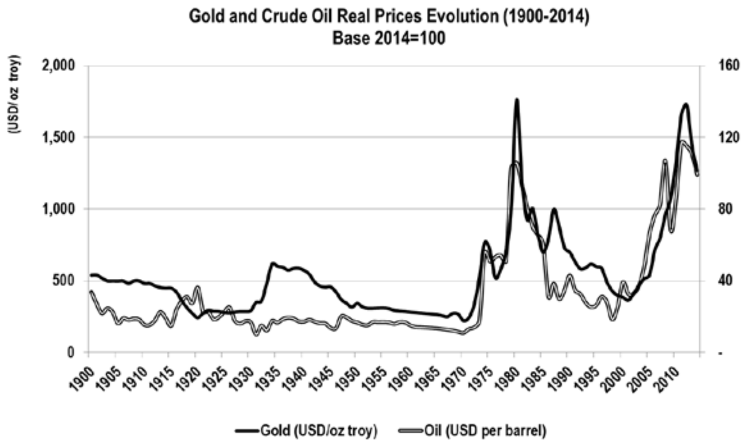

Figure 3 - Gold and Crude Oil real prices evolution 1900-2014, base 2014
(Adopted from British Petroleum, 2015; FED, 2016; USGS, 2015)

Copper

Global political, economic and technological evolution have been key drivers for copper production. The economic growth of ancient civilisations increased copper production mainly due to its use as a coinage for trading. The Roman Empire production totalled about 4 and 5 million tonnes. In the Chinese Empire, copper coins were the official standard for international trading (Hong et al., 1996; Radetzki, 2009). However, the decline of these Empires resulted in a dramatic reduction of copper production as seen in Figure 4.

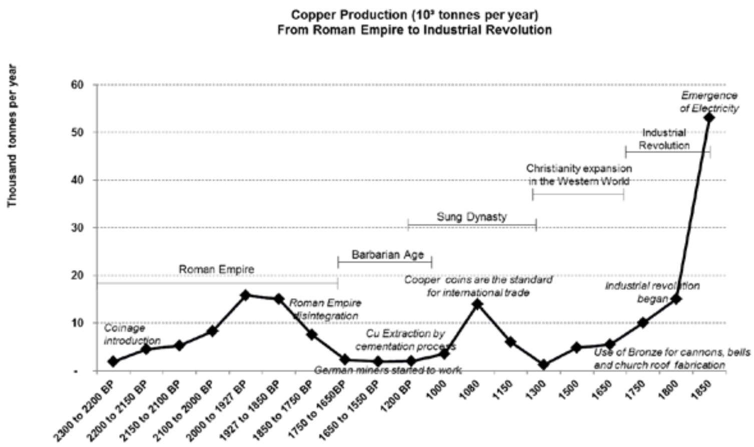

Figure 4 - Copper production evolution and its relation to historical events since the last two thousand years
(Adopted from Cochilco, 2015; FED, 2015a; Hong et al., 1996; Radetzki, 2009; The World Bank, 2015)

The copper market is highly competitive due to the large number of suppliers and buyers participating that have neither market share predominance nor influence on prices. It is also characterised by the supply inflexibility in the short term due to technical restrictions, that contrast with the high volatility in the demand (Svedberg & Tilton, 2006; Tapia Cortez et al., 2015; C. Watkins & McAleer, 2004).

Since the emergence of the Industrial Revolution, copper has become a major raw material for many industries, and the 'discovery' of electricity is one of the main milestones for the copper industry. The so-called industrial economies triggered a new "Machine Age" that has promoted the widespread and intense use of copper in the construction, electricity and transformation sectors. Because of its conductivity characteristics, copper has been used extensively in the telecommunication, electric, electronic, automotive, aviation and manufacturing industries. Therefore, copper production and demand has also significantly increased, making it an essential metal for the economy of both countries, the miners and the manufacturers-industrialised (Geman and Smith, 2013; Pierdzioch et al., 2013; Radetzki, 2009; Tapia Cortez et al., 2015; Thompson, 2006)

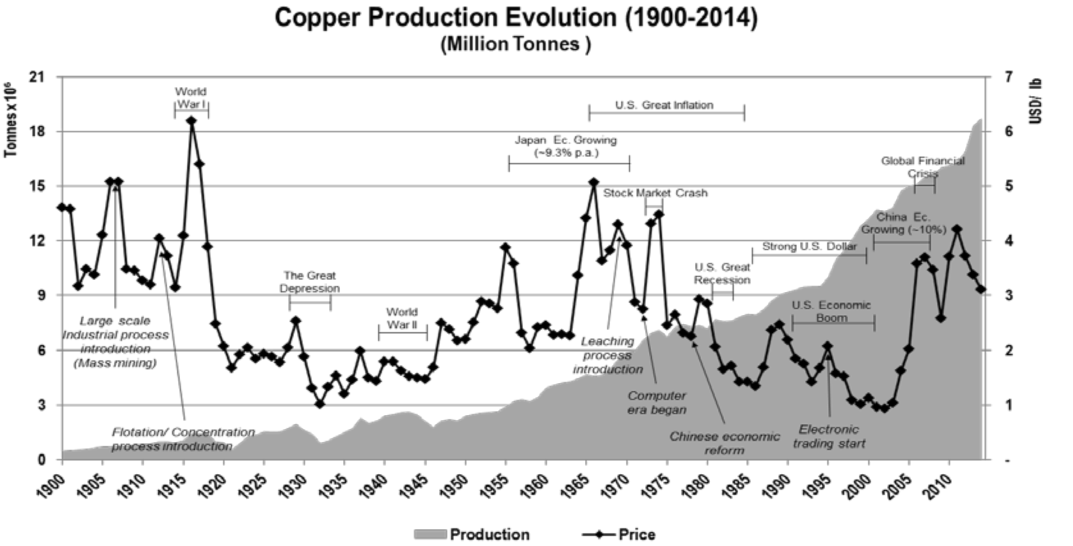

Figure 5 - Copper prices and production evolution 1900-2014 (Adopted from Cochilco, 2015; FED, 2015b; Hong et al., 1996; Radetzki, 2009; Slade, 2015; The World Bank, 2015).

Primary production (exploitation) has been the historical distinctive feature of the copper market. During the 20th century, three iconic technologies for copper extraction and processing were introduced expanding dramatically the production capacity that changed not only copper mine operations but also the nature of the copper market. Steam shovels were introduced in 1906 promoting massive mining; the discovery of flotation technology in 1911 allowed sulphate mineral processing and the introduction of leaching process in 1968 allowed the processing of low-grade material and a capital cost reduction (Slade, 2015).

Nevertheless, during the last decades, the copper availability has also increased because of the addition of recycling of scrap that between 1985 and 2007 accounted for about 15% to 20% of total copper refined consumption (Radetzki, 2009). Figure 5 shows copper prices and production evolution, and its relation with most significant technological milestones for both the mining industry and the society since 1900.

HISTORICAL COGNITION - EVIDENCES FOR DYNAMIC COGNITION

Adrangi et al. (2001) examined daily prices of crude oil, heating oil and unleaded gasoline traded on the NYMEX finding evidence for the non-linear behaviour of these commodities. Abdullah and Zeng, (2010) and Panas and Ninni (2000) argued for the deterministic-chaotic and highly volatile behaviour of the European oil market. Along with variant and invariant tests, Panas and Ninni (2000) used historical events related to wars and major political decisions to argue for the deterministic nature of the oil market driven by political variables that also control its structure. The possibility of the dynamic and unpredictable behaviour of the oil market has also promoted the introduction of Machine Learning (ML) to represent its prices (Abdullah & Zeng, 2010; Alquist & Kilian, 2010; Yousefi, Weinreich, & Reinarz, 2005). Shouyang et al. (2005) investigated the dynamics of historical events and its effects on the oil prices forecasting by using a combination of three ML techniques. An Artificial Neural Network (ANN) captured the dynamic fluctuations of oil prices over time, and Mining Text (MT) and Rules-Expert Systems (RES) techniques captured the sudden unexpected changes in trend dynamics. Abdullah and Zeng (2010) predicted long and short-term oil prices by using Hierarchical Conceptual (HC) and Artificial Neural Networks-Quantitative (ANN-Q) models, which are able to represent non-linear dynamics and the learning process by integrating quantitative and qualitative historical data. Quantitative information refers to supply and demand. Qualitative information relates to the news releases regarding predicted oil prices and the interpretation of market experts.

The macro economy provides the most influential variables for understanding the asymmetric dynamic of gold prices where the U.S. Dollar exchange rate is perhaps the most significant among all of them. Tully and Lucey, (2007) examined the influence of macroeconomic variables for gold prices and asserted that the Financial Times Stock Exchange (FTSE cash), the U.S. Dollar, the British Pound, the U.S. interest rate and the U.K. consumer price index are the more influential. To forecasting gold prices, Aye et al., (2015) investigated the link between financial data and economic indexes of uncertainties. The business cycles, interest rates and US. Dollar exchange rates were used as financial factors, and the U.S. economic policy uncertainty and the Kansas City Fed's financial stress index were used to capture the uncertainties and expectations into the market. They concluded that the economics indices have less predictive power than the financial variables, and the U.S. Dollar exchange rate index is the most important factor when forecasting gold prices. The close relation between gold price and the U.S. Dollar quotation in undeniable; nevertheless, the U.S. Dollar market has also a political intervention. Governments of gold producing countries have the power to depreciate local currencies against the U.S. dollar during low prices seasons to equalise the balance of trade.

Ahrens and Sharma (1997) studied and characterised the behaviour (temporal or dynamic) of the real prices of eleven SMC; aluminium, bituminous coal, copper, iron, lead, nickel, petroleum, natural gas, silver, tin and zinc. They found that the prices of aluminium, bituminous coal, lead, nickel, petroleum, and zinc exhibited a trend stationary processes and that the prices of copper, iron, natural gas, silver, and tin exhibited a different stationary trend (Ahrens & Sharma, 1997; Withagen, 1998). By examining the same metals via the Lagrangian multiplier unit root, Lee et al. (2006) affirmed that the prices of mineral resources are “stationary around deterministic trends with structural breaks” evidencing the non-random-cognitive behaviour of eleven SMC including oil and copper. Panas (2001) argued for its dynamic nature and cumulative long-term dependence of aluminium, copper, lead, tin, nickel and zinc prices in the London Metal Exchange (LME). Panas (2001) affirmed that copper and aluminium prices exhibit long-term memory settled by self-similarities; therefore, describe its behaviour as random is inappropriate. The chaotic behaviour of tin and zinc prices was also suggested; however, he notes that a more detailed analysis would be required to confirm this assertion. He et al. (2015) asserted that the complex behaviour of the metallic commodities exhibits nonlinear and chaotic features, and corroborated the chaotic behaviour of zinc.

CONCLUSIONS

This paper discussed the dynamic behaviour and cognitive capacity of crude oil, gold and copper markets by examining the influence of economics, psychological and technological factors for the market structure and prices over time. An empirical assessment was performed by analysing the evolution of historical events and mathematical-statistical results from previous researches.

The oil market exhibits a remarkable sensitivity to sudden geopolitical events due to its oligopolistic configuration led by the OPEC and the high concentration of reserves and production in the Middle East. Wars, coups and revolutions have had a significant influence for prices fluctuations by generating expectations and speculations concerning the future political environment in producer countries as well as regarding the financial environment for companies. It has resulted in a characteristic pattern of price that increases before the conflict blows up; gradually declines once the fighting starts and finally, due to the rise of a new conflict, prices increase suddenly returning to nearly the same level before the war.

Due to its strategic global financial nature as a reservoir of value, as a hedge against risk and its monetary asset characteristics, gold prices are highly influenced by the U.S. economy. Psychological factors affecting U.S. economy such as speculation and expectations regarding its monetary policy, interest rate and economic stimulus have been the main variables affecting gold prices. Speculation regarding interest rate decreases and the U.S Dollar devaluation boosts gold demand; therefore, prices increase. On the other hand, interest rate increases and the consequent appreciation of the U.S. Dollar lowers the risks of a devaluation of the U.S. currency, so investors have a lower demand for gold as a risk hedge and therefore reduce their demand for gold. Changes in the monetary policy and interest rates in the U.S. are entirely related to the political-economic strategies of the government. Therefore, linked to the psychological states of the decision makers in the form of expectations, which is based on the learning process bringing to light the deterministic and cognitive behaviour of gold prices.

The copper market, its demand and prices has been historically linked to the technological development of the mineral extraction, construction, and the transformation industries. The introduction of new machinery and the electricity power during the Industrial Revolution boosted copper demand resulting in larger effects for prices that had fallen during the previous century. This trend has been only interrupted by the World War I and by the emergence of the developing economies of Japan and China that increased prices mainly because of speculative demand. The appearance of new technologies such as telecommunication, electric, electronic, automotive, aviation and manufacturing industries has increased dramatically copper demand due to its physics and chemical properties. New extraction and processing technologies have promoted copper production increasing and cost-decreasing allowing that the copper supply continue to increase while prices decrease.

The qualitative assessment provided sufficient evidence to argue for the dynamic-cognitive behaviour of prices of crude oil, gold and copper in the long-term. They also exhibit deterministic, effects propagation and sensitivity to initial conditions features. It was found that its markets behaviour is driven by economic, political and technological events that have generated significant structural changes spreading its effects over time. In addition, the chaotic dynamics of the prices of crude oil and its sub-products, the political influence of the U.S. economy for gold prices and the long-term memory of copper prices have also been suggested in previous research. Thus, the ingrained belief of stochastic behaviour of oil, gold and copper prices appears to move away and define it as a dynamic learning process based on psychological states (or merely dynamic cognition) seems to be more appropriated.

Finally, to confirm the dynamic behaviour of crude oil, gold and copper prices and avoid its miss-characterisation (stochastic into deterministic and vice versa), the stationarity and determinism properties of the time series should be empirically investigated by statistical tests. The ACF, Ljoung-Box plot, ADF, PP and KPSS tests to examine stationarity and the FNN method used to assess determinism are suggested as further research.

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EFFECT OF THE BILL OF THE NEW BRAZILIAN MINING CODE ON THE MINING SECTOR

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EFFECT OF THE BILL OF THE NEW BRAZILIAN MINING CODE ON THE MINING SECTOR

ABSTRACT

In June 2013, the Executive Branch of the Brazilian Government submitted to the Chamber of Deputies a proposal for a new mining code. The proposal was inspired by the Brazil oil sector regulatory framework, and it may be seen as an example of the resource nationalism revival caused by the 2000's commodities super cycle. The proposal includes, among other innovations, an auction system to replace the current "first-come, first-served" system for granting exploration licenses. Additionally, the Ministry of Mining and Energy, confident that the proposal would be easily approved, halted the granting of new mining licenses in 2012. However, the proposal is still under review by the Deputies Chamber. Although the Ministry of Mining and Energy resumed granting mining licenses in 2013, the regulatory instability of the mining sector has caused a steep decrease in new mining investments, with exploration activities particularly affected. Now that commodities super cycle has ended, it is necessary to rethink changes to the Brazilian Mining Code to increase the investment attractiveness of the mining sector and rebuild the confidence of mining investors, who are much more selective now than they were a few years ago.

KEYWORDS

Brazilian Mining Code**,** regulatory framework, resource nationalism, investment attractiveness

INTRODUCTION

Mining laws are frequently changed. According to Mitchell (2009), more than 100 countries changed their mining laws from 1985 to 2005. The instability of mining laws is due primarily to mineral commodity price cycles. When prices are low, the prevailing changes in mining laws are beneficial to companies to attract more private investments for mining activities. However, when prices are high, the objectives of mining law changes are typically one or more of the following: i) to increase government share of mining profits, usually by imposing higher royalties, tax rates, and export levies; ii) to tighten state control over mining activities, which may include strict regulation over mining activities and mandatory participation of state-owned companies on mining joint ventures; and iii) to develop the local economy, especially the industrial sector, by establishing obligations such as a minimum percentage reserved for local beneficiation and industrialization of the ore and minimum thresholds for the use of local equipment, services, and supplies. This set of policies and the ideology behind it are known as resource nationalism.

The windfall profits generated by the mineral commodity price boom during the 2000s, as expected, stimulated a new wave of resource nationalism. This trend was especially strong because the mining laws of many countries were implemented during the 1990s, when mineral commodity prices were lower than in the 2000s, and neoliberal economic policies became dominant around the world. Encouraged by the World Bank, many countries adopted mining laws inspired by neoliberal ideals (i.e., reliance on foreign private investments instead of state investments). The regulatory framework was friendly to investors, and privatization of state-owned mining companies was recommended (World Bank, 1992). The role of the state was limited to regulating the mining sector, mainly to guarantee the rights of investors and competition among companies. Throughout the 1990s, the World Bank improved its mining policies and became more attentive to local miners and social and environmental issues (Van der Veen, Remy, Williams, Lundberg, & Gotthard, 1996).

Despite the good results obtained from the World Bank mining policies, many countries have reacted against the mining laws inspired by these policies. These laws are considered too favorable to companies, and governments have demanded a greater share of the mining profits. From 2008 to 2012, about 30 countries adopted at least one measure that could be classified as resource nationalism

(EY, 2013), and resource nationalism was considered the most relevant risk that mining faced in 2011 and 2012 (EY, 2012, 2013). Complaints against mining laws have also been heard in Brazil. Although the Brazilian Constitution may be considered nationalist, federal government officials have been asking for changes to the Brazilian Mining Code in accordance with the principles of resource nationalism since the middle of the 2000s.

The set of rules for mining activities as set forth by the Brazilian Constitution is: i) mineral resources constitute a distinct property from the land where they are located; ii) mineral resources are property of the Union; iii) besides the Union, states and municipalities receive a share of the mining royalty; iv) prospecting and exploitation of mineral resources require, respectively, authorization and concession by the Union; v) mined products are owned by the concessionaire; vi) exploitation of mineral resources must comply with national interests; vii) mining activity is allowed to Brazilians and companies organized under Brazilian laws that have their headquarters and management in Brazil; viii) mining in border areas and indigenous lands is subject to special conditions (to be) defined by law; ix) share of the revenues from mining activities is ensured for landowners; x) authorization for prospecting is for a set period of time; xi) transfer of mining rights requires prior consent of the grantor authority; xii) miners are responsible for environmental damage caused by mining activities and restoring the site. It is important to note that oil, natural gas, and nuclear substances are under state monopoly, and their exploration is regulated by specific laws.

In accordance with the constitutional rules, mining is regulated by the Brazilian Mining Code, Decree-Law No. 227 of 1967, which was revised in 1996. The government agency that supervises mining activities in general and carries out most of the bureaucratic work related to mining authorizations and concessions is the National Department of Mineral Production, whose acronym in Portuguese is DNPM. Incidentally, all acronyms of Brazilian government agencies will be written in Portuguese in this paper.

In September 2009, the Minister of Mines and Energy announced that the draft of the new mining code was ready and would be sent to Congress later that year. On the same occasion, the Minister provided hints about its content through the following declaration: “In the past Brazil had to rush to exploit ores and today we do not have such a hurry” (Fariello, 2009). In September 2010, the Minister of Mines and Energy once again declared that the proposed new regulatory framework for mining would be soon be completed (Bitencourt, 2010). The same promise was repeated in August 2011 (Bitencourt, 2011).

Meanwhile, in May 2011, the Ministry of Mining and Energy (MME) launched the “The National Mining Plan 2030” (Ministry of Mining and Energy, 2011). The authors of the plan analyzed future scenarios for the Brazilian mining sector, concluding that “modernization” of the mining legal framework is necessary to guarantee sustainable development of the sector. In the context of this plan, modernization means updating the Brazilian Mining Code according to the ideology of resource nationalism. The purposes were to increase government take and ensure more state control over the pace of mining activities.

At long last, in June 2013, the Executive branch sent to the Chamber of Deputies the long-awaited bill for the new Brazilian Mining Code (Chamber of Deputies, 2013). This proposal will be referred to as NBMC in this paper. In her speech for the public presentation of the NBMC, President Dilma Rousseff explained that the new legal framework for the mining sector would allow a breakthrough in a strategic sector of the Brazilian economy. The President added that progress would be measured in greater competitiveness for business and higher return for the whole society (Presidency of the Republic, 2013).

Almost all stakeholders of the mining sector—industry, lawyers, experts, state and municipal government officials, unions, environmentalists, and DNPM officials —have criticized the proposed rules. This criticism is the main reason why the NBMC is still under review by the Chamber of Deputies 3 years after its presentation. At this moment, there is no expectation of its approval in the forthcoming months. Even if it is approved, the NBMC will likely be extensively amended by the Deputies. Even then, the bill must still be submitted to the Federal Senate, where its review will not be rapid.

The authors of this paper aim to analyze the effect of the NBMC on the mining sector's investment attractiveness. Additionally, since the economic conditions of the mining sector differ from those at the time the NBMC was written, the authors evaluated the adequacy of the proposed rules to the present scenario, when mineral commodity prices are low. To achieve these purposes, this paper is divided into three sections: in the first section, the NBMC and the current Brazilian Mining Code are compared; in the second section, the attractiveness of the Brazilian mining sector during the last 5 years is analyzed; and in the third section, the concluding remarks of the work are presented.

COMPARISON OF THE CURRENT BRAZILIAN MINING CODE AND THE NBMC

The main changes proposed in the NBMC are presented in this paper in three groups: processes for obtaining mineral rights, public governance of the mining sector, and royalty and fees.

Processes for Obtaining Mineral Rights

Currently, there are six different processes for obtaining mineral rights in Brazil: two for mineral resources in general, and four for specific cases. They are: i) authorization, which is needed for the exploration of mineral resources in general and is granted by the DNPM; ii) concession, which is needed for the exploitation of mineral resources in general and is granted by the MME; iii) licenses, which are restricted to the exploitation of construction aggregates and is granted by municipalities and the DNPM (this is a simpler process than authorization and concession); iv) permits, which are restricted to small mining of precious metals and stones and is granted by the DNPM; v) monopoly regimes, which apply to the exploration and exploitation of oil, natural gas, and nuclear substances; and vi) extraction license, which is needed for the exploitation of construction aggregates for use in public works by governmental agencies and is granted by the DNPM. We will consider for comparison purposes just the two first processes, because the NBMC would not significantly change the other four processes for specific cases.

Authorization is granted for a set period of time on a "first-come, first-served" basis. Only a free area (i.e., without existing mineral tenure) can be claimed. If during the authorized period of prospecting a mineral deposit that is technically and economically feasible to exploit is found, the miner can submit an exploitation project to the DNPM and a claim for concession to the MME. The concession will be valid until the depletion of the mineral reserve.

The NBMC would profoundly change the granting of mining rights. Basically, the first-come, first-served system would apply only to the exploitation of construction aggregates. In the NBMC, this process is referred to as authorization. For mineral resources in general, the first-come, first-served system would be replaced by an auction system.

For special areas chosen by the Federal Government because of their high geological potential, a bidding process would be mandatory for granting mining concessions. Scoring of the bid may consider signature bonus, discovery bonus, share of the revenue of the mining activity, investments during the exploration phase, and other criteria defined in the bidding documents. These documents establish minimum local content rules and technical, legal, economic, and financial requirements for the bidders. The winner of the bid would sign a concession contract with a duration of up to 40 years, which may be extended for successive periods of up to 20 years.

In the remaining areas, the system would be a public call, a process simpler than an auction. If a company asks the grantor for the mining rights of an area, the grantor would issue a public call to search for additional companies interested in the same area. If more than one company is interested in the area, there would be a bidding process. If not, the company interested in the mining rights of the area would sign a concession contract similar to that used for special areas.

The main reason for these changes in the process for obtaining mining rights is concern about speculative practices. According to the Federal Government, companies without any technical and economic capacity may acquire exploration authorization for the sole purpose of retaining the area, without adequate prospecting efforts, for the subsequent negotiation of the mining rights.

Public Governance of the Mining Sector

The NBMC would strengthen the role of the granting authority and expands its duties. According to the MME, this action is justifiable because the granting of mining rights is virtually automatic under the current mining code: after completing all bureaucratic requirements, the applicant obtains the exploration authorization. The Federal Government wishes to provide the grantor with a higher degree of discretion in the process of granting mining rights.

Besides strengthening the granting authority, the NBMC includes three major innovations in the public governance of the mining sector: creation of the National Council of Mineral Policy (CNPM), elimination of the DNPM, and creation of a regulatory agency called the National Agency of Mining (ANM). In addition, the increased duties of the state-owned Brazilian Geological Service (CPRM) would emphasize mining exploration.

The CNPM would follow the model of the existing National Council of Energy Policy. It would be an advisory body linked to the Presidency of the Republic and chaired by the Minister of Mines and Energy. Its role would be to formulate and propose policies for the mining sector. Among the duties of the CNPM are two examples of resource nationalism: to propose initiatives for promoting the local increase in the added value of mining products, and to establish guidelines for the local content of mining projects. The other two duties are notable because of their impact on mining exploration. They are to choose special areas where the granting of mining rights would be obtained by the mandatory bidding process, and to select mineral substances whose exploration would be allowed through the new authorization process.

The ANM would regulate and supervise the mining sector. Its duties would include organizing biddings and public calls, including the defining of bidder requirements; collecting mining royalties and fees; managing concession and authorization contracts; and supervising mining activities on site to ensure that regulations are followed, and best practices are implemented.

Lastly, the emphasis of the CPRM on prospecting activities is necessary because the Federal Government needs to understand the geological potential of the areas to be offered before the auction occurs. Otherwise, the Federal Government cannot tailor the economic parameters of the bidding processes.

Royalty and Fees

Under the current law, the mining royalty (i.e., financial compensation for the exploitation of mineral resources) is 0.2% to 3%. The rate for each mineral substance is set by law. The basic rate, applied to most mineral substances, is 2%. The royalty base is the gross revenue less transportation costs, insurance, and taxes levied on the commercialization of the mineral substance.

The NBMC would establish only the maximum rate of the royalty: 4%. The rate applied to each mineral substance would be defined by decree. The royalty base would be the gross revenue less taxes levied on the commercialization of the mineral substance. The Federal Government expects that the NBMC would double the current royalty revenue (Presidency of the Republic, 2013).

Besides the changes in the rate and base of the royalty, the NBMC would establish a supervising fee. This new fee would be paid by all mining companies. Its value would be set according to the operational gross revenue.

ATTRACTIVENESS OF THE BRAZILIAN MINING SECTOR

Mining in Brazil has a tradition of more than 400 years. The country has some of the largest ore deposits in the world and is an important producer and exporter of high-quality ores. Therefore, it is not surprising that mining is an important supporting column of the Brazilian economy. The trade balance of the mining sector has been highly positive, mainly because of iron ore exports, and has contributed to the accumulation of foreign reserves.

Although mining activity represents less than 2% of the gross domestic product of Brazil, its importance is greater than this low percentage suggests. The mining sector supplies raw materials to many production chains and requires equipment from the local capital goods industry. In addition, employment in the mining sector has strong ripple effects on other sectors of the Brazilian economy.

From 2005 to 2011, the global demand for minerals increased, in large part because of the high rate of global growth. Brazilian mineral production (BMP) also increased during this period. Its growth in the 2000s was remarkable, as shown in Figure 1. After the end of the 2000s commodity super cycle, BMP began to fall but was still significant. The BMP was USD 26 billion in 2015 and is expected to reach USD 30 billion in 2016. The outlook for mining activity is optimistic for the coming decades.

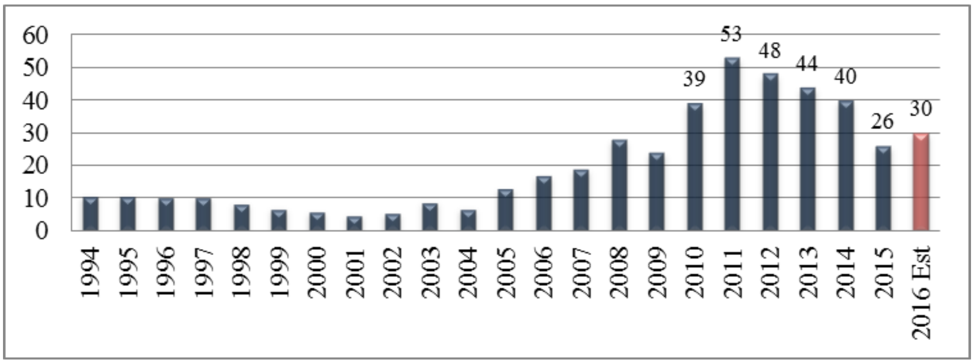

Figure 1 – Brazilian mineral production in USD billion (Source: Brazilian Mining Association)

Thus, considering the weight of the mining sector in the Brazilian economy, every change to the regulatory framework of the sector must be carefully planned and introduced. Otherwise, the regulatory risk may become excessive, and mining companies may reduce their investments in the country. A deep change in the regulatory framework, such as that introduced by the NBMC, creates uncertainty for investors. To assess how the NBMC and the long legislative debate for its approval affect the investment attractiveness of the Brazilian mining sector, we turned to the well-known Survey of Mining Companies, which has been published yearly by The Fraser Institute since 1997.

The "Survey of Mining Companies 2015" (Jackson & Green, 2016) compares attractiveness for mining investments across countries and subnational regions. According to Jackson and Green (2016), "the survey is an attempt to assess how mineral endowments and public policy factors such as taxation and regulatory uncertainty affect exploration investments." The survey is sent to mining company managers and executives. The answers are analyzed, and the Investment Attractiveness Index is constructed, taking into account both mineral and policy perception. The first is represented by the Mineral Potential Indexes, which rate regions based on their geologic potential. The second is represented by the Policy Perception Index, which measures the effects of government policies such as mining regulation, the legal system, taxation, infrastructure, and environmental regulation on the exploration investments of mining companies.

There are two Mineral Potential indexes, reflecting best practices and current practices. Both indexes evaluate how geological potential encourages investments. The first evaluation, the Best Practices Mineral Potential Index, is performed under a hypothetical world-class policy environment, whereas the second evaluation, the Current Practices Mineral Potential Index, is performed under the real policy environment. The numbers obtained are normalized for easy comparison between them. A complete explanation of the survey methodology is available in Jackson and Green (2016). Besides calculating the indexes, Jackson and Green (2016) also rank countries according to their index scores.

Table 1 shows the Investment Attractiveness Index, Policy Perception Index, Best Practices Mineral Potential Index, and Current Practices Mineral Potential Index for Brazil from 2011 to 2015, and the corresponding rank of Brazil among countries and subnational regions included in the survey. Analysis of the scores over time suggests that Brazil's performance is disappointing. After all, Brazil has a huge territory, larger than 8.5 million km^2, is a world-class mineral producer, and has a variety of regions with geological potentials similar to those of mineral resource-rich areas in Canada and Australia, which are ranked at the top of the survey.

Table 1 – Investment Attractiveness Index, Policy Perception Index, Best Practices Mineral Potential Index, Current Practices Mineral Potential Index scores of Brazil from 2011 to 2015, and corresponding among the countries and subnational regions evaluated in the "Survey of Mining Companies 2015" (Jackson and Green, 2016)

Index / Ranking	2015	2014	2013	2012/ 2013	2011/ 2012
Investment Attractiveness Index	61.45	69.27	65.63	64.99	75.45
Investment Attractiveness Ranking	56 / 109	40 / 122	45 / 112	36 / 96	24 / 93
Policy Perception Index	56.57	59.17	63.65	64.98	67.75
Policy Perception Ranking	69 / 109	77 / 122	65 / 112	53 / 96	49 / 93
Best Practices Mineral Potential Index	0.65	0.76	0.67	0.65	0.81
Best Practices Mineral Potential Ranking	44 / 109	20 / 122	33 / 112	35 / 96	21 / 93
Current Practices Mineral Potential Index	0.32	0.29	0.31	0.44	0.54
Current Practices Mineral Potential Ranking	67 / 109	70 / 122	69 / 112	43 / 96	28 / 93

Brazil's Investment Attractiveness Index score decreased significantly from 2011 to 2012. No explanation for this decrease is given in the "Survey of Mining Companies 2012–2013" (Wilson, McMahon & Cervantes, 2013). The likely cause was the decision of the DNPM and MME to delay the granting of mining concessions for metal ores at the beginning of 2012, even before the NBMC was announced (Borges & Rittner, 2012). At that time government officials believed that the NBMC would be announced soon and approved quickly by the National Congress. They therefore expected to grant new mining rights under the rules of the NBMC. However, the government officials were wrong, and concession proceedings for metal ores were suspended for more than 1 year. In addition to causing the postponement of investments, which amounted to USD 10 billion (Borges & Rittner, 2013), the suspension resulted in the loss of orders and jobs in the production chain of the mining sector (Durão, 2012). The granting proceedings were resumed in 2013, but since then mining companies have had to sign a commitment agreement that states they must comply with conditions established by subsequent law and sectoral regulation.

The Investment Attractiveness Index score recovered partially from 2012 to 2014 but then decreased more than 10% in 2015. One possible reason for this decrease is the steep decrease in metal prices in the last 2 years. This decrease affected iron ore in particular, which represents approximately 70% of the BMP. However, Brazil's Investment Attractiveness rank fell 20 places from 2012 to 2015, indicating that the deteriorating performance of Brazil may not be attributable just to the end of the commodities super cycle. Since all countries were affected by declining mineral commodity prices, other factors likely contributed to this decrease in the Investment Attractiveness Index score.

The index scores and rankings in Table 1 show that policy perception must be one of these reasons. Brazil's Policy Perception Index score fell more than 10% from 2013 (the year of the NBMC announcement) to 2015. In addition, the Current Practices Mineral Potential Index score fell almost 30% in 2013. This fall is a strong indication of the poor policy environment in that year. Although it is not possible to determine whether the NBMC was the sole cause of the worsening policy perception in 2013, the "Survey of Mining Companies 2013" (Wilson & Cervantes, 2014) includes the comments of two executives of small mining companies with activities in Brazil, and both executives expressed concern about the NBMC. These worries are understandable, since abolishing the first-come, first-served system would strongly affect small companies, especially junior companies, since they are unable to compete against big companies for rich mining areas under the equal conditions in the bidding system.

What is clear from the data in Table 1 is that the Brazilian policy environment is an obstacle to improving the investment attractiveness of the mining sector. Investment attractiveness is lower than might be considering the geological potential of Brazil. In fact, there is plenty of room for improvement in the policy environment, as shown by the gap between the Best Practices Mineral Potential Index score and the Current Practices Mineral Potential Index score.

Thus, "The National Mining Plan 2030" (Ministry of Mining and Energy, 2011) is correct when diagnosing the need to modernize the legal framework of the mining sector, but the prescriptions (i.e., resource nationalism and bidding system) are inadequate. It would be better to attentively watch other countries and look for successful cases. Let's put the focus on Latin America countries. The report "World Exploration Trends 2016" (SNL Metal and Mining, 2016) shows the top destinations for nonferrous exploration investments in 2015. In Latin America the top destinations were Chile, Peru, and Mexico, which received, respectively, 7%, 6%, and 6% of the global exploration investment. In contrast, Brazil received only 3% of this investment. The lower investment in Brazil reflects the lower evaluation of the country according to mining companies' perceptions, as shown in Table 2.

Table 2 – Investment Attractiveness Index, Policy Perception Index, Best Practices Mineral Potential Index and Current Practices Mineral Potential Index scores of selected Latin American countries evaluated in the "Survey of Mining Companies 2015" (Jackson and Green, 2016) from 2011 to 2015

Index	Chile	Mexico	Peru	Brazil
Investment Attractiveness Index	79.81	68.93	69.26	61.45
Policy Perception Index	83.50	71.14	66.80	56.57
Best Practices Mineral Potential Index	0.77	0.68	0.71	0.65
Current Practices Mineral Potential Index	0.62	0.48	0.47	0.32

In 2015, the budget for nonferrous metals exploration was USD 9.2 billion, less than half the record USD 21.5 billion budgeted in 2012 (SNL Metal and Mining, 2016). In this period of falling exploration investment budgets, it is not advisable to adopt a mining law like the NBMC, which is restrictive to exploration investments. Furthermore, with this move away from junior companies, which specialize in mining exploration, the bidding system will work only if there is a minimum geological knowledge of the areas offered for auction. The exploration activities currently undertaken by mining companies will need to be carried out by the CPRM. It is the nationalization of the mining risk.

CONCLUDING REMARKS

The NBMC has positive features such as improved public governance of the mining sector, unification of mining rights for exploration and exploitation, and the provision of more detailed concession contracts. However, other features such as the bidding system and the increase of royalty rate and fees will reduce the investment attractiveness of the Brazilian mining sector.

The NBMC mimics the Brazilian regulatory framework of the oil and gas sector, which was shaped by the state monopoly. However, a state monopoly does not exist for mining, except for nuclear minerals. Additionally, it is not likely that the bidding process used in the oil and gas sector, which offers only a few hundred areas in one or two auctions per year, is appropriate for the mining sector, since the DNPM grants 10,000–20,000 exploration authorizations each year.

To protect against speculative practices, it would be better to enforce the rules of the current mining code, rather than adopting a bidding system. The current mining code has instruments to suppress such practices.

The increase in royalty rate and fees is inappropriate in this period of low mineral commodity prices, when many Brazilian mines have closed as their exploitation has become uneconomical. Furthermore, the government take in the mining sector includes all taxes collected from mining companies, as well as the royalty. Although the royalty rates in Brazil may seem low, taxes in general are high, and the tax system is too complex. Unfortunately, because of the fiscal crisis, many Brazilian states and municipalities see the mining sector as a cow to be milked immediately, without any strategic concern for the long-term development of the sector.

The investment attractiveness of the Brazilian mining sector is currently lower than that of most other countries with significant mineral production. The NBMC must therefore be rethought in its fundamentals, or the competitiveness gap between Brazil and these countries will broaden further. To that end the NBMC should focus on creating a regulatory framework that is stable and friendly to investors to attract the scarce exploration investments available in the world. This objective can be achieved without giving up the state's supervisory role or the government take. There are many good examples of mining regulatory frameworks around the world. These examples should be analyzed and, if feasible, adapted to the Brazilian reality.

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ESTIMATION OF LONG TERM SUSTAINABILITY FOR SILVER SUPPLY

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ESTIMATION OF LONG TERM SUSTAINABILITY FOR SILVER SUPPLY

ABSTRACT

Silver is depleting due to intensive mining and inadequate replenishment from recycling. Moreover, installation of c-Si type photovoltaics (PV) are demanding silver in an exponential rate since 2000. The study investigate in sustainable development of silver supply by simulating silver supply and demand. The model includes silver physical supply unit and fabrication demand unit balanced by withdraw supply released from investors and investment demand absorbed by investors from 2015 to 2050. Different aspects of dynamic technology progress including substitution of silver in PV cells, improvement of electricity conversion efficiency of PV modules, innovation of silver recycling process from used PV scrap, and improvement of current recycling rate of silver contained old scrap are discussed under sensitivity analysis. In the supply unit, total physical supply is modeled as sum of mining production composed by productions from silver mines as main product and from gold, copper, zinc and lead mines as byproduct under logistic regression. And, recycling production is formulated as a function of silver fabrication demand and recycling rate probability distribution under Weibull distribution. In the demand unit, silver demand is subdivided into demand for electronics and batteries, photography, decoration and other uses modeled as a function of macroeconomic indicators (world population and world GDP) and demand for PV modeled as a function of PV installation capacity, silver consumption rate, and PV electricity conversion efficiency. Above all, primary and secondary resource potential are discussed under the content of sustainability. The result shows that silver supply cannot be sustained unless technology progress materialized. And main driving force of silver demand turns out to be PV installation. Therefore, reduction of silver demand for PV sector can significantly relieve the supply shortage. However, silver resource is depleting quickly regardless of the reduction. It calls for further improvement of recycling rate.

KEYWORDS

Silver supply, silver demand, technology, supply shortage;

INTRODUCTION

Silver is one kind of mineral resources endowed in the earth crust with very limited reserve size. It is depleting quickly both economically and physically due to human wantonly exploitation. Current recycling input ratio for silver is around 25-30 percent, which is unable to compensate the depletion of primary resources. Moreover, compelled by supply shortage of fossil fuels and intensifying global warming, more and more renewable energy facilities are installed, including c-Si type PV in which silver is used for electrode paste. Increasing installation of PV is pulling silver demand for PV up and may further threat the sustainability of silver supply. The study is therefore aimed at forecasting silver supply and demand in the following 35 years (up to 2050) in order to provide solutions to relieve the latent supply shortage.

METHOD

The model includes a base case study according to current situation and a sensitivity analysis for four technology factors. There are two units included in the model, silver physical supply unit and silver fabrication demand unit. The two units are balanced by withdraw supply and investment demand (Figure 1). In the supply unit, total physical supply is modeled as sum of mining production and recycling production. For silver mining production, it comes both from silver mines as main product and from gold, copper, zinc and lead mines as byproduct. They are simulated by Hubbert linearization and normal logistic regression respectively. Silver contained old scrap recycling production is formulated as a function of silver fabrication demand and recycling rate probability distribution under Weibull distribution. In the demand unit, silver demand is subdivided into demand for electronics and batteries, other industry uses, photography, decoration and PV. Except PV, others are modeled as functions of either world GDP or world population. Silver demand for PV is modeled as a function of PV installation capacity, silver consumption rate, and PV electricity conversion efficiency. In addition, silver withdraw supply is calculated as silver physical supply shortage below its corresponding fabrication demand, silver investment demand is computed as silver supply surplus over its corresponding fabrication demand.

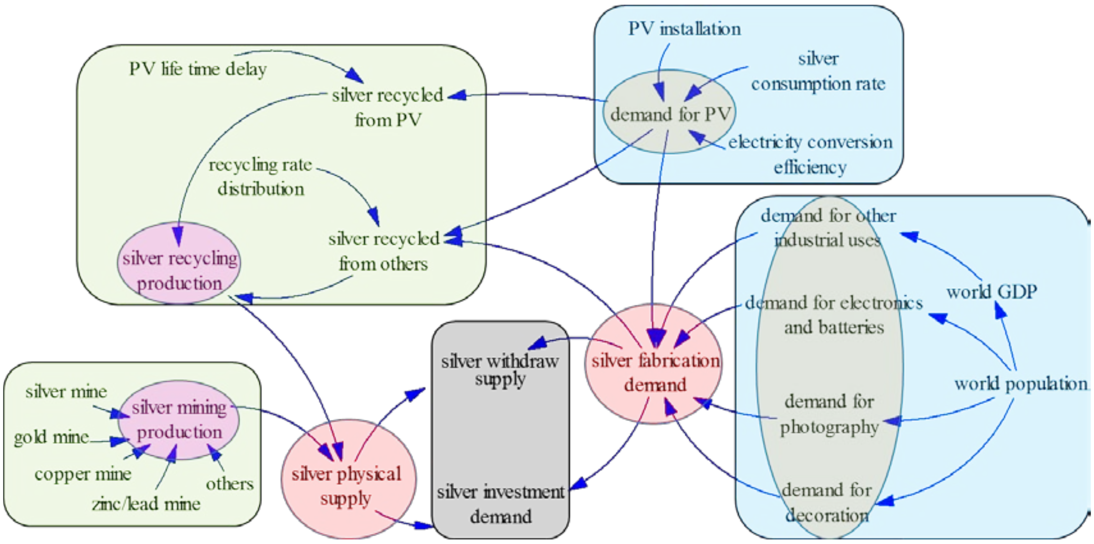

Figure 1 – Causal loop diagram of silver supply and demand framework

Silver Supply Unit Modeling Methods

Silver mining production from the gold mines and silver mines is modeled by equations (1a) and (1b). The formulas are commonly used for resource consumption simulation, especially since Hubbert used them to predict the peak in US conventional oil production (Marion King Hubbert, 1966). In equations, URR is the ultimately recoverable resource for silver, b is the curve shape constant, t denotes year, and t_{max} is the peak production year, Q_t represents cumulative production in year t, P_t is the annual production in year t. URR is estimated on the basis of the grade decline along with cumulative production increases using raw material group's data. The URR of silver from gold mines is estimated to be 180,000 metric ton and 600,000 metric ton from silver mines.

$$Q_t = \frac{URR}{1+e^{-b\times(t-t_{max})}}. \tag{1a}$$

$$P_t = Q_t - Q_{t-1}. \tag{1b}$$

Silver mining productions from copper mines and zinc and lead mines are modeled by equations (2a) and (2b). The method, introduced by Marion King Hubbert (1982), is called the Hubbert linearization. In the equations, a and b are constants simulated by regression. URR is taken as the intersection value of the Hubbert linearization curve with the horizontal axis because that point represents the maximum cumulative production when annual production decreases to zero. In addition, according to historical records, silver mining production using other sources accounts for 15% of the total production in average.

$$\frac{P_t}{Q_t} = a \times Q_t + b\ . \tag{2a}$$

$$URR = -\frac{b}{a}. \tag{2b}$$

The current recycled silver from old scrap doesn't include PV scrap, because of its limited scale and low silver weight concentration ratio (Carol Olson et al., 2013). Therefore, as displayed in equation (3), silver recycling production is simulated as a function of silver fabrication demand except PV (D_t) and recycling rate Weibull probability distribution ($f(x;\lambda,\kappa)$). Where x denotes period of delay, namely, in use time of silver contained products. Maximized 20 years of delay is applied in the regression, represented by λ. κ is found to be 0.25 using least square root regression analysis (Figure 2). The reason for arbitrarily applying 20 year as maximum lifespan of silver contained products is that most silver seems to be recycled within 10 years of service period from historical records (Figure 3). 20 year is used to improve accuracy.

$$R_t = \sum_{x=1}^{20}\left\{D_{t-x} \times \left[\frac{\kappa}{\lambda}\left(\frac{x}{\lambda}\right)^{\kappa-1} e^{-\left(x/\lambda\right)^{\kappa}}\right]\right\} \quad (3)$$

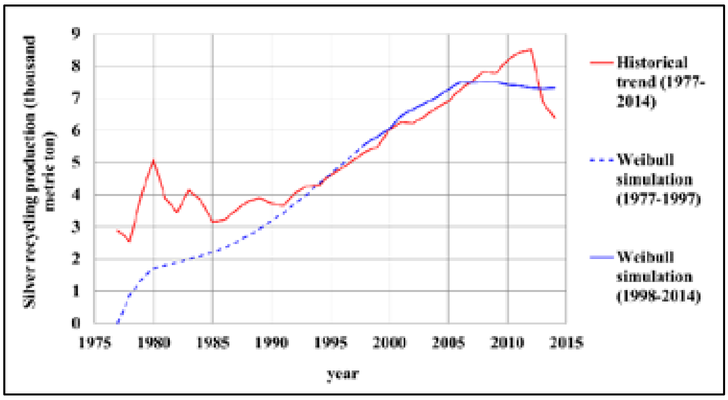

Figure 2 – Silver old scrape recycling regression under Weibull distribution

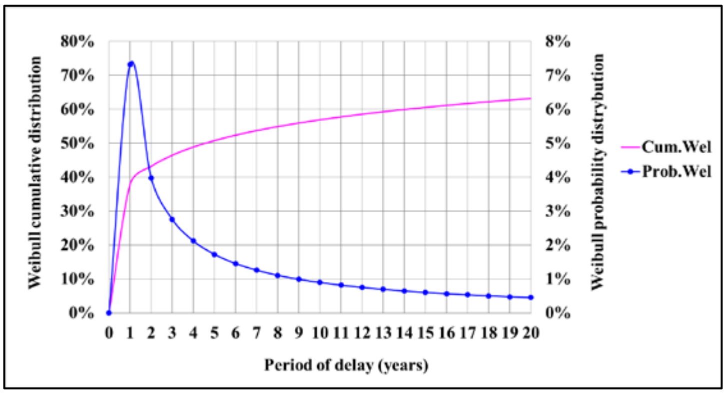

Figure 3 – Silver recycling rate Weibull distribution

Silver Demand Unit Modeling Method

Silver fabrication demand is separately modeled using intensity of use (Figure 4). Concretely, silver demand per capita for electronics and batteries recorded a minor fluctuation with 0.951 gram/person in average since 2010. This value thus is applied to predict silver demand for the sector. Because silver demand per capital for decoration, namely, jewelry and silverware, also experienced similar trend with 1 gram/ person in recent 10 years, thus the average value of 1.09 gram/person is applied similarly. Since 2000, silver demand per capita for photography witnessed rapid decline owing to the substitution by digital cameras (Jeffrey M. Christian et al., 2015). Thus, the declining trend is applied to estimate future silver demand for photography. Similarly, the declining trend of silver demand per USD GDP (constant 2005) for other uses since 2010 is used to predict future silver demand for the sector. In addition, world population data used in the model were adopted from World Bank. World GDP is regressed as the power trend line of world population.

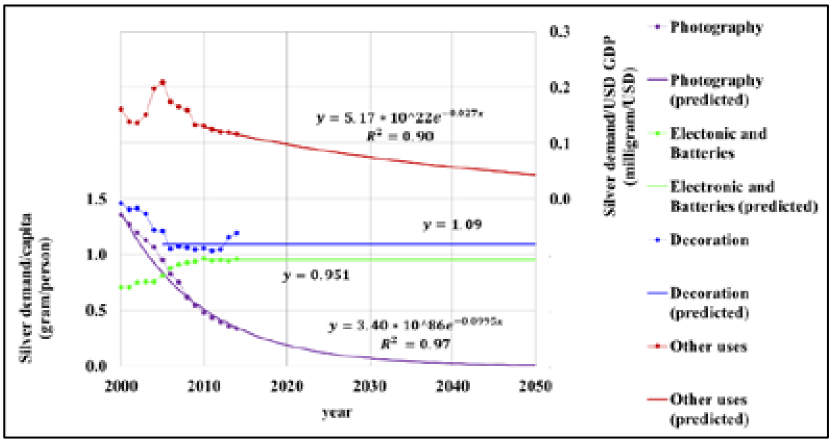

Figure 4 – Silver fabrication demand simulation according to historical trends

Silver demand for c-Si PV ($D_{(PV)}$) is formulated as a function of its installed capacity (E_{PV}), electricity conversion efficiency (EF), and silver consumption rate (CR), as shown in equation (4).

$$D_{(PV)}\ (ton) = \frac{E_{PV}\ (Gigawatt) \times CR\left(\frac{gram}{metre^2}\right)}{EF\left(\frac{kilowatt}{metre^2}\right)}. \tag{4}$$

According to the hi-Ren scenario predicted by Cédric Philibert et al. (2014), a total of 1,721 GW of PV will be installed globally by 2030 and 4,671 GW by 2050. Among the projected installation of PV, 90% are assumed to be c-Si cells according to its current market share. The average electricity conversion efficiency of commercial silicon modules was 16% in 2013 (Cédric Philibert et al., 2014). The current silver consumption rate is roughly 8.77 g/m^2 in average for the c-Si PV sector in 2014 (Jeffrey M. Christian et al., 2015; Manoël Rekinger et al., 2015).

Sensitivity Analysis Modeling Method

In the base model, all parameters are chosen according to current situation. While there are several technological factors may change the picture of cumulative (2015-2050) silver supply shortage and surplus including silver consumption rate reduction, PV electricity conversion efficiency improvement, PV recycling process innovation, and silver recycling rate improvement. Wherein, cumulative difference of investment demand and withdraw supply (2015-2050) is used to magnitude net cumulative supply surplus and shortage.

To be concrete, according to the Axel Metz et al. (2015), silver consumption rate is expected to fall to 1.64 g/m^2 by 2025 owing to its substitution with copper. Their expectation is taken as 100% improvement by 2050 for sensitivity analysis since their estimation is relatively optimistic compared to current situation. The average electricity conversion efficiency of commercial silicon modules is expected to increase up to 23% by 2020 and 25% by 2050 (Paolo Frankl et al., 2010). This estimation is taken as 100% improvement as well. A 30-year delay with 30% recycling rate (similar to the recycling rate of other fabrication old scraps) assumed on the basis of the module's lifetime and owing to the lack of historical records is applied similarly. In addition, recycling rate of other silver fabrication old scraps is assumed to increase to 50% by 2050 from 29.7% (obtained from Weibull regression) which requires a 1.5% annual incremental from 2015 to 2050. This assumption is also used for 10% improvement in sensitivity analysis. Multiple improvement is a combination of all above mentioned improvement case. 100%, 75%, 50%, and 25% of increments are modeled and compared for each factor ultimately.

In the content of sustainable supply of silver, both primary resource potential and secondary resource (urban resource) potential are estimated. To clarify, the primary resource potential is calculated by simulated final cumulative production by the time of depletion subtract cumulatively produced silver. Depletion time of primary silver resource is calculated by the quotient of total primary resource potential and mining production. Urban resource potential of silver is estimated as recycling potential of all silver contained in use stock in the society, displayed in equation (5).

$$UR_t = \sum_{x=1}^{20}\left\{D_{t-x} \times \left[\sum_{m=n+1}^{20} \frac{\kappa}{\lambda}\left(\frac{m}{\lambda}\right)^{\kappa-1} e^{-\left(m/\lambda\right)^{\kappa}}\right]\right\} \quad (5)$$

RESULT AND DISCUSSION

The result (Figure 5) shows that silver mining production will peak around 2021 with roughly 27 thousand ton's yield and will decrease to current level before 2030. By the end of the forecasting period, namely 2050, production rate will decline to around 7 thousand metric ton. Silver mining production share from silver mines are increasing throughout the forecasting period from less than 40% to almost 70%. It indicates decline of by product ratio and increase of mining supply flexibility. Silver recycling supply from old scrap will maintain the present quantitative level. Under current recycling situation, recycling supply of silver cannot compensate the depleting primary resource.

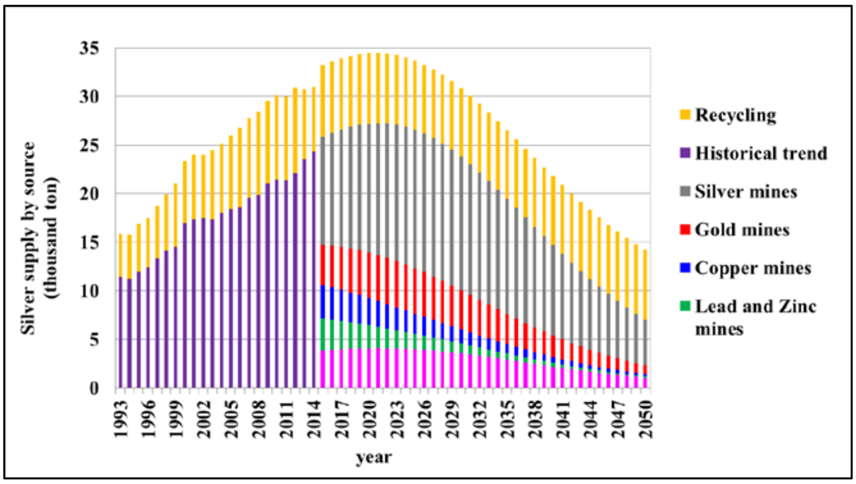

Figure 5 – Silver supply prediction by sector in base case

The result (Figure 6) shows silver demand increase from electronic and batteries, and decoration will be balanced by decrease from other photography and industry uses. The main force that drives silver demand up comes from PV sector. It is expected to exceed demand for photography and become the third biggest silver demand sector. Almost 9 thousand ton will be required for PV sector by 2030 accounting for almost 30% of the total physical production of that year. Although its demand will decline to around 6 thousand ton by 2050, silver demand for PV will account for more than 40% physical supply in the year because since primary resource depletion rate excess silver demand decrease of PV.

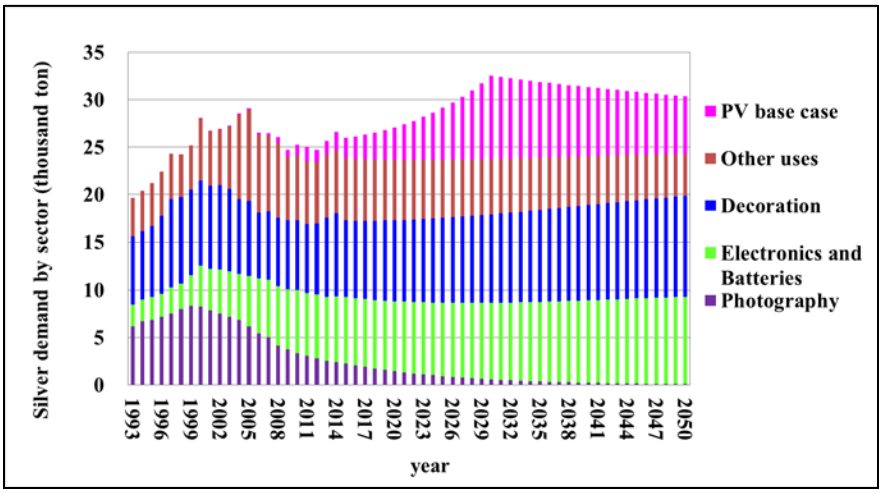

Figure 6 – Silver demand prediction by sector in base case

By the end of the forecasting period, there will be more than 50% of silver demand depend on less reliable and high cost releases from investors in the base case (Figure 7). Technology improvements can reduce the dependency on such unreliable source for different extend. Wherein, silver recycling rate improvement works most effectively. Through multiple progress, supply from disinvestment can be reduced to roughly 25%, and recycling is expected to support more than 45% of the demand.

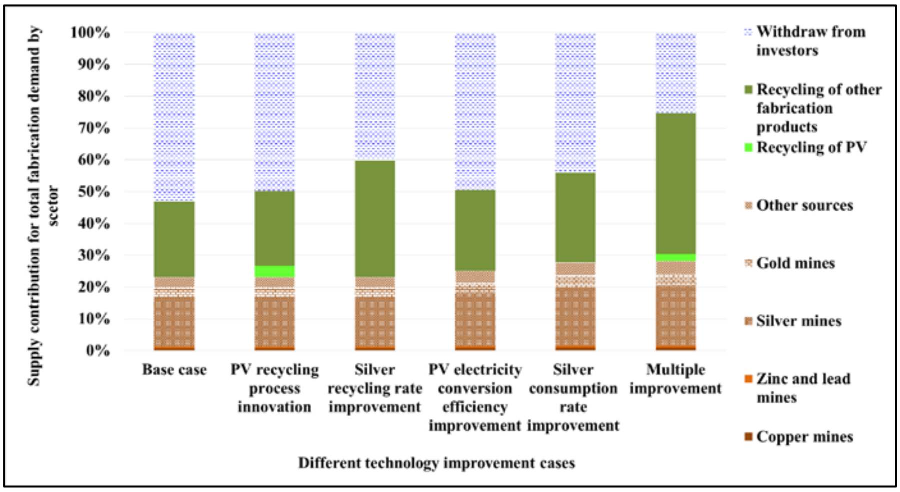

Figure 7 – Estimated silver supply contribution for total fabrication demand by sector in 2050

In the base case (Figure 8), more than 110 thousand ton of cumulative supply shortage is observed from the prediction. Through technology improvement, shortage could be relieved or offset for different degrees. Silver consumption rate reduction turns out to be the most sensitive factor and it could completely offset the cumulative shortage under roughly 80% of targeted reduction. PV recycling process innovation is the least effective factor in terms of relieving the cumulative supply shortage followed by improvement of silver recycling rate and PV electricity conversion efficiency. Under multiple progress, around 40% of targeted improvement could offset the shortage and 100% of technology improvement could create 90 thousand ton of cumulative surplus.

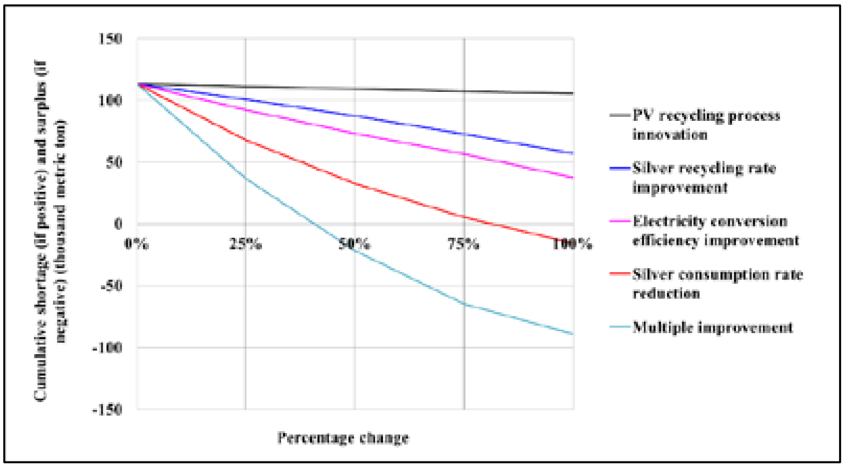

Figure 8 – Sensitivity of cumulative (2015-2050) silver supply shortage and surplus under different technology considerations

Silver market will display supply surplus until 2030 in the base model, and afterwards, silver supply shortage will keep on climbing by the end of the forecasting period, so as in PV recycling process innovation and silver recycling rate improvement cases (Figure 9). Through PV electricity conversion efficiency improvement and silver consumption rate reduction, supply deficit can be delayed for 2 to 5 years. Under multiple progress, silver deficit won't come until 2040. And in that case, there is more than enough silver stocked above ground to fill the physical supply shortage.

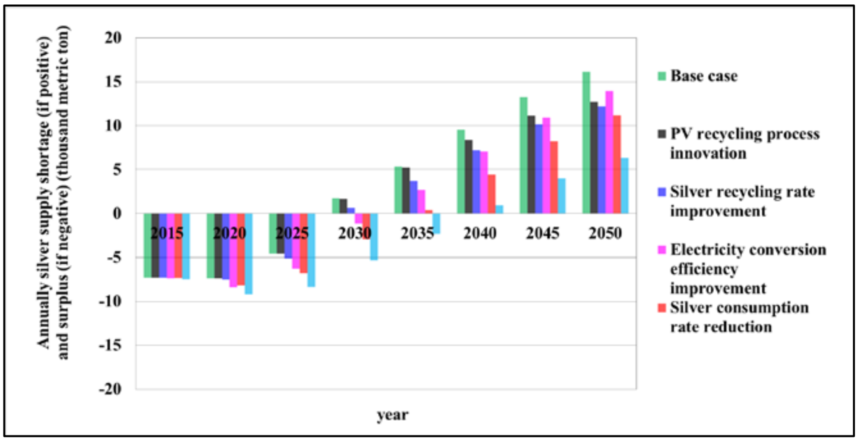

Figure 9 – Annually estimated silver supply shortage and surplus (shown every five year)

Although recycling of old scrap seems less sensitive factors, it should not be underestimated when talking about sustainability of silver supply. Silver primary resource is estimated depleting quickly (Figure 10) from more than 95 years in 1995 to less than 30 years in 2015. And, it is expected to decrease to around 10 years by 2050 and reach depletion in 2100 based on the simulation. PV recycling process innovation and silver recycling rate improvement can significantly increase the urban resource potential to around 110 and 80 thousand metric ton from roughly 50 thousand metric ton by the end of 2050 (Figure 11). PV recycling rate innovation is likely to generate large urban silver resource.

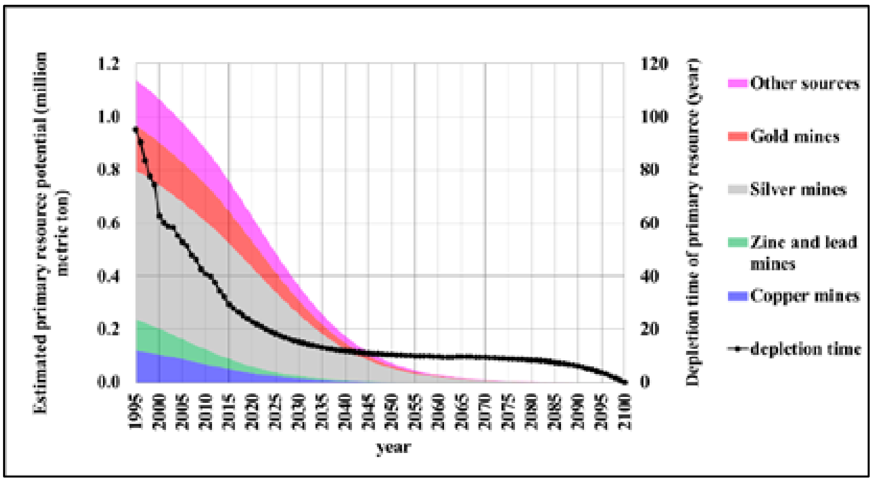

Figure 10 – Silver resource depletion time simulation

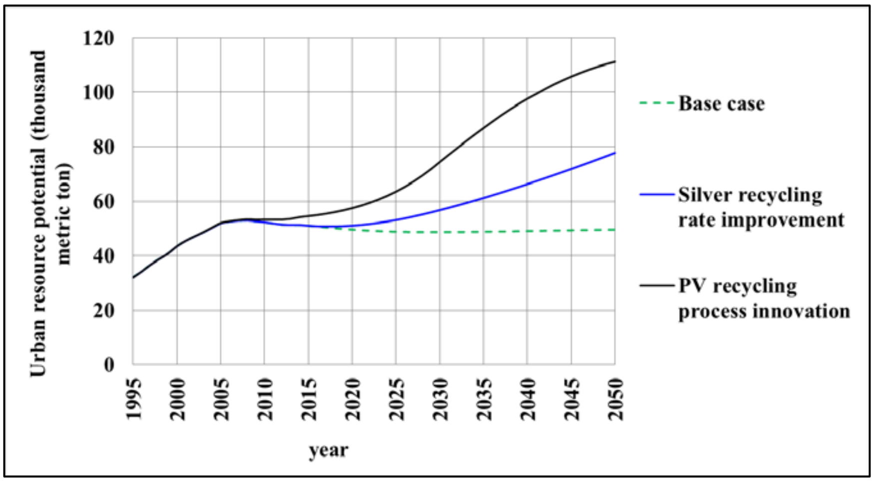

Figure 11 – Silver urban resource potential estimation

CONCLUSION

Silver mining production will decline quickly after 2010. And production from silver mines hold higher resource prospect compared with other sources. Recycling production is expected to contribute to increasingly share in total physical supply. Silver fabrication demand except PV will be stable as a whole. And the main increase comes from demand for PV which will cause large supply deficit during the forecasting period. Improvement of silver recycling rate is expected to increase the supply security. Reduction of silver consumption rate for PV seems to be the most effective factor to decrease the supply shortage. Multiple improvement is required to maintain a stable and sustainable market for silver. However it does not mean that silver supply can sustain in long term. Primary silver resource will deplete by 2100. Urban resource cannot reach the same magnitude as current mining production and therefore, only works as supplement of mining production. It calls for further improvement of recycling rate to maintain the sustainability of silver supply. And it is never enough to emphasize the importance of resource saving and substitution to decrease the dependency on critical resources.

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EVOLUTION OF MINING CONCESSIONS IN BRAZIL – 2000-2015

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EVOLUTION OF MINING CONCESSIONS IN BRAZIL – 2000-2015

ABSTRACT

The mining supercycle registered in the beginning of the century deeply impacted Brazil, bringing about a number of benefits to society. Not only Brazil, but almost all of Latin America benefited from the increase in commodity prices in general. The objective of this panel is to present the evolution of mining authorization figures in Brazil, for the period 2000-2015. In the period of reference, a total of 44.497 mining authorizations were granted in the country. The availability of resources, globally, and the reduction of risk aversion also favored mining expansion in Brazil during this supercycle. Following Chinese demand decrease, US economy recovery and the Federal Reserve expansionist policies, there is a trend of reversion of the cycle, with the reduction of mining authorizations, initially in the mineral research phase.

KEYWORDS

Mining authorization, Mineral activity, supercycle

INTRODUCTION

The objective of this panel is to present the evolution of mining authorization figures in Brazil, for the period 2000-2015. In such period, mineral activity was strongly promoted, with investment attraction and encouragement of new projects, from research to the implementation of new projects and production expansion. In the main part of this text, a series of charts, tables and maps will be provided in order to show: a) the overall evolution of mining concessions in Brazil, in the period of reference; b) the evolution of concessions of iron ore in Brazil (as the most important example of ore exploration in the country); and c) a list of selected projects approved in the period.

EVOLUTION OF MINING CONCESSIONS IN BRAZIL (2000- 2015)

a) An overall approach:

Between 2000 and 2015, around 5000 mining concessions were granted in Brazil, as depicted in Chart 1. Chart 2 presents the stock of mining concessions in selected years. In the first year presented in the Chart (1975), there were 2.949 mining concession titles, whereas in the last one (2015) the figure had climbed to 9.973 titles. The increase in the domestic and in the foreign demand, in a context of the commodity supercycle, had played a very significant role for this growth. Map 1 shows all mining concessions in Brazil (as of 31 January 2015).

Titulos / Titles		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	TOTAL
Requerimentos de pesquisa / Applictaion for Exploration Permit	1	10.071	11.548	11.766	13.976	14.413	16.362	17.334	23.561	26.875	16.037	19.855	26.695	20.463	19.106	15.512	14.455	278.029
Autorizações de pesquisa / Exploration Permit	2	21.220	11.225	9.309	11.066	10.925	14.451	12.875	13.901	18.269	15.123	18.299	18.309	8.860	13.562	12.215	17.525	227.134
Concessões de Lavra / Mining Concession	3	300	309	362	303	335	389	437	324	268	404	204	195	331	177	261	491	5.090
Registros de Licença / License Registration	4	1385	1429	1.315	1.383	1.312	1.727	1.534	1.496	1.220	1.132	1.548	1.588	1.645	1.767	1.802	1.802	24.085
Permissões de Lavra Garimpeira / Small Scale Mining Consent	5	37	8	338	52	99	73	89	46	106	122	368	258	316	212	162	175	2.461
Registros de Extração / Extration Registration	6		44	90	70	86	88	179	134	146	202	185	185	136	131	195	226	2.097
Guias de Utilização (GU) / Usage Guide	7	247	903	803	623	416	443	400	337	354	469	798	971	943	1161	1083	813	10.764
Total (3+4+5+6+7)			Mining authorizations															44.497

Table 1: Amount of Mineral Clain 2000-2015
Source: DNPM

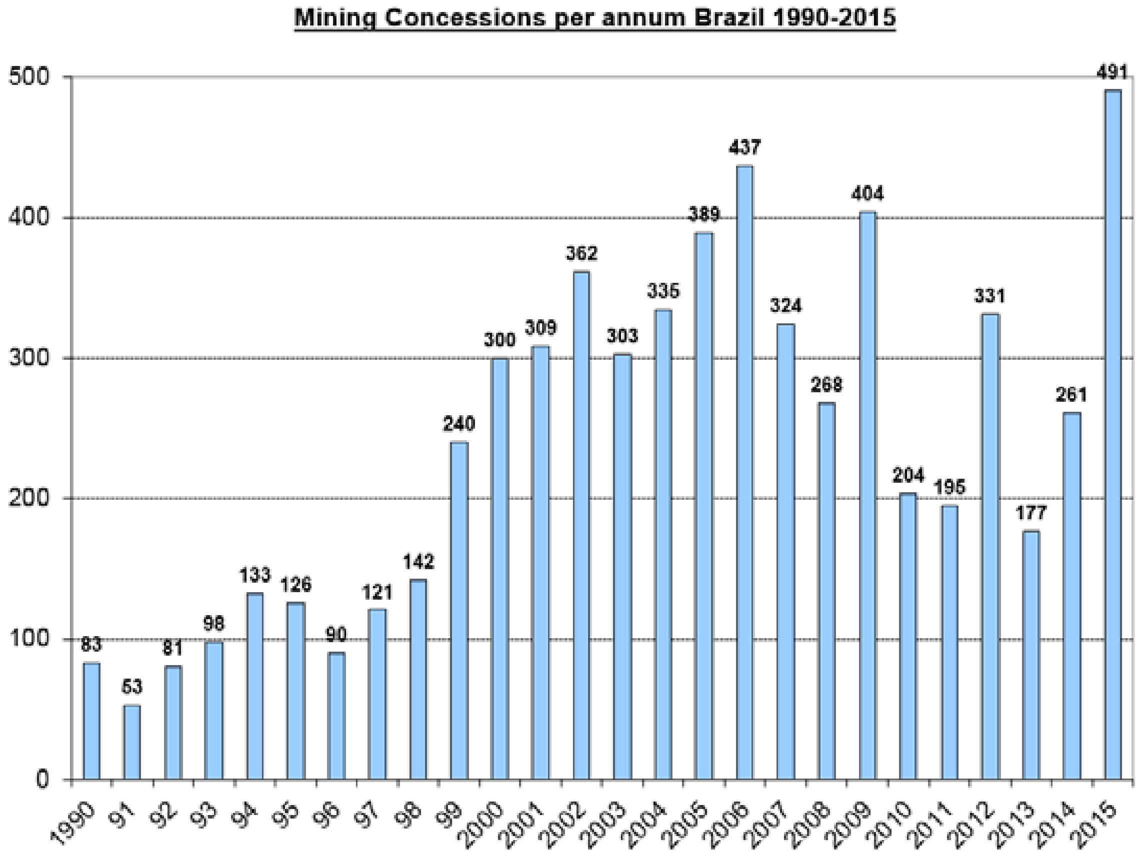


Chart 1: Number of Mining Concessions granted between1990 and 2015
Source: DNPM

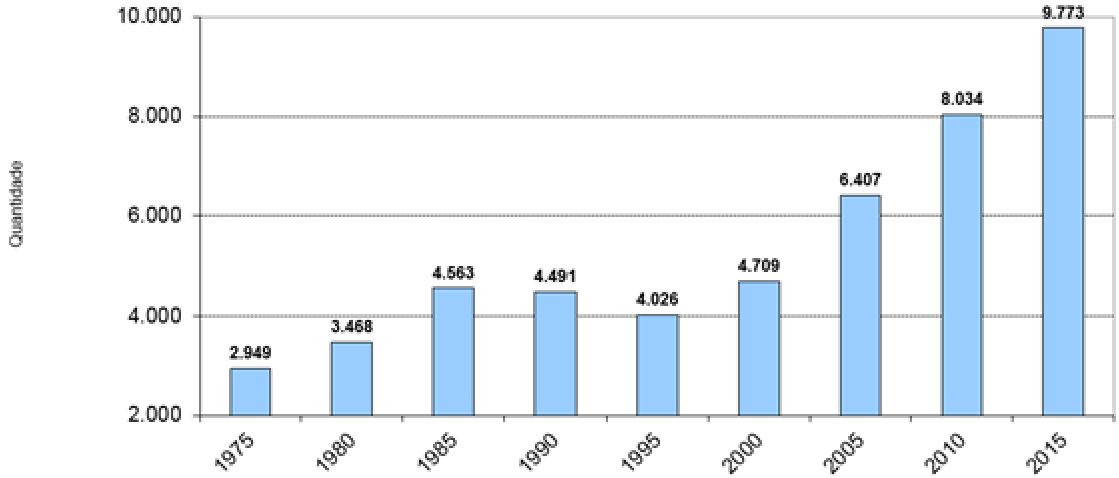
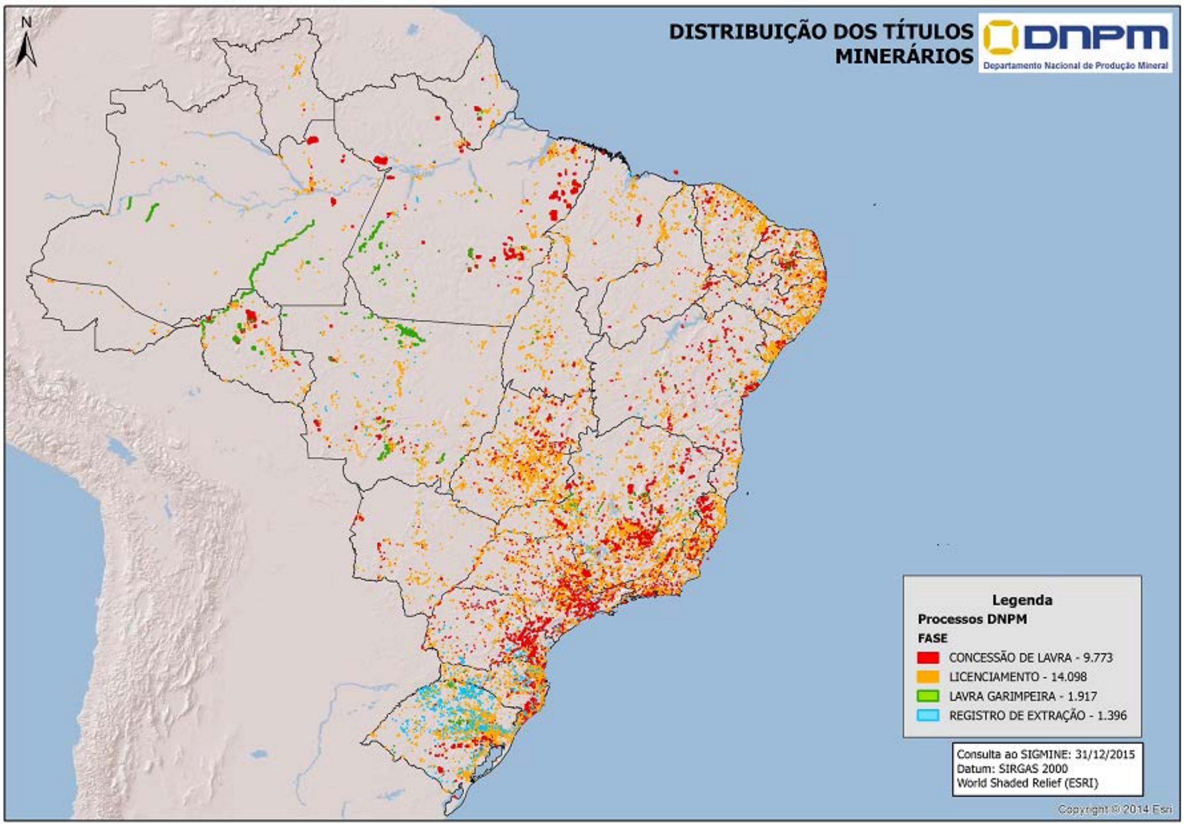


Chart 2: Evolution in the stock of mining concessions in selected years– 1975-2015
Source: DNPM

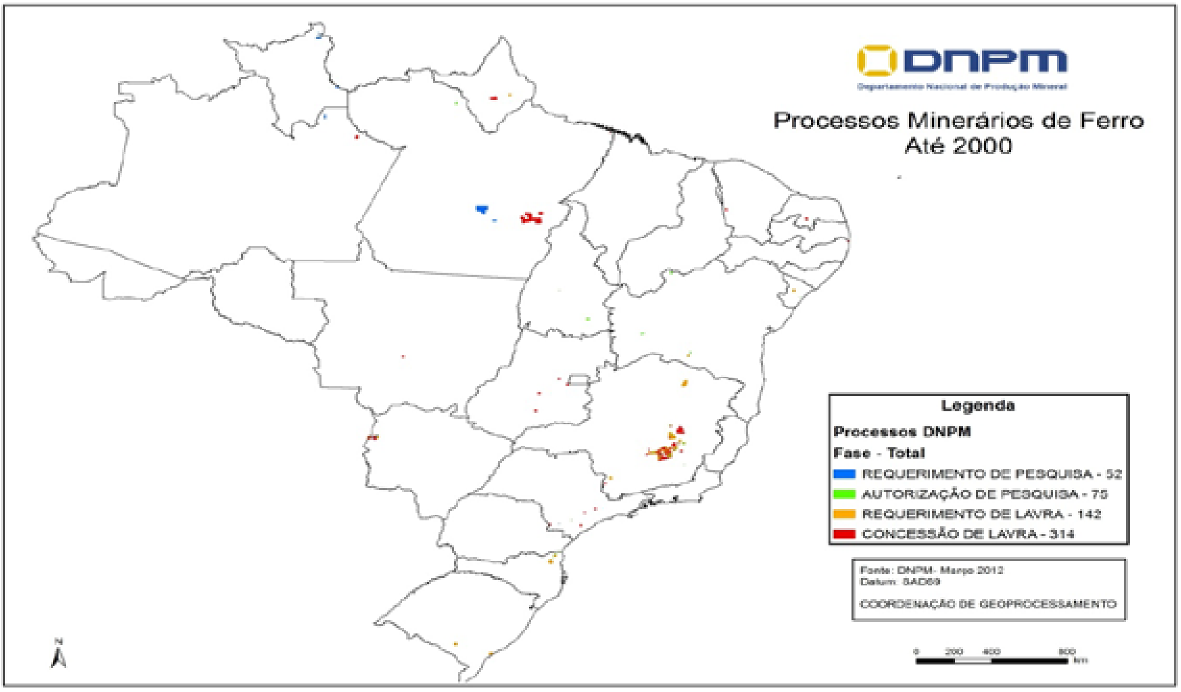


Map 1: Map of mineral exploration concessions in Brazil (as of 31 December 2015)
Source: CGTIG/DNPM

b) a case study (iron ore)

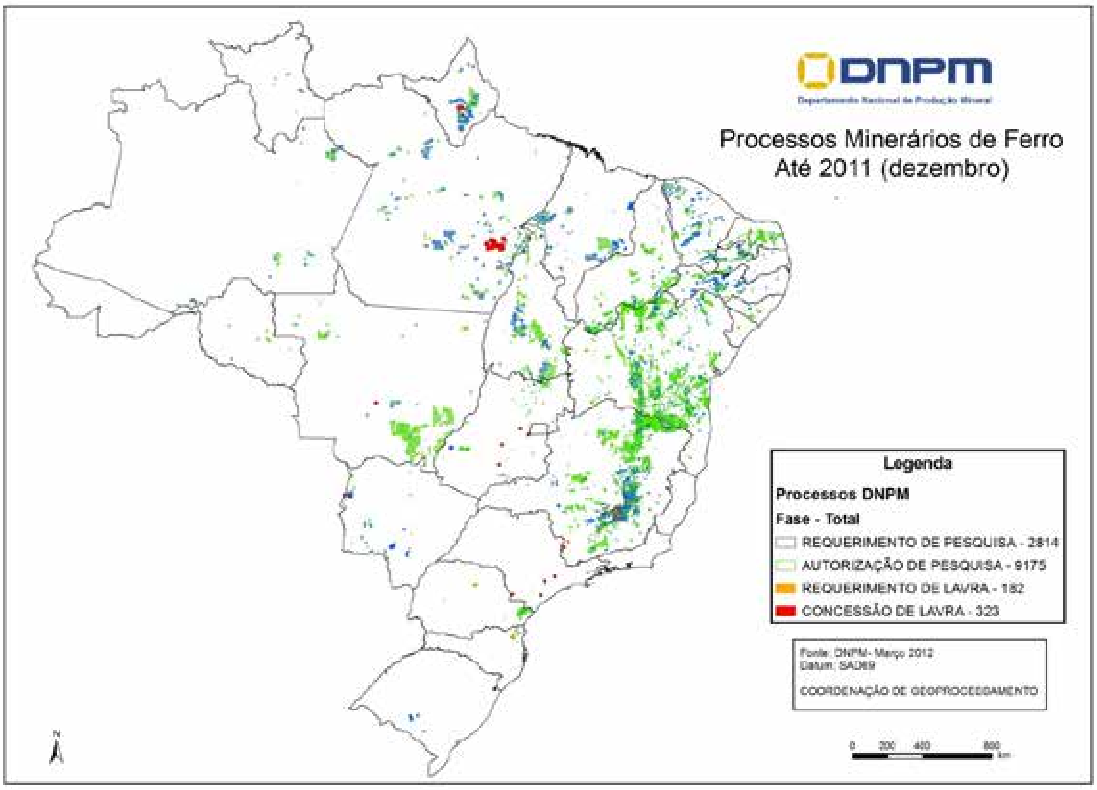
The same pattern of significant overall increase in mining concessions can be found in the case of iron ore. Maps 2 and 3 illustrate the evolution of mineral claims for iron ore, which figures prominently in the Brazilian mining sector. For mining research only, almost 12000 titles were issued. In 2011, the annual iron ore exports reached the remarkable figure of $ 41.7 billion. Prices, then, reached values of the order of US $ 190/ton. Between 2005 and 2015, the total value of exports of iron ore reached a total of US $ 230 billion. It is noteworthy that between 2005 and 2015, about 20 smaller mining projects in Brazil were initiated, given the high price of iron ore. The process of mergers and acquisitions in the iron ore sector accounted for approximately US $ 33 billion dollars in Brazil, between 1999 and 2015

Map 2 below depicts the situation of iron ore mining titles in Brazil, for the year 2000.



Map 2: Iron ore processes (as of 2000)
Source: CGTIG/DNPM (2012)

Map 3 below depicts the evolution of the situation, taking figures of the end of 2011. New titles related to mineral research (11.860 new titles in the blue and green areas) are shown on the map. One can see that new frontier of research and production can be found mainly in the north of the State of Minas Gerais, and in the states of Bahia, Tocantins, Mato Grosso, Piauí, Rio Grande do Norte, among others).



Map 3 Iron ore processes (as of 2011)
Fonte: CGTIG/DNPM (2012)

c) Selected projects

As a result of the growth in the mining sector in Brazil since 2000, several projects were estableshed since the year 2000, specially as regards, iron ore, copper, gold, nickel and bauxite. A list of some of these projects is provided below:

<u>2000</u>
INB/BA (Uranium - INB)

<u>2002</u>
Pellletizing São Luiz / MA (Iron Ore -Vale)
Americano do Brasil / GO- (Níckel -Prometálica)
Córrego do Sítio/MG (Gold – Anglogold)

<u>2003</u>
Mineração Buritirama/PA (Manganese – Buritirama)
Mineração Sertão/GO (Gold –Troy)

<u>2004</u>
Sossego/PA (Cooper - Vale)
Aboboras/MG (Iron Ore – Vale)
Capão Xavier/MG (Iron Ore – Vale)
Fábrica Nova/MG (Iron Ore – Vale)

Palito/PA (Gold – Serabi)

2005
Mineração Pedra Branca do Amapari/AP (Gold – Beadell)
Galvani/Angico Dias/BA (Phosphate – Galvani)
Serra da Borda-São Francisco/MT (Gold – Yamana)
Fábrica Nova/MG (Iron Ore- Vale)

2006
Brucutu/MG (Iron Ore – Vale)
Paragominas/PA (Bauxite – Hydro)
Turmalina/MG- (Gold – Jaguar)

2007
Fazendão/MG (Iron Ore – Vale)
Chapada/GO (Cooper/Gold - Yamana)
Prometálica/MT (Zn/Cu/Pb – Prometálica)

2008
Pelletizing Samarco III /ES (Iron Ore - SAMARCO)
Fazendão/MG (Iron ore – Vale)
Mundo Mineração/MG (Gold – Minera Gold)
São Vicente/MT (Gold - Yamana)
Andorinhas/PA (Gold – Troy)
MMX Amapá/AP (Iron Ore - MMX)

2009
Itabiritos –Vargem Grande/ Pico / MG (Iron ore / Pelletizing – Vale)
Juriti/PA (Bauxite - ALCOA)
Mirabella / BA (Níckel – Mirabella)
Bentonita/BA (Bentonite - Cia Brasileira de Bentonita)

2010
Caeté/MG (Gold- Jaguar Mining)
Aurizona/MA (Gold – Luna Gold)
SAFM/MG (Iron ore – SAFM)
Miguel Bournier/MG (Iron Ore – Gerdau)
São Vicente/MT (Gold - Yamana/Aura)

2011
Onça Puma/PA (Nickel - Vale)
Barro Alto/GO (Níckel - Anglo)
Paciência/MG (Gold – Jaguar)
Viga/MG (Iron Ore – Ferrous)

2012
Carajás expansion 40 Mt/PA (Iron Ore – Vale)
Premier/GO (Gold - Cleveland)
Nova Xavantina /MT (Gold – Caraíba/Nx Gold)
Ernesto/Pau a Pique/MT (Gold - Yamana/Aura Gold)
Salobo I/PA (Cooper -Vale)

2013
Conceição Itabiritos/MG (Iron Ore – Vale)

Tubarão VIII/ES (Pelletizing- Vale)
BAMIN/BA (Iron Ore – ENRC)
Mbac/TO (Phosphate – Mbac)
Pelletizing VSM/MG Pelletizing - Vallourec-Sumitomo)
C1 Santa Luz/BA (Gold – Yamana/Briogold)
Pilar/GO (Gold – Yamana – Briogold)
Riacho dos Machados/MG (Gold – Carpathian/Briogold)
Mineradora Santo Expedito/GO (Bauxite – Santo Expedito- Min. Curimbaba)
Proj Tucano/AP (Iron ore co product gold – Beadell)
Posse/MG (Iron Ore – Cruzader)

2014
Maracás/BA (Vanadium – Largo resources)
IVª Pelletizing/ES – Iron Ore - SAMARCO)
Minas Rio/MG (Iron ore – Anglo Ferrous)
VIIIª Pelletizing/ES – Iron Ore – Vale)
Serra Leste Carajás/PA (Iron Ore – Vale)
Salobo II/PA (Cooper – Vale)
Cancana/RO (Manganese – BMC)

2015
Cauê Itabiritos/MG (Iron Ore – Vale)
Conceição Itabiritos/MG (Iron Ore – Vale)
Projeto Bonito/PA (Phoshhate – B&A Mineração)

2016
Antas North/PA (Cooper – Avanco)
Braúna/BA (Diamond – Lipari)
S11D/PA (Iron Ore – Vale)

2017-2020 (Estimated)
Rondon/PA (Bauxite -Votorantim)
Patrocínio/MG (Phosphate - Vale)
Carnalita/SE (Potassium -Vale)
Mara Rosa/GO (Gold – Amarillo)
Curinga/PA (Gold – Magellan)
Juruena/MT (Gold – Crusader)
Tocantizinho/PA (Gold – Eldorado)
CBMM/MG (ETR – CBMM)
Pedra Branca/PA (Cooper – Avanco)
Belo Sun/PA (Gold – Belo Sun)
Boa Esperança/PA (Cooper/Caraíba)
Vale verde/Al (Cu/Au/Fe – Eldorado)
Borborema/RN (Gold – Crusader)
Itataia/CE (Uranium – Phosphate – Galvani & INB)
Santa Maria/RS (Zinc – Votorantim)
Serra Verde/GO (ETR – Mining Ventures)
Aripuana/MT (Zinc – Votorantim)

We can also highlight several projects related to gold mining (Amarillo, Belo Sun, Cruzader, Eldorado Gold) and rare earths (CBMM, Serra Verde). In the State of Pará, Vale do Rio Doce and several other companies have promising copper areas. The bauxite mining has also promising projects in the states of Pará, Goiás and Bahia (Amargosa project of Rio Tinto). Brazil can also emerge as a significant player in the titanium mining with projects in Minas Gerais, Goias, Pernambuco and Rio Grande do Sul.

CONCLUSION

Despite the reversal in the supercycle of commodities, many projects are currently being implemented in Brazil. The S11D project that Vale do Rio Doce is currently implementing in the State of Pará will consolidate the company's position as the largest global player in iron ore. In other metallic minerals, new projects (iron ore, bauxite, copper, gold, nickel) are strengthening the capability of mining in Brazil. In 2014, the production levels of these mineral goods reached record volumes as a result of the expansions and new projects. In 2011, at the peak in the price of commodities, the value of Brazilian mineral production reached approximately US $ 53 billion. It is necessary to develop private and public policies for the mining sector in order to maximize the competitiveness and sustainability of the productive sector throughout the production chain.

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TERMS EMPLOYED IN THIS TEXT (PORTUGUESE-ENGLISH):

Requerimento de Pesquisa: Applictaion for Exploration Permit
Autorização de Pesquisa: Exploration Permit
Relatório de Pesquisa: Exploration Report
Relatório de Pesquisa Aprovado: Exploration Final Report Approved
Concessão de Lavra: Mining Concesson
Registro de Licença: License Registration
Permissão de Lavra Garimpeira: Small Scale Mining Consent
Registro de Extração: Extration Registration
Títulos minerários: Mineral Claim
Cessão parcial: Partial Assign
TAC : Adjustment Conduct Term
Guia de Utilização: Usage Guide

GLOBAL TRENDS IN MINING PRODUCTION

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24th World Mining Congress
MINING IN A WORLD OF INNOVATION
October 18-21, 2016 • Rio de Janeiro /RJ • Brazil

GLOBAL TRENDS IN MINING PRODUCTION

ABSTRACT

Knowledge about global trends in mining production is the basis of a forward-looking minerals policy. Since the early 1980ies the Austrian Federal Ministry of Science, Research and Economy publishes on an annual base the statistical compendium "World Mining Data". This is done in close cooperation with the International Organizing Committee for World Mining Congresses. "World Mining Data" nowadays is a reference book with details on minerals production figures of 63 different mineral commodities from 168 countries around the world. "World Mining Data" provides an indispensable basis for commodity forecasts and activities in minerals policy at national and global level.

The author - one of the compilers of "World Mining Data" - discusses the different regional and sectoral trends in global mining production in the past three decades: Production data are broken down by continents, by economic blocs, by development status of producer countries, by political stability of producer countries and by groups of minerals. Special attention is payed to market concentrations and their possible influence for supply risks.

Nowadays almost 60% of worldwide minerals production comes from Asia. Since 2003 China is the most important minerals producing country both in terms of volume and in terms of value with a share of 27% of total world production in 2014. 60% of world minerals production still comes from developing countries or least developed countries and also almost two thirds of world minerals production comes from unstable or extreme unstable countries. In the latest years high country concentrations are detected within Commodities like REE, Cobalt, Tungsten, Antimony a.s.o. If producing countries of those raw materials are also detected as political instable supply risk is increasing.

KEYWORDS

World Mining Data, Mining Production, Minerals Policy, Country Concentration of Minerals, Political Stability of Producer Countries, Supply Risk

INTRODUCTION

Knowledge about global trends in mining production is the basis of a forward-looking minerals policy. Since the early 1980ies the Austrian Federal Ministry of Science, Research and Economy publishes on an annual base the statistical compendium "World Mining Data". This is done in close cooperation with the International Organizing Committee for World Mining Congresses. "World Mining Data" nowadays is a reference book with details on mineral raw materials production figures of 63 different mineral commodities from 168 countries around the world. "World Mining Data" provides an indispensable basis for commodity forecasts and activities in minerals policy both at national and global level. Most recently the European Commission used production data and Herfindahl-Hirschman-Indices from "World Mining Data" to work out the latest Critical Raw Materials Report.

World Mining Data

Mineral production figures in the annual publication "World Mining Data" are presented in different forms: by Minerals (at present 63), by continents, by development status of producer countries (according to United Nations), by country groups and economic blocs, by political stability of producer countries (according to World Governance Index of World Bank), by annual per-capita-income (according to World Bank), by value in USD, by ranking of producer countries and by countries from A to Z (at present 168). Moreover a so-called Herfindahl-Hirschman-Index HHI_{mod}, an adequate means to work out country concentrations of mineral raw materials as basis for current issues of supply risk, is highlighted. All these special features make the "little" difference between "World Mining Data" and other mineral statistics compendiums.

Sources of production figures in "World Mining Data" are coming from:

- Questionnaires which are sent via Austrian Embassies to competent Authorities of producer countries (e.g. Geological Surveys, Ministries, Chamber of Mines, …)
- Questionnaires which are sent to Members of the International Organizing Committee for World Mining Congresses
- ICG (International Consultative Group of Non-Ferrous Metals): current members are WBMS (World Bureau of Metal Statistics), BGS (British Geological Survey), USGS (US Geological Survey), BGR (German Geological Survey), BRGM (French Geological Survey), NRCan (Natural Resources Canada), different Study-Groups in Lisbon (Copper, Lead/Zinc, Nickel), and BMWFW (Austrian Federal Ministry of Science, Research and Economy). ICG meetings are held every year to discuss production figures.
- iea (International Energy Agency), bp - British Petrol , WNA - World Nuclear Association, KPCS - Kimberley Process Certification Scheme, …
- Journals (e.g. Industrial Minerals, Metal Bulletin, …)

In "World Mining Data" minerals are grouped into five commodity groups:

- Iron and Ferro-Alloy Metals: Fe, Cr, Co, Mn, Mo, Ni, Nb, Ta, Ti, W, V
- Non-Ferrous Metals: Al, Sb, As, Bauxite, Bi, Cd, Cu, Ga, Ge, Pb, Li, Hg, Re, REE, Se, Te, Sn, Zn
- Precious Metals: Au, Ag, Pt, Pd, Rh
- Industrial Minerals: Asbestos, Baryte, Bentonite, Boron, Diamonds, Diatomite, Feldspar, Fluorspar, Graphite, Gypsum, Kaolin, Magnesite, Perlite, Phosphates (P2O5), Potash (K2O), Salt, Sulfur, Talc, Vermiculite, Zircon
- Mineral Fuels: Steam Coal, Coking Coal, Lignite, Natural Gas, Petroleum, Oil Sands, Oil Shales, Uranium

For further analyses it is very important to know that production figures published in "World Mining Data" do not refer to crude ore (ROM/Run of mine) or concentrate produced from it, but indicate the content of recoverable valuable elements and compounds. Otherwise it would not be possible to compare metals or also some industrial minerals from different countries. For instance Iron Ores vary between 30% Fe-content (carbonate ores) and 66% Fe-content (oxide ores). In the group of industrial minerals for instance Phosphates have also a greater range in P_2O_5-content: Phosphates from North Africa's sedimentary deposits range between 15% and 35% P_2O_5-content. On the other hand P_2O_5-content of North European or Russian Phosphate deposits which contain mainly Apatite accounts more than 45%.

Also total world production figures in "World Mining Data" do not include Bauxite production to avoid double counting as Bauxite is the base raw material in Aluminium production. Moreover all other metals are presented in content figures. Only Bauxite is presented as crude ore. Nevertheless production figures of Bauxite are listed both in commodity chapter and country chapter of "World Mining Data".

Construction minerals such as sand and gravel or ornamental and dimension stones are not listed in "World Mining Data" so far as these materials are usually produced for local commerce only and are not traded on a worldwide basis. Hence, authentic statistics on construction minerals are not available.

Total World Mining Production

Total World Production by Continents

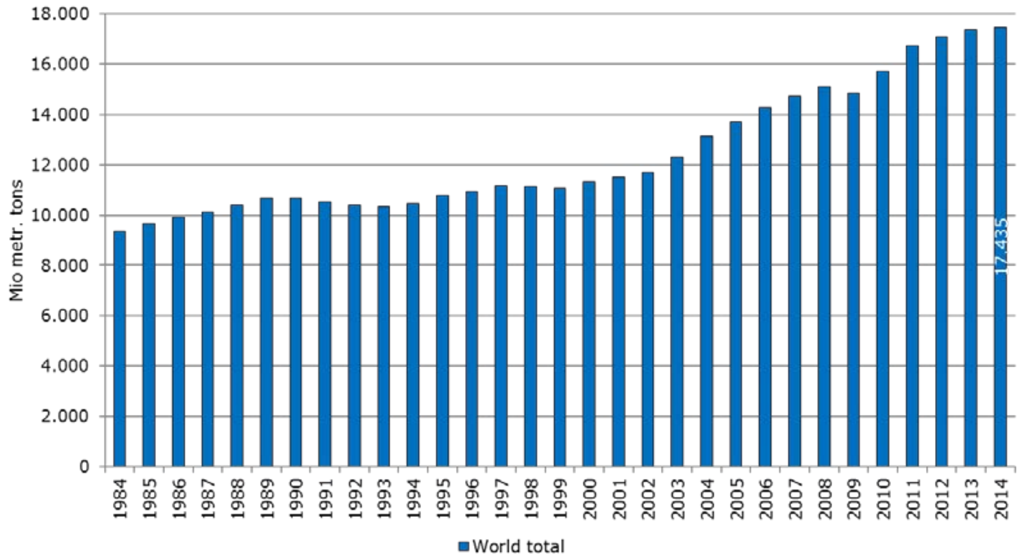

Figure 1 - World mining production 1984 - 2014
(without construction minerals, in Million metr. t)

Total World production of mineral raw materials without construction minerals is plotted in figure 1. In the early 1980ies and 1990ies total world production was around 10 Billion metric tons with a slight upward trend until the end of the century. After 2002 a sharp increase is detectable - the mineral raw materials rally began with yearly growth rates of 3% to 4% triggered by China's raw material hunger. The enormous increase was suddenly interrupted by the World economic crisis in 2008 which had negative effects in world mining production in 2009 (negative growth rate of -1.8%). 2010-2012 were years with significant growth rates of 5.8% and 6.5% in mineral raw materials production. Since 2013 the curve began to flatten with growth rates of 1.6% in 2013 and only 0.5% in 2014. Main reasons for this could be the flattening of world economy and the steep downward trend of mineral raw material prices.

	Production 2014 in Million metr. t	Share %	Δ% 2013 / 2014
Asia	10.222	*58.6*	*-0.3*
North America	2.589	*14.8*	***+5.9***
Europe	1.500	*8.6*	*-4.5*
Latin America	1.152	*6.6*	*-0.5*
Oceania	1.028	*5.9*	***+7.0***
Africa	943	*5.4*	*-1.2*
Total	**17.435**	***100.0***	***+0.5***

Figure 2 - World mining production 2014 by continents
(without construction minerals, in Million metr. t)

In 2014 World's total production of mineral raw materials without construction minerals was around 17,435 Million metric tons. Asia is the biggest producer of mineral raw materials with 10,222 Million metric tons (about 58.6% of total production), followed by North America with 2,589 Million metric tons (about 14.8% of total production), and followed by Europe, Latin America, Oceania and Africa. Largest growth rates in 2014 are detected again in Oceania (i.e. mainly Australia) with 7% followed by North America with 5.9%. Figures 2 and 3 show these trends in detail.

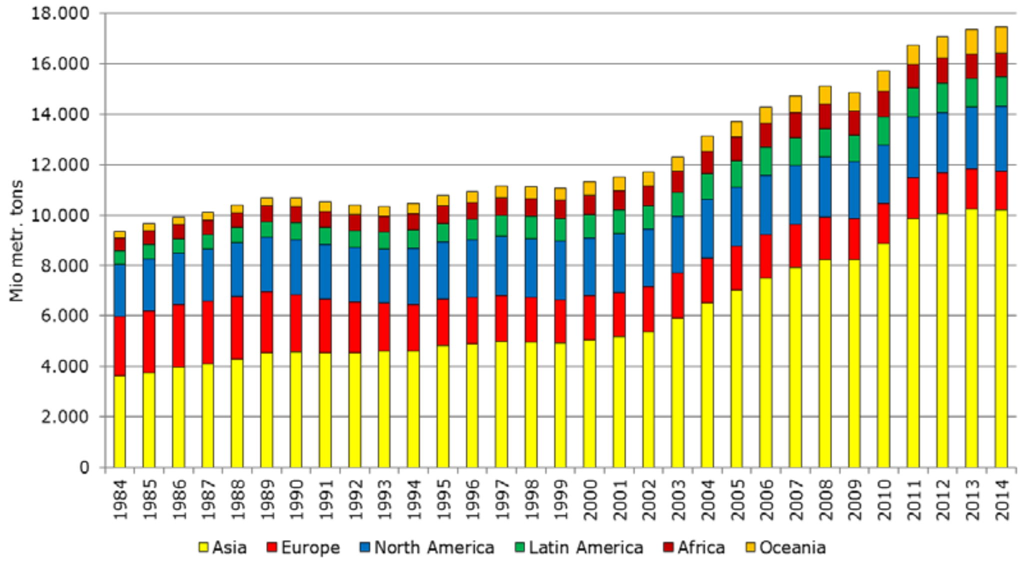

Figure 3 - World mining production 1984 - 2014 by continents
(without construction minerals, in Million metr. t)

Asia has doubled its mineral raw materials production since 2000. The main producer countries in Asia in 2014 are China (45.8% share of Asia), the Asian part of Russia (11.7% share of Asia), India (8.4% share of Asia) and Indonesia (5.7% share of Asia), see figure 4.

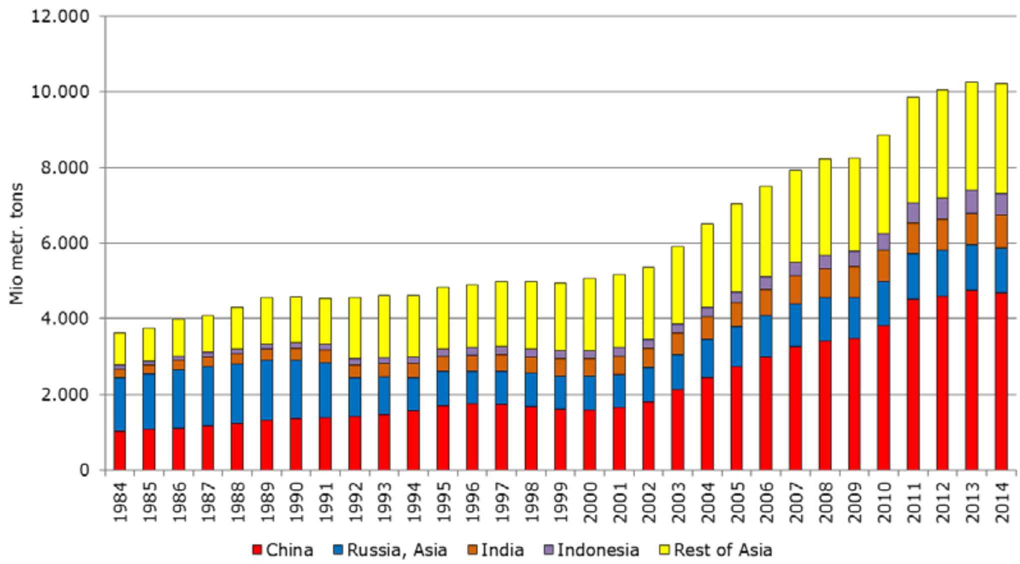

Figure 4 - Mining production 1984 - 2014 Asia, main producer countries
(without construction minerals, in Million metr. t)

Figure 5 shows mineral raw materials production of Europe compared to North America.

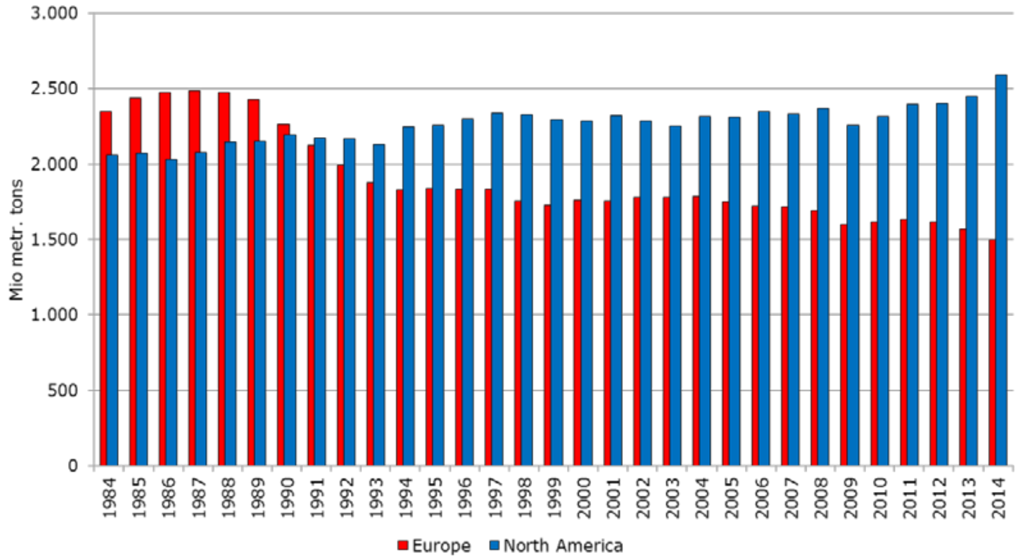

Figure 5 - Mining production 1984 - 2014 Europe vs. North America
(without construction minerals, in Million metr. t)

Since over 30 years North America's (i.e. mainly United States and Canada) mineral raw materials production is at a constant high level with a significant plus in 2014 due to rapid increase of mineral fuels production mainly shale gas. Europe's sharp production decrease in the early 1990ies was triggered by the lower coal production these days all over Europe. Since years Europe is the only continent with a constant decline in mineral raw materials production!

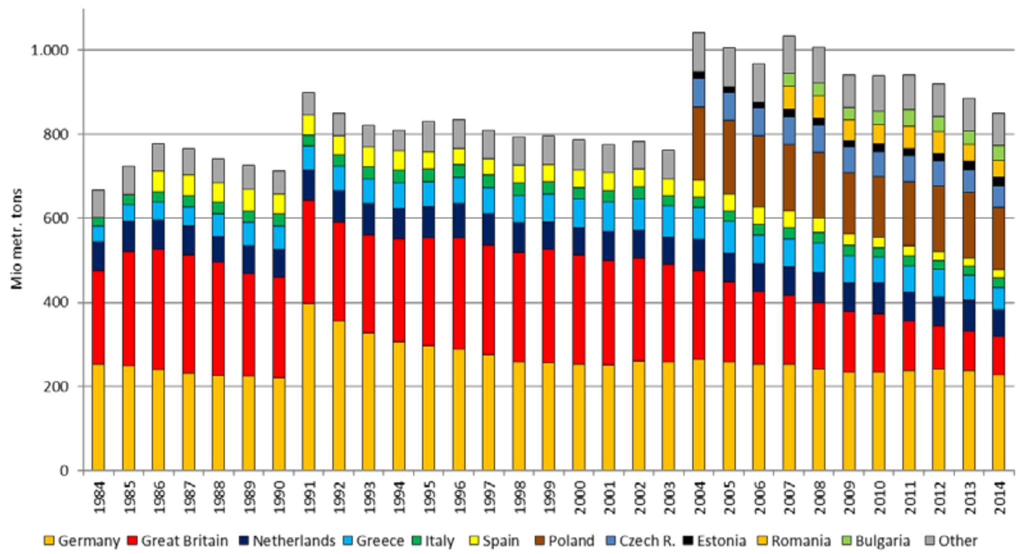

Figure 6 - Mining production 1984 – 2014: European Union
(without construction minerals, in Million metr. t)

Within the European Union this general trend is similar to whole Europe's production. European Commission has noticed this trend and undertook active countermeasures since 2008 with several Raw Materials Initiatives to foster European minerals production. The main reason for the decreasing trend in mineral raw materials production within the EU is the dramatic decline in UK's production (Figure 6, red bars) caused by a sharp fall of Northern Sea's mineral fuels output.

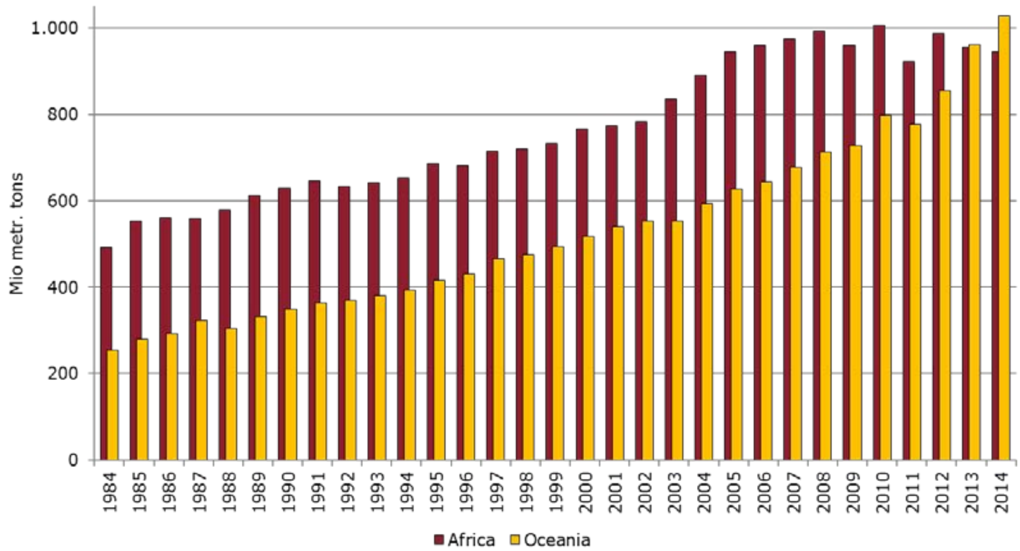

Figure 7 - World mining production 1984 - 2014 Africa vs. Oceania
(without construction minerals, in Million metr. t)

Figure 7 shows mineral raw materials production of Africa compared to Oceania. Oceanian production which is resulting mainly from Australia's production rates shows a straight forward looking exponential curve and has quintupled since the early 1980ies with absolute growth rates of 9.8% in 2012 and 12.5% in 2013.

In Africa, civil wars in Libya and other African countries caused an extreme decreasing trend in 2011 with -8.2% followed by an increase of +6.9% in 2012 with the resumption of petroleum production in Libya. In 2013 and 2014 African production declined again with -3.2% and -1.2%. Thus, Oceania has overtaken the so-called mineral rich continent Africa since 2013. In this context once more it becomes apparent that wars, economic crises and disasters have a lasting negative effect on mining production.

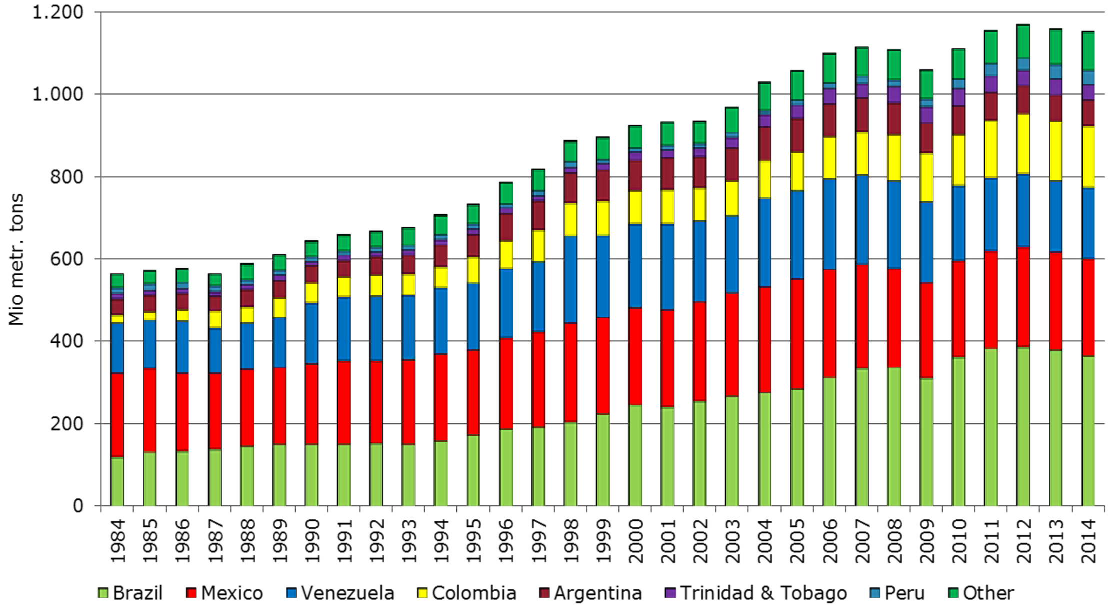

Figure 8 - Mining production 1984 - 2014 Latin America
(without construction minerals, in Million metr. t)

Latin America's mineral raw materials production (Figure 8) also shows a linear increase since 1984. Since 2012 a slight decrease is detectable caused by the slight declining Brazilian production (Figure 8, green bars).

Total World Production by Groups of Commodities

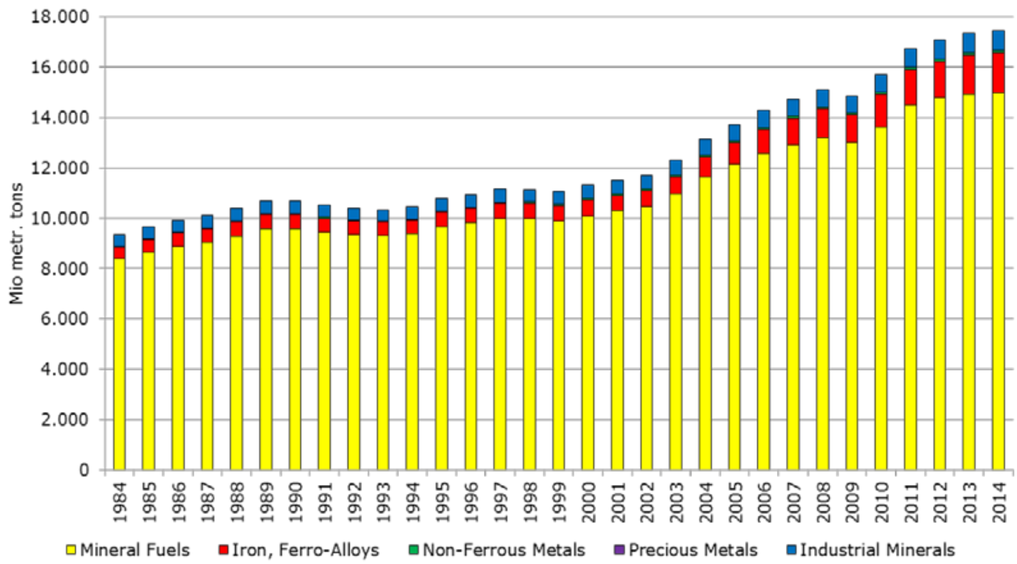

Figure 9 - World mining production 1984 - 2014 by groups of minerals
(without construction minerals, in Million metr. t)

The group of Mineral Fuels dominates the World production of mineral raw materials with more than 85% of total in 2014 followed by the group of Iron and Ferro Alloy Metals with 9% and the group of Industrial Minerals with 4.5% (Figure 9). The production figures of Non-Ferrous Metals and Precious Metals are not shown in figure 9 because they are to low compared to the other groups of commodities.

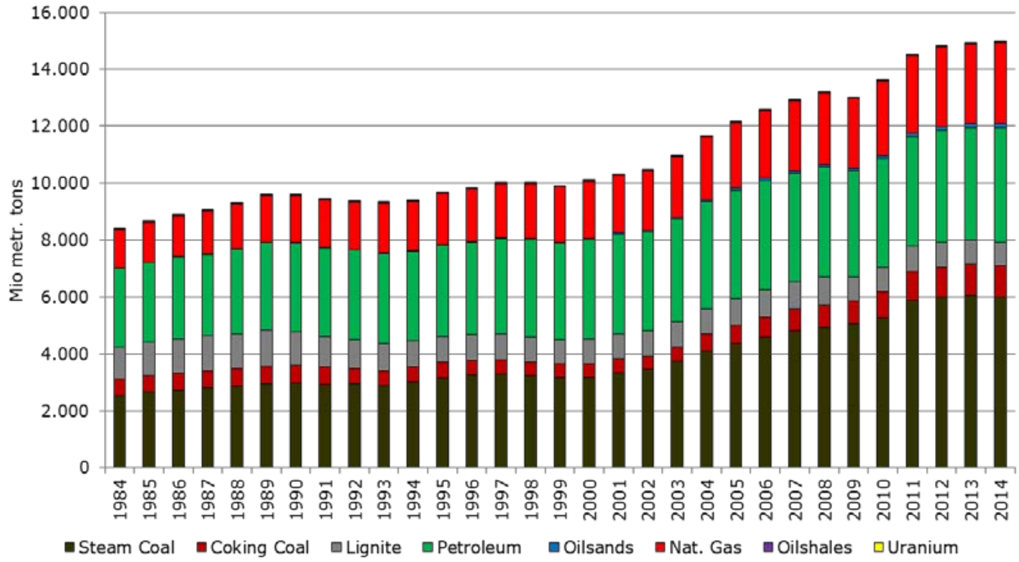

Figure 10 - World Mining production 1984 - 2014 by groups of minerals, Mineral Fuels (in Million metr. t)

The group of Mineral Fuels (Figure 10) confirms the global trend demonstrating the sharp increase in production of mineral raw materials beginning in the early 2000s with yearly growth rates of 3% to 4% triggered by China's high amount in steam coal production. More than half of Mineral Fuels production results from coal mining! In 2014 China produced a total of 3.6 Billion metric tons of coal! In contrast all other Mineral Fuels show a very stable tendency. However, figure 10 demonstrates exactly the opposite to the world wide initiatives concerning increasing usage of renewable energies in the light of the implementation of the Kyoto Protocol which was adopted in 1997.

Figure 11 shows the dominance of Iron Ore in total quantity within the group of Iron and Ferro Alloy Metals. The production figures of all other Ferro Alloy Metals are marginal compared to Iron Ore.

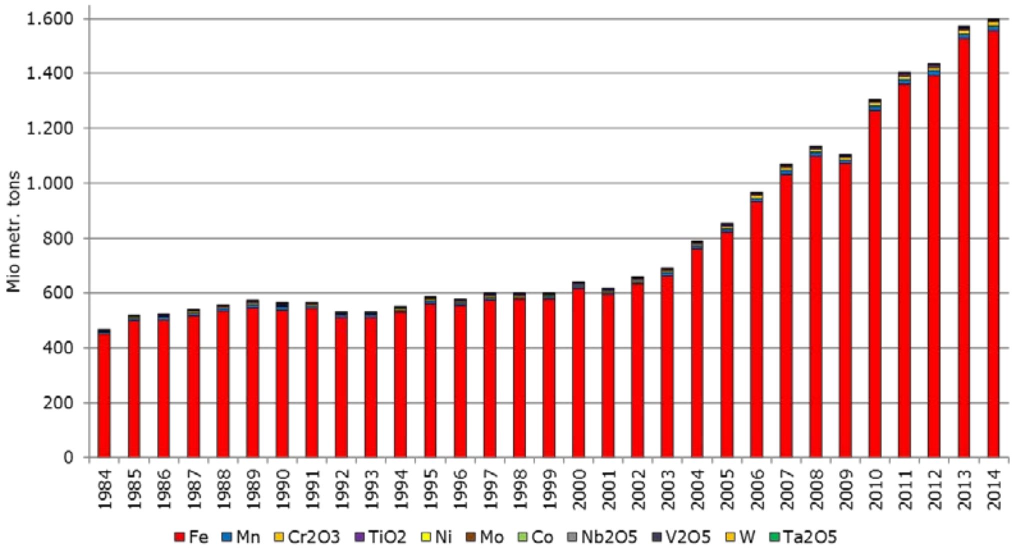

Figure 11 - World Mining production 1984 - 2014 by groups of minerals, Iron and Ferro Alloys (in Million metr. t)

Iron Ore production on a worldwide base is presented in figure 12. In 2014 three countries dominate the world Iron Ore market with 71%: China (Figure 12, red bars), Australia (Figure 12, blue bars) and Brazil (Figure 12, orange bars). Moreover figure 12 shows the substantial increase of Iron Ore production with a factor 4.5 in China and Australia starting in 2003 up to 2014. The other major Iron Ore market players, especially Brazil, show an approximate slight stable growth rate over the last decade.

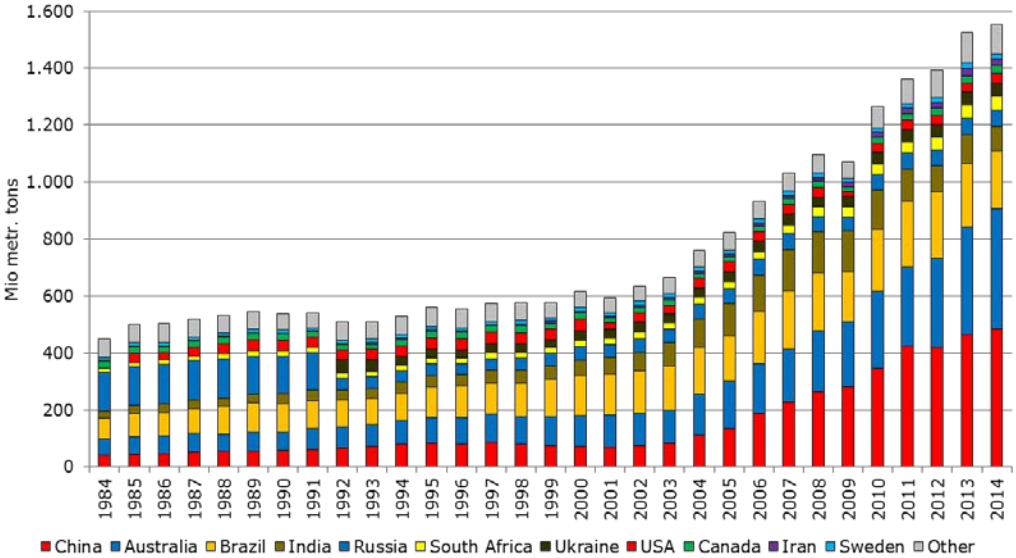

Figure 12 - World Mining production 1984 - 2014, Iron Ores (metal content, in Million metr. t)

The Nickel production on a worldwide base is shown in figure 13. It shows that since 2006 new players joined the global Nickel market with major growth in production, in particular The Philippines (Figure 13, red bars) and Indonesia (Figure 13, green bars). Due to government mandated export ban/restrictions of crude ores in 2014 the production of mineral raw materials in Indonesia collapsed.

Production figures of all other major Nickel producing countries like Russia, Australia and Canada are at constant high level over decades with only slight increases.

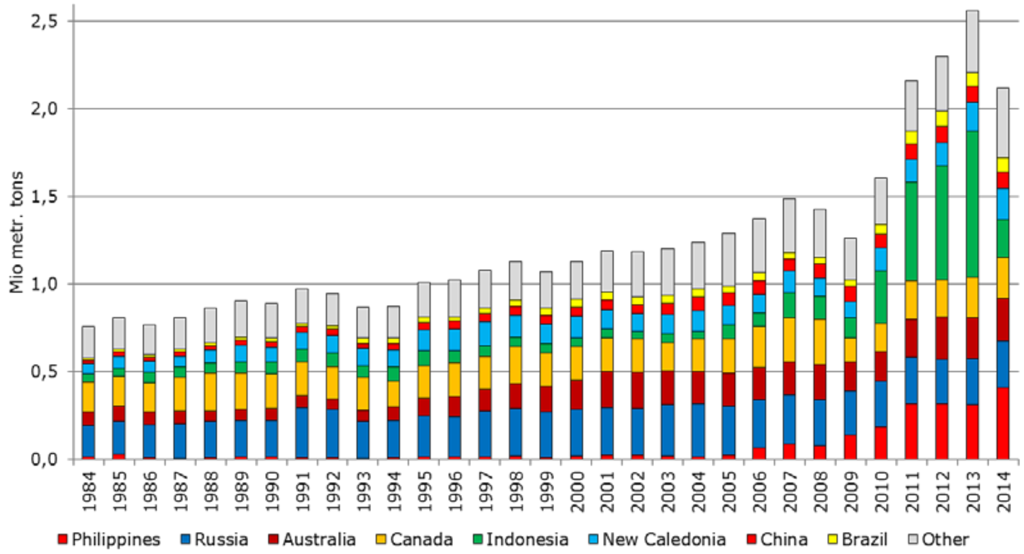

Figure 13 - World Mining production 1984 - 2014, Nickel
(in Million metr. t)

The dominance of Aluminium in the group of Non-Ferrous Metals due to rapid increases of China's production figures is demonstrated in figure 14, followed by Copper, Zinc and Lead. The production figures of all other Non-Ferrous Metals are marginal compared to above mentioned metals.

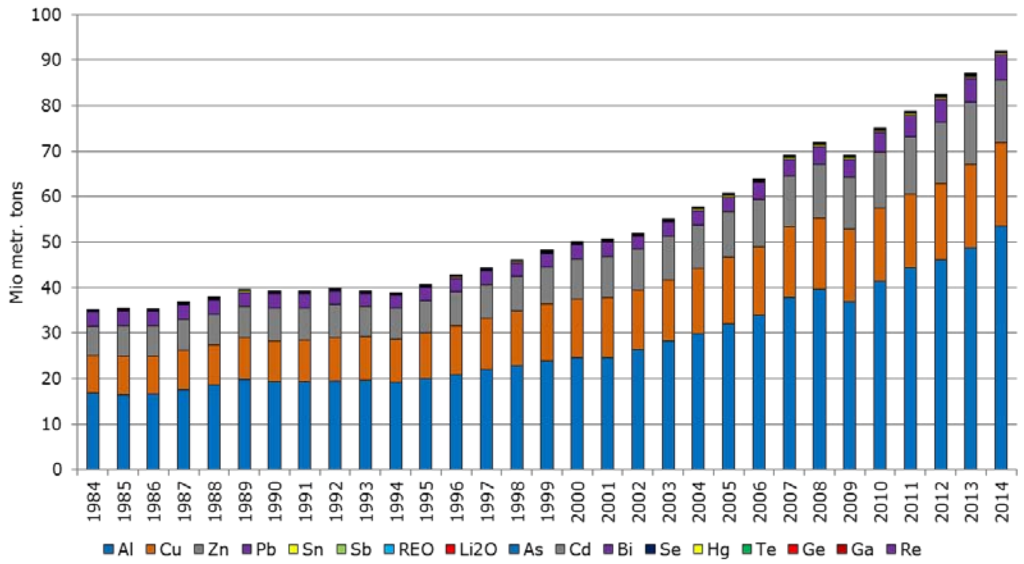

Figure 14 - World Mining production 1984 - 2014 by groups of minerals, Non-Ferrous Metals
(without Bauxite, in Million metr. t)

As Brazil is the third most important global Bauxite player in 2014, global Bauxite production from 1984 to 2014 is presented in figure 15 (Brazil, orange bars). Moreover the chart also shows the high amount of China's Bauxite production in 2014 (Figure 15, red bars) and furthermore the above mentioned crude ore production collapse of Indonesia (Figure 15, green bars) due to export ban/restrictions in 2014. For this reason in 2014 the worldwide total Bauxite production is nearly the same as in 2012.

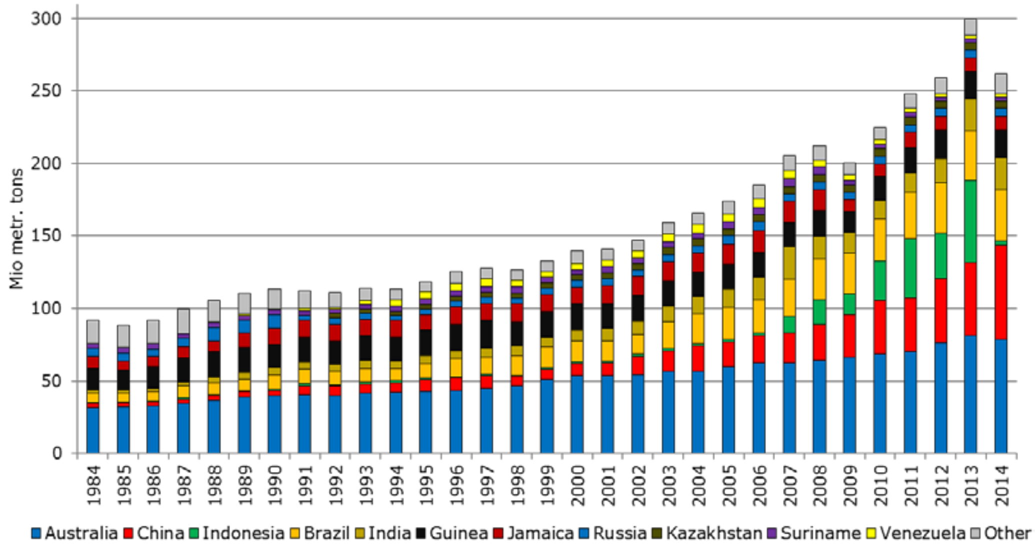

Figure 15 - World Mining production 1984 - 2014, Bauxite
(in Million metr. t)

In the group of Precious Metals with production figures of a bit more than 30,000 metric tons in 2014 the dominance of Silver is highlighted in figure 16. The Silver to Gold production ratio is about 9:1 in 2014 with Silver primary metal production of around 27,000 metric tons and Gold primary metal production of around 3,000 metric tons. Platinum Group Metals like Platinum (159,250 kg primary metal), Palladium (192,700 kg primary metal) and Rhodium (19,120 kg primary metal) were mined at an total amount of 371 metric tons of primary material in 2014.

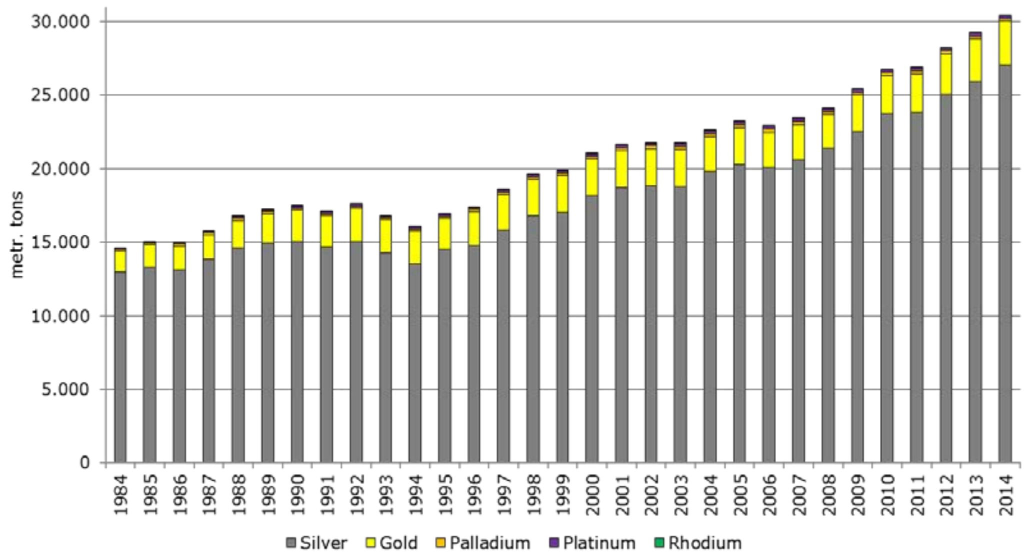

Figure 16 - World Mining production 1984 - 2014 by groups of minerals, Precious Metals
(in metr. t)

Silver production has a long tradition and history in Latin America. Big players in Latin America's Silver production are Mexico, Peru, Chile, Bolivia and Argentina (Figure 17). Main producer countries outside Latin America are China (3rd Rank), Australia (4th Rank), Russia, Poland and USA.

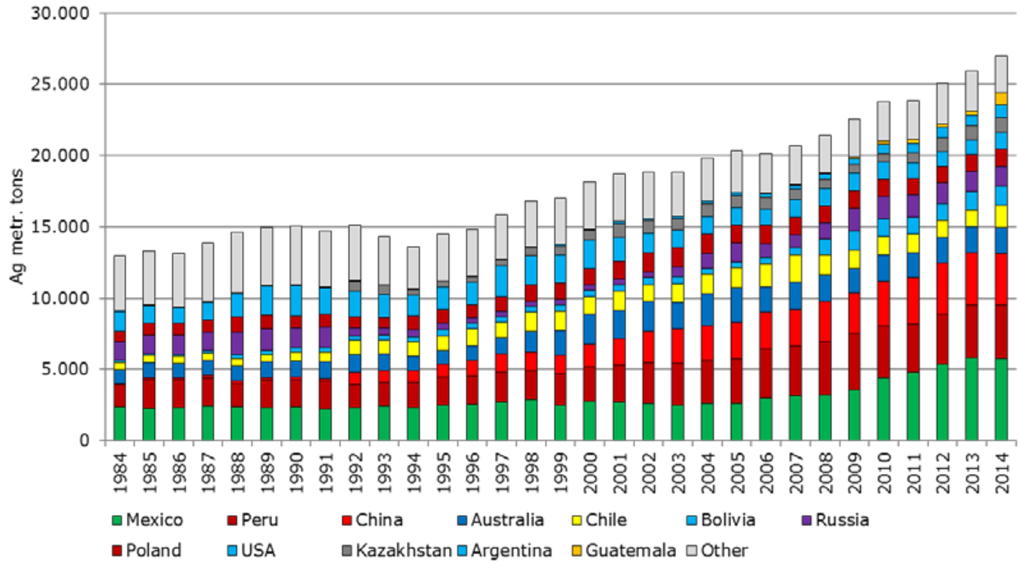

Figure 17 - World Mining production 1984 - 2014, Silver
(in metr. t)

China is the largest producer of mineral raw materials since a decade. Figure 18 shows this predominance for the actual year 2014. With a total output of 4.7 Billion metric tons of mineral raw materials in 2014 China shares 27% of world mining production. China is the world's largest producer of 29 mineral raw materials: namely four Iron and Ferro Alloy Metals, 13 Non-Ferrous Metals, one Precious Metal, nine Industrial Minerals and two Mineral Fuels.

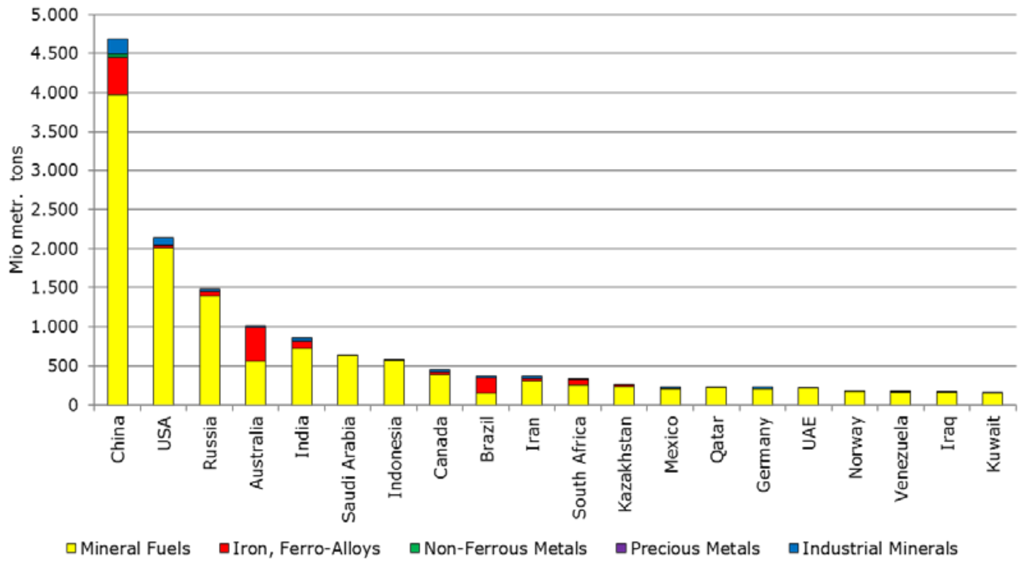

Figure 18 - The 20 largest producer countries 2014
(without construction minerals, in Million metr. t)

Figure 18 shows that in 2014 China is followed by the United States with production of 2.1 Billion metric tons sharing 12.3% of world's total, followed by Russia, Australia and India. Latin America's countries are at the 9th place (Brazil) and at the 13th place (Mexico).

Total World Production by Development Status of Producer Countries

An attempt was made to identify development status of all countries that produce mineral raw materials. The different producer countries were classified according to international standards taking into consideration in particular UNCTAD and IIASA classifications. The designations "developed", "in transition" and "developing" are intended for statistical convenience and do not necessarily express a judgement about the stage reached by a particular country or area in the development process.

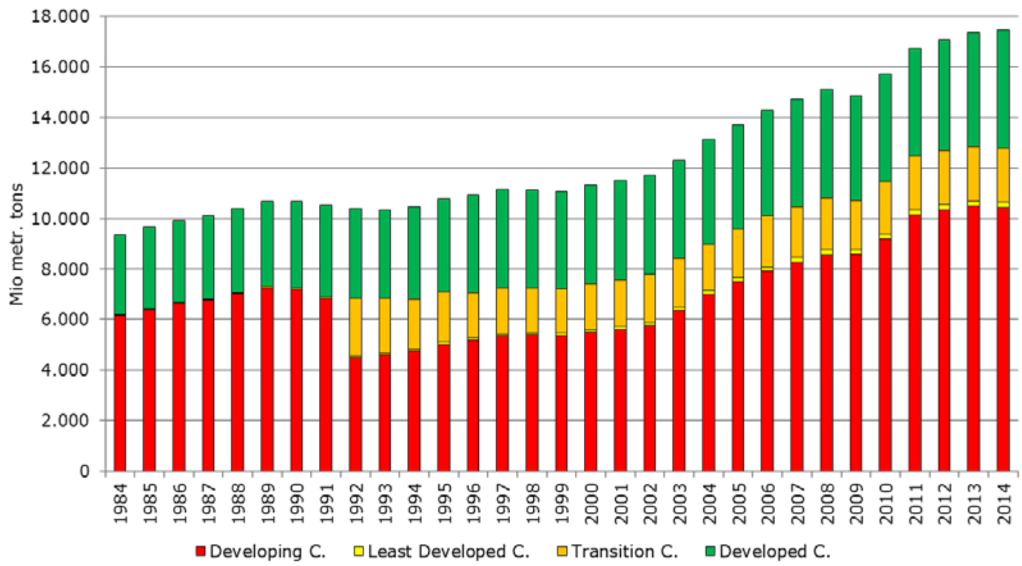

Figure 19 - World mining production 1984 - 2014 by development status of the producer countries acc. to United Nations (without construction minerals, in Million metr. t)

About 60% of the worldwide mineral raw materials production comes from developing and least developed countries. The increase trend seen in recent years seems to be changing in 2014 showing a slight decrease. Figure 19 clearly shows the importance of those kind of countries. However, the production of mineral raw materials in transition countries remains static. Nevertheless there is only a poor increase of mineral raw materials production in developed countries.

Total World Production by Annual Per Capita Income of Producer Countries

For analytical purposes, World Bank member economies and all other economies with populations of more than 30,000 inhabitants have been grouped annually according to GNI. Economies are classified annually among income groups to gross national income (GNI) per capita, using the World Bank Atlas method of calculation. The groups are: low income < 1,045.- USD per capita, lower middle income < 4,125.- USD per capita, upper middle income < 12,736.- USD per capita and high income > 12,736.- USD per capita.

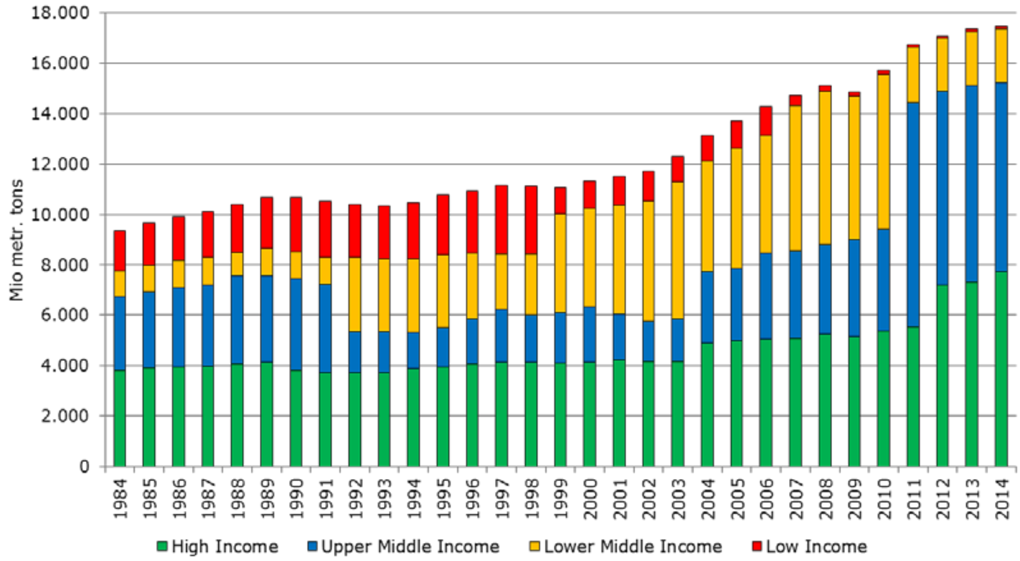

Figure 20 - World mining production 1984 - 2014 by annual per capita income in USD in the producer countries acc. to World Bank (without construction minerals, in metr. t)

The combination of mineral raw materials production figures of "World Mining Data" with the above mentioned "GNI per capita in USD" data sets of World Bank clearly shows the rapid growing importance of countries with "high income" and "upper middle income" and a dramatic decline of mineral raw materials production in "low income" and "lower middle income" countries (Figure 20).

Supply Risks

The location of mineral deposits are predetermined by geology and, unfortunately, unequally distributed in a global view. As minerals are not renewable and mineral deposits are exhaustible they are characterized by limited lifetimes. The supply of mineral raw materials can be influenced by artificial shortages as well. Even a short interrupt of mining activities in war and conflict areas can have strong influences to both the national and international economy. Any direct or indirect disturbance of the supply chain may cause serious problems to the downstream industry.

Political Stability of Producer Countries

The worldwide Governance Indicators rely on 31 data sources, including surveys of enterprises and citizens, and expert polls, gathered from 25 different organizations around the world (D. KAUFMANN, A. KRAAY & M. MASTRUZZI 2010). These provided data derived from hundreds of questions about governance. Before aggregation is carried out each question is mapped to one of six dimensions of governance: (1) Voice and Accountability; (2) Political Stability and Absence of Violence; (3) Government Effectiveness; (4) Regulatory Quality; (5) Rule of Law; (6) Control of Corruption. In this context Political Stability and Absence of Violence is defined as a measure of the perception of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including political violence and terrorism (KAUFMANN et al. 2010).

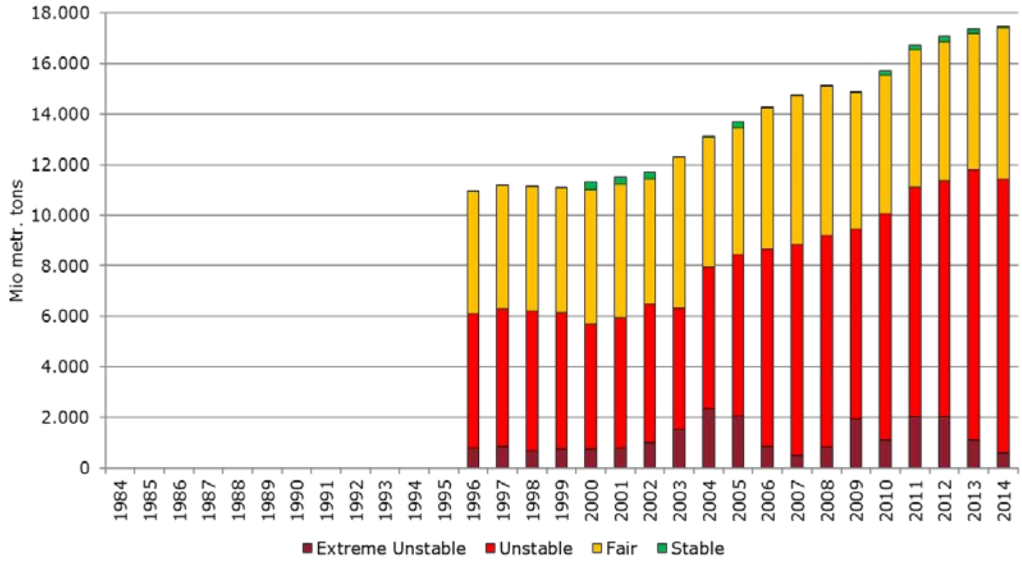

Figure 21 - World mining production 1984 - 2014 by political stability of the producer countries acc. to WGI by World Bank (without construction minerals, in Million metr. t)

The values of measurements of political stability are indexed with a mean of 0 and a standard deviation of 1 in each period. Virtually all scores lie between -2.5 and +2.5, with higher scores corresponding to political stability. The aggregate estimates convey no information about trends in global averages of governance, but they are informative about changes in individual countries over time.

Figure 21 shows distinctly that almost two thirds of the global mineral raw materials output is coming from political instable or political extreme unstable countries. The trend seen in recent years with very significant increases seems to be changing in 2014 the first time showing a slight decrease.

Concentration of Producer Countries

The Herfindahl-Hirschman Index (HHI) is a commonly accepted and used measure of market concentration. HHI is calculated by squaring the market share of each company competing in the same market and then summing the resulting numbers. Only one company means 100% market share. In this case the HHI would equal 10,000 (100^2), indicating a monopoly. A market consisting of 4 companies with shares of 50%, 30%, 15% and 5%, results in a HHI of ($50^2+ 30^2+15^2+5^2$) = 3,650. The HHI takes into account the relative size and distribution of companies in a common market and approaches zero when a market consists of a large number of companies of relatively equal size. The HHI increases both as the number of companies in the market decreases and as the disparity in size between those companies increases.

In the United States markets in which the HHI is between 1,000 and 1,800 points are considered to be moderately concentrated, and those in which the HHI is in excess of 1,800 points are considered to be concentrated. In the European Union the threshold to concentrated markets is 2,000.

Since 2008 "World Mining Data" calculates the concentration of producer countries by HHI similarly to the company index as basic indication factor for supply risk. To avoid misunderstandings with the "classical" HHI, the countries concentration index is named as $_{(mod)}HHI_{(ct)}$.

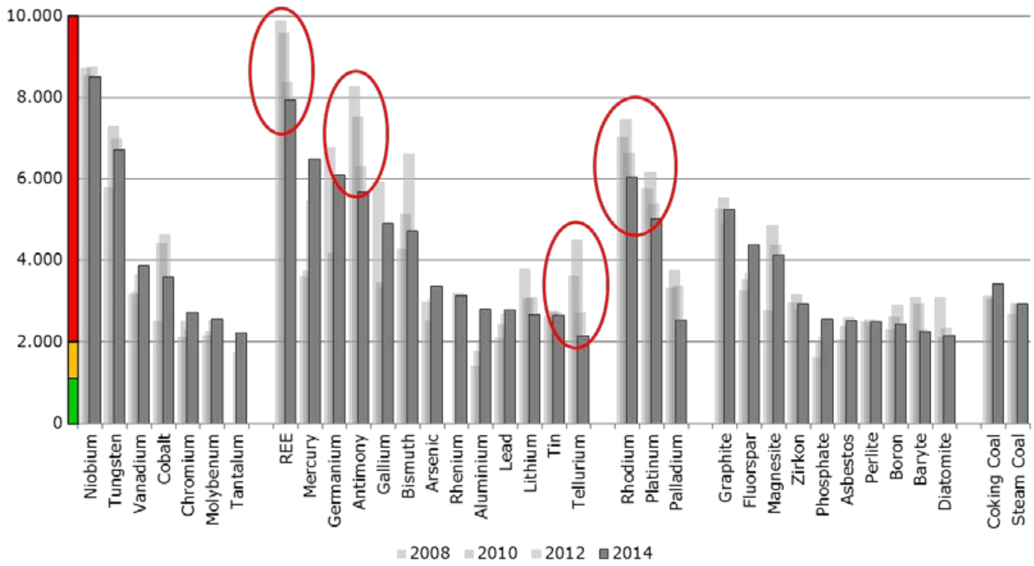

Figure 22 - Herfindahl-Hirschman Indices of selected mineral raw materials > 2.000 (country concentration low =green, moderate = orange, high = red)

In figure 22 several mineral raw materials with Herfindahl-Hirschman Indices of more than 2,000 are detected for the years 2008 to 2014. Not surprisingly Niobium (HHI 8,497 in 2014) and Tungsten (HHI 6,709 in 2014) are the most country concentrated minerals with a distance to Vanadium and Cobalt in the group of Iron and Ferro Alloy Metals. Iron (HHI 1,956 in 2014), Manganese (HHI 1,742 in 2014) and Nickel (HHI 950 in 2014) are moderately respectively low concentrated and therefore not compiled on this graph.

In the group of Non-Ferrous Metals Rare Earth Metals, Mercury and Antimony are the most country concentrated metals. Since 2008 Rare Earth Metal's HHI drops from almost 10,000 (highest concentrated market quasi monopoly of China) to about 8,000 in 2014 due to new players in the REE market with new production sites in Australia and USA at this time. Beside REE also Antimony shows this reduction of country concentration (Figure 22).

In the group of Precious Metals Rhodium (HHI 6,639 in 2014) and Platinum (HHI 5,382 in 2014) are the most concentrated metals showing a slight decreasing trend. Silver (HHI 1,035 in 2014) and Gold (HHI 576 in 2014) are not shown in figure 22 as deposits of both are widespread and well distributed in production figures throughout the world. High country concentrated Industrial Minerals are Graphite, Fluorspar and Magnesite. In the group of Mineral Fuels higher country concentrations are detected within Steam Coal (HHI 2,930 in 2014) and Coking Coal (HHI 3,419 in 2014). Petroleum, Natural Gas, Lignite and Uranium are worldwide well distributed and therefore only considered as low or moderate country concentrated (Figure 22).

CRITICAL RAW MATERIALS STUDIES BY EUROPEAN COMMISSION

As mentioned above European Commission (EC) has noticed the trend of rapid declining production of mineral raw materials in European Community countries and undertook active countermeasures since 2008. One part of these EC efforts was a Study on Critical Raw Materials in 2010 introducing a methodology to identify raw materials deemed critical to the EU. In 2011 a list of Critical Raw Materials was created; this list was revised in 2014 using the same methodology. Critical Raw Materials combine a high economic importance to the EU with a high risk associated with their supply (upper right quadrant in Figure 23).

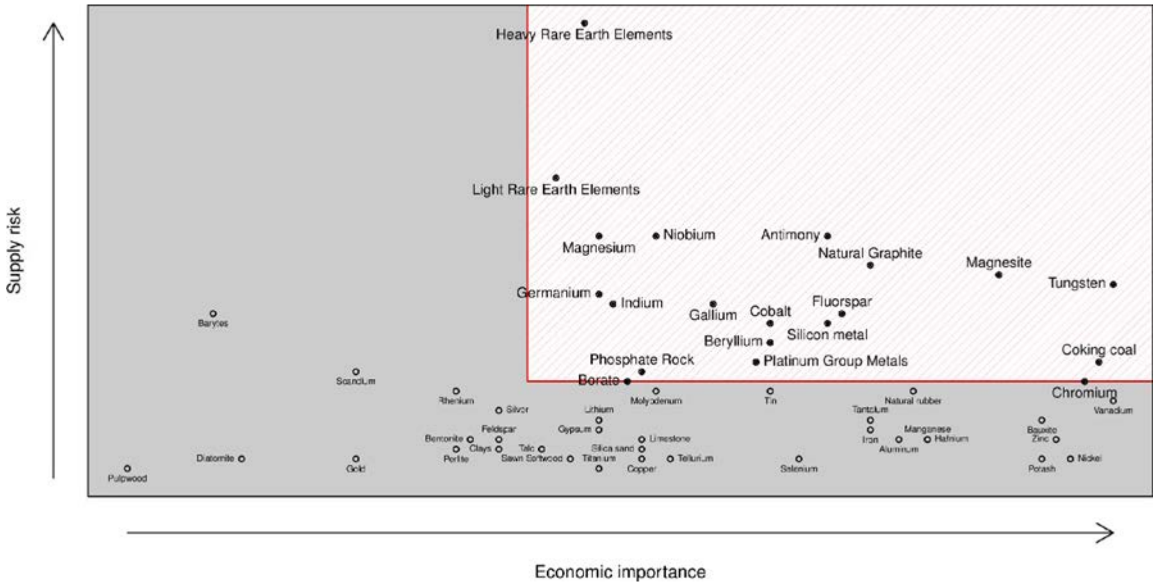

Figure 23 - Critical Raw Materials 2014, European Commission

Authors of "World Mining Data" were highly involved in methodology finding process to identify critical raw materials by defining calculation procedures using production figures and also Herfindahl-Hirschman Indices from "World Mining Data". Supply risk was defined by HHI, recycling rate and substitutability of mineral raw materials. On the other side economic importance of mineral raw materials was defined by usage in individual industrial mega-sectors and European gross domestic product (EUROSTAT data).

In 2014 the supply risk index and the economic importance of more than 50 materials have been plotted into a diagram, indicating the criticality of minerals for supply of European industry (Figure 23). As a result the following 20 mineral raw materials located in the upper right quadrant (Figure 23) have been considered as critical (in alphabetical order): Antimony, Beryllium, Borates, Chromium, Cobalt, Cooking Coal, Fluorspar, Gallium, Germanium, Indium, Magnesite, Magnesium, Natural Graphite, Niobium, PGMs, Phosphate Rock, REEs (Heavy), REEs (Light), Silicon Metal and Tungsten.

CONCLUSION AND RÉSUMÉ

Extensive knowledge of mineral raw materials production is the key element for all succeeding considerations in minerals policy both at a national and global level. In 2014 world mining production was still growing but at a much slower rate than the years before. World economy crisis in 2008 is illustrated by a very sharp decrease of mineral raw materials production in the following year 2009. Hence economic crises and also wars (e.g. civil war in Libya) have a direct impact on mineral raw materials production. The upward trend in production in the subsequent years 2010 to 2013 is remarkable. China predominates the worldwide mineral raw materials production although similar high growth rates seen in the last years will not continue. European and European Union mineral raw materials production is declining steadily. Hence programs developed by the European Commission should boost mineral raw materials production within Europe.

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GOVERNMENTAL AND REGULATORY INCENTIVES FOR EXPLORATION MINING ACTIVITIES IN BRAZIL: A QUICK REVIEW AND A PROPOSAL PROSPECTIVE

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GOVERNMENTAL AND REGULATORY INCENTIVES FOR EXPLORATION MINING ACTIVITIES IN BRAZIL: A QUICK REVIEW AND A PROPOSAL PROSPECTIVE.

ABSTRACT

With the advent of the Constitution of the Federal Republic of 1988 [CF88], the legal, regulatory and institutional framework of mineral sector has presented distinct periods in regard to incentives, or their absence, by the central governments to mineral exploration. The first period covers up to 1995 when the undertaking of mineral exploration by a company that wasn't domestic corporation was constitutionally forbidden. After Amendment to the Constitution nº 6, of 1995, when the second period started, state action spread in the "laissez-faire" of dealers. Under this aegis, the public entities, despite lacking a holistic view, acted in order to not compromise private sector investment in mineral exploration and, consequently, the replacement of reserves for future mining. This period coincided with the advent of a "boom" in commodities demand caused also by Chinese effect. In Brazilian case, it is evident how the beginning of governmental discussion in 2007 marks the end of this period, that resulted in Bill nº 5.807, of 2013, an initiative from President of Republic. The third period corresponds to the discussion in Congress started in 2013, currently the main arena of mineral discussion. It turns out that mining sector is in the interregnum of great cycles of commodities and this factor may contribute to the remodeling of Brazilian legal framework. This work aims to contribute, beyond the understanding of the previous three periods, to the discussion of incentive mechanisms for acceleration of mineral exploration. For instance, a temporary legal benefits specific to commodities with national interests, for example, a relief of royalties – Financial Contribution for Mineral Exploration [CFEM] for new concessions that successfully discover deposits of national interest, or, as another mechanism, the exemption or deferring of PIS/PASEP and Contribution to Social Security Financing [COFINS] for supply chain in the mining stage.

KEYWORDS

Brazilian mining policy, legal framework, public policy, mining exploration, economic incentives

INTRODUCTION

The development of the Brazilian mineral economy precedes the proclamation of the republic in 1889, but had its developmental peak in the post Second World War period. The main point of development of that time occurred between 1960 and 1980, with the creation of specific governmental structure for planning and implementation of national development. The highlight of that period, the Master Ten-Year Plan for evaluation of mineral resources in Brazil - 1965-1974, the Ten-Year Plan of Mining - 1980-1989 and Steel Master Plan ¬- 1977-1986.

Under the aegis of the 1967 Mining Code, Decree Law No. 227 of February 28, 1967, the Brazilian mining sector developed mostly by earmarked investments in the public budget and the activities performed by state enterprises. At that time, it the participation of foreign capital in mining activities was allowed, however, onyl minority interest. The verticalization of the activities of state companies that accounted for, for example, the majority of production of ferrous minerals and steel products, and the price control exercised by the central government accounted for a negative factor to the participation of private companies in the mining sector. Nevertheless, business groups, whether national or international, participated in the mining or processing into higher value-added goods.

However, with the crisis that hit the Brazilian economy in the eighties - the lost decade - the central government had to allocate fiscal resources in the same way it had done in the previous period. The research activities, especially those of basic geological mapping, presented dependence on public budget resources and in view of the economic conditions was reduced. The non-dependent segment of the National Treasury, public companies with their own revenues, were also weak due to, for example, the price control by the central government. Therefore, both government agents who had leveraged the research activities were unable to maintain previous levels. At the end of that period, the Constitution of the Federative Republic of Brazil [CF88], 1988, from which point this paper concerns, was promulgated.

1st PERIOD: FOREIGN INVESTIMENT FORBIDDEN

The CF88 has brought innovations to the Brazilian economy, especially from the perspective of the freedom of the private entity acting in the economy. From this point, the central government failed to exercise explicit price controls for some products, such as goods originating from the steel industry. In the state organization plan, the municipality was elevated to the level of federal entity, providing it with political and administrative autonomy and establishing, therefore, sources of income of origin, such as the Financial Contribution for Mineral Exploration [CFEM].

Despite the innovations, the CF88 has restricted the participation of foreign capital in research activities and exploitation of mineral resources in the country. The constituent legislature originally established thatt only Brazilian or Brazilian companies had the right to exercise such activities. In practical terms, foreign companies could keep the activities in Brazil if they verticalize operations with the use of ore mined for their own consumption and no longer have a majority of the voting capital.

It happened that companies affected by the changes introduced by CF88 were characterized mainly as exploration and mining of mineral resources. The mining exploration segment was impaired, since uncertainty about the ownership and the incorporation of new reserves of mineral exploration, with the cancellation or postponement of some projects. Mining concessions, due to transitional constitutional provisions could be maintained through vertical integration and, because of their expertise in mining and not necessarily in its processing, international companies have chosen mostly by the formation of *joint ventures* with Brazilian investors (Barboza, FLM, 1995).

The annual investments in mineral exploration reduced approximately US $ 134 million between 1978 and 1985 to US $ 47 million between 1990 and 1994, the main reduction brought about by foreign capital (Andrade, MLA et al., 1996) as shown in Table 1. With regard to capital for expansion of mines already in operation, there was also a reduction, but to a lesser extent than that seen in the amount of new deposits for research: $ 544 million to 310 (Andrade, MLA et al., 1996).

The main international actors in this period were Alcan, Alcoa, Billiton, Norsk Hydro and iodine were Alcan, Alcoa, Billiton, Norsk Hydro and Reynolds in Aluminum; BHP, C. Itoh, Mitsui, Mitsubishi and Nisshi Iwai in iron; Anglo-American, Amcor, Amira, Gencor, Inco, Rio Tinto and Molycorp in nickel, niobium and gold (Barboza, F. M. L., 1995).

Also preclude the unfavorable economic conditions for the development of mining activities. Brazil has not recovered from the fiscal crisis that persisted since the previous decade, and inflation did not allow the business sector to perform planning rationally. Commodity prices remained low since the oil countershock and per se operated as a disincentive to mineral exploration activities.

Table 1 - investment in mining research

Years	Average annual value (US$ Million)	Participation (%)		
		Public sector	National private sector	Foreign sector
1978/1985	134	27,3	34,3	38,4
1986/1989	93	27,1	36,1	36,8
1990/1994*	47	60	35,7	4,3

Source: Andrade, M.L.A *et. al.,* 1996.
* estimated

The weakness prevented the domestic companies playing the role that was developed by the government in previous periods. On the other hand, the State disposed of the share control of those steel companies responsible in part for the processing and industrialization of mineral goods produced in Brazil, through auctions held by the Brazilian Development Bank [BNDES]. This factor contributed to the reallocation of available resources in order to prioritize acquisitions in the steel industry to the detriment of mineral exploration for new discoveries.

These conditions remained, with little variation from 1988 to 1996 and contributed to the modification of the guidelines of the central government and the constitutional and statutory framework for the mining sector. The second half of the twentieth century played host to the trend of increased state participation in the creation of tens of State Owned Enterprises [SOE], under the ideological intention of maintaining national sovereignty in natural resources, and at the end of that period, change in order to improve governance for the state participating as regulator and not more prevalent as a direct economic agent (Triner, Gail D., 2011). In fiscal terms, an increase in tax burden on net revenue by establishing PIS / PASEP and Contribution to Social Security Financing [Cofins] in order to keep financial health in the public sector.

The transition between the two periods has as a timeframe, the enactment of Amendment to the Constitution [AC] n°. 6 of 1995 and Law No. 9,314, of 1996 held a mini makeover in the legal framework of the mining sector.

2nd PERIOD: REFORMING LEGAL FRAMEWORK AND COMMODITIES BOOM

The second period was the guided by the gradual increasing of fiscal stability and economic determinants parameters to resume investments in mineral exploration and expansion of production capacity. AC # 6, 1995, re-established the possibility of investment by international capital in the mineral exploration and production, as long as you were under the aegis of the homeland laws. The Law No. 9,314, of 1996 aimed for, in general, less bureaucratic procedures for the granting of mining rights by the Brazilian Mining Bureau [DNPM], by the limitation of discretion of the executor of public policy.

In tax terms, the reform of the tax framework in order to equalize the tax burden on the productive sector when compared with other countries was promoted. First, Law No. 9249 of 1995 promoted the exemption from income tax on dividends, which was 15% of net profit. In addition, it sanctioned to Complementary Law No. 87 [Kandir Law], 1996, which established the non-levy of tax on transactions relating to the movement of goods [VAT] for goods intended for export. In fact, promoted changes sought also to offset the increased tax burden that reordered the public finances in the previous period. As for the conduct of mining processes, DNPM served to allow the performance of the private sector without intervention beyond the regulatory power by the public entity, it is the state action spread in the "laissez-faire" of dealers.

Put the basic conditions, the business environment has improved and investments were resumed. Since 2000, the mining sector has undergone a process of specialization: on one hand, the major Companies began to act primarily in the implementation of mining projects already cubed and classified as world class, low-risk and capital-intensive, however, with adequate return the necessary expertise for implementation of highly complex projects; on the other hand, allowed the capitalization via exchange of specialized companies values in mineral prospecting activity with high risk and low capital intensive (Bustamante, L.A.C et al, 2013). Companies operating in the second case are called Junior Companies.

Early last decade, China's need for commodities led to demand-side pressure, removing the availability of mineral surplus in the world market and therefore resulted in the increase of the price of these inputs. This factor was responsible for enabling the mining of bentonite deposits of higher production costs and sharpen the aggressiveness of entrepreneurs, so much that they were urged to seek capital on the stock exchanges on which investors showed they are more susceptible to take the risk for the research activity in Brazil.

It can be considered that the above process was responsible for the specialization of the activities of the mining sector and represented an increase of efficiency (Bustamante, L.A.C et al, 2013), ie increased benefits for both participants, including consumers.

As derivation, some Junior Companies sought to implement projects of lower cost in order to maintain continuous flow of capital from the profit of the production of their own fields, such as those who worked in the gold prospecting and related goods. This flow of capital was responsible for allowing the maintenance of activities, even at lower levels, in times of lack of resources in the financial market, as happened in the 2008 crisis.

At the same time, in the second half of 2006, the oil province of the pre-salt, which are located hydrocarbon mega-fields in the passive margin of the Atlantic, was discovered, in the exclusive economic zone of Brazil. This factor did resume by the decision-makers, the debates about sovereignty over natural resources and the distribution of gains from the extractive activities. At the time, the National Energy Policy Council [CNPE] initiated the discussion of new legal and regulatory framework that in the future would be termed as production sharing.

Discussions in the oil sector influenced the political body to resume similar debate on the mining sector and, together with the financial crisis of 2008 represented the end of the second period addressed here, in the case of Brazil. For the world, the demand boom for commodities lasted for a few years more.

However, the sudden change in the conduct of mineral policy, with decreasing condition assumed in the early 2000s, was seen as na expected break by the private sector and aggravated the effects of the shortage of international origin of funds specifically for the activity mineral prospecting.

3rd PERIOD: THE COMPLEXITY OF PUBLIC INTERVENTION

After the interregnum of five years, the President of the Republic submitted for consideration to the Legislature the Bill N°. 5807, of 2013, which proposed new legal framework, regulatory and institutional framework for the mining sector in Brazil. In part of this period, the Brazilian Mining Bureau and the Ministry of Mines and Energy discretionally changed the way of conducting mining processes: the first restricted the search authorization to new requirements, while the second failed to grant new mining concessions. These factors were sufficient to sterilize the aggressiveness of mineral prospecting entrepreneurs. In addition, it defined the end of the high price of mineral commodities cycle. Currently, the new framework that will govern the mining activity remains unclear in the country.

The mining bill can be divided into three parts: a) reformulating of the Brazilian Mining Bureau, b) the new tax regime applied to mining sector and c) legal framework.

There is consensus on the reformulation of the responsible entity for implementing the mineral policy among industry players. The change in structure, however, needs to be accompanied by sufficient human resources, material and financial resources to meet the challenges imposed by the new legal framework.

Regarding the tax system, the proposal extends the possibilities of increased government take proposing to establish signature bonuses, bonus discovery and profit sharing of mining, in addition to maintaining CFEM. Regarding the last two terms, it falls that both would be in the form of participation in the result of the exploitation of mineral resources set out in § 1 of Art. 20 of CF88.

The Supreme Court [STF] dealt with the suposed CFEM tax. It, apart from conluding that CFEM would not be a tribute, reveals that the term "compensation" would not be linked to the negative consequences of exploitation and the legislation, to set the billing as the calculation basis, established a "stake in the outcome of exploration", understood to be, in this case the result as a product of mining (BRAZIL, 2001). On the face of it, there would have to be double charging for the same generator factor, which would cause, per se, imply that the tax model needs further improvement.

Regarding the legal framework, it can be noted that the proposal would greatly provide the implementer of public policy instruments to intervene in the development of activities in several mining districts. In short, a lack of balance in public-private relationship and governance would have to be envisioned and, therefore, a lack of incentives to increase the activities of the mining sector, especially those for the exploration of new deposits.

PROPOSAL PROSPECTIVE: REGULATORY AND FISCAL INCENTIVES

One can not speak of regulatory proposal without addressing the legal framework. The code of existing mines, regardless of the qualities that have been presented since its enactment and reforms that have adapted to the preterit reality can be improved in terms of allocation of rights and duties among the stakeholders.

First, it is necessary to clearly define the roles of government and private actors participating in the mineral policy: in Brazil, the mining bureau is responsible for the inspection process of the legal obligations that grant the right to mining and the registration of mining rights, the mining register. These steps need to at least be treated as independent under penalty of interference of the first process in the second.

The lack of a contract for the granting of mining rights can enter a discretionary factor by the implementer of the mineral policy prejudice to the holder of the grant agent for exploration and exploitation of natural resources. The contract may detail detailed procedures that are not legal, the obligations, work plan for prospecting - to be negotiated between the company and mining bureau - as evidence for the expansion of the term mineral exploration if reasonable guidelines if they are seen as the best practices of the mining industry or the expiry of conditions or the time of extinction. Therefore, it is one of the instruments establishing governance and that will result in sustainable development.

Still, the contract would bring stabilization clauses, which would explain under what conditions subsequent legal changes to your subscription would affect your object. Nevertheless, it is reasonable that, with the agreement of the figure, there mortgagebility of rights, which means using it to guarantee bank loans (Mutemeri, N. 2010). Finally, it should cover the constitutional precepts of advertising and impersonality, for example, using models or contracts of adhesion.

For the mining sector, it is usual to apply the right of priority, also called first-come-first-served basis. In the government proposal, the changes to the bidding system are discussed. To do so would require the development of a competitive bidding system, which is uncommon in the mining sector, but it should be regarded as an alternative to the traditional system and not as a parallel legal framework. In Congress the possibility of the new code embracing this kind of anomaly was discussed.

Note that, regardless of the form chosen for the grant of mining rights, it should be transparent, impersonal and easy to understand by the three links, entrepreneurs, government and population affected by activities, and provided with fair terms. Anyway, the proposal must and should be improved within the appropriate environment for the debate, which is the National Congress.

The second point that defines the competitiveness is the tax system, ie the form of allocation of income derived from mining activity. It is an integral part of the legal framework and, by derivation, is crucial for sustainable development and fair distribution of income. For that, you need as much as possible: a) maximize the economic benefits [economic pillar] of the host country with direct income, generate employment, increase in hiring for the supply chain of goods and services and technological innovation capacity; and b) to minimize the negative impact on the local community [social pillar] in order to contribute to poverty reduction (Cotula, L., 2010).

The proposal contained in the bill submitted by the Presidency, in terms of tax regime, kept charges and innovated with the proposed profit sharing, discovery bonuses, inspection fee and the signing bonus, which would have similar generating factor to the authorization application fee of the current mining code, however, subject to charge in duplicate.

In addition to the taxes levied by all sectors of the economy, are charges of the mineral sector: during the phase of mineral exploration, several requirements, such as authorization, [registration fee], payment for footprint [land rents] for the surface rights [property tax] and during the mining, CFEM [royalties]. The new project also would be burdened with: signing bonus [single amount paid at the time of signing of the concession agreement], bonus discovery [amount to be paid by the declaration of commerciality], profit sharing [royalties based on profit].

Regarding the current code and the proposals under discussion in the Legislative branch, it should be noted that both lack of improvement for not fitting the cyclical changes characteristic of the mineral sector and simplicity of understanding to evaluate the mining business by entrepreneurs.

The fiscal regime of the current code displays the characteristic of capture income through a production-based tax system, with royalties based on production, land rents, property tax. The system in question has a high number of variables, which complicates the decision by the entrepreneur in the exploration stage, the highest risk.

It is noted that the tax system needs, beyond the simplicity of understanding, be fair to not overly encumber the miner at the time of the fall and prices and therefore capture the income allocated to the host country. For Brazil, for example, it would be more effective than tax regime unburdened rates in the mineral exploration stage and instituted income capture system with royalties - CFEM -guided by being production-based, part of being profit-based, or the price range quoted internationally. However, it should be distinguished as a commodity and project size, since you can not compare the small mining with a world class type projects. It seems reasonable that the profit-based royalties are caught mainly from world class projects.

One way to encourage mineral exploration in Brazil would be to improve the collection of land rents type, which is known as annual fee per hectare. For this, and the legislation allows, increase the progressivity factor with high encumbrance for those projects where the entrepreneur retains the area for a long time.

In addition, the collection does not differentiate between the different mining districts, the available infrastructure and the maturity of mineral development - it is a greenfield or a brownfield -. Notably, the poorest regions in geological knowledge, infrastructure or even with low per capita income could reduce the collection via land rents so as to encourage those companies specializing in mineral exploration to develop their activities in these districts.

In fiscal terms, in the 70's, initiatives to stimulate mineral exploration were established. The Geological Survey of Brazil [CPRM] and public funding agencies gave specific funding for mineral exploration activity with public budget resources or specific charges. The funded projects were granted with risk clause majority, in which the entrepreneur has no obligation to repay the loan in case of no success in prospecting activities, or without risk clause, retaining the obligation to repay the loan by the entrepreneur. Between 1971 and 1978, 104 projects were received and 50 contracted, with 38 at risk clause mode - only five successful - with the use of 11% of the available financial resources (CVRD 1992) and possibly by those who did not need to resort to this type of instrument, but done to be economically advantageous.

It must be recalled that the public budget is a scarce resource, where the demands exceed the resource availability. But it is possible to make a little effort with unburdening annually submitted to the National Congress. Therefore, it is necessary to identify any benefit, which would be those companies specializing in mineral exploration - the Junior Companies - when carrying out activity in greenfields. However, you can opt for different means of funding, since these entrepreneurs may use other instruments to develop their activities. For this, it seems to be reasonable to defer PIS / PASEP and Contribution to Social Security Financing [Cofins] for supply chain in the prospecting and mining stage for new concession for a certain period and in order to signal that the future earnings benefited all participants.

Weighing-in against the fragility that the public finances of the central government are undergoing. Thus, one can consider using a temporary reduction of CFEM for new concessions, according to criteria that stimulate research of new deposits and mineral commodities of interest to the country, especially those that have a negative impact on the trade balance. This improvement, likely through legal improvement, needs to have limited application, excluding the benefit of the mining operations or exploration permits taking place in national territory.

Nevertheless, this type of decision may encounter resistance from subnational entities due to the portion of CFEM aimed at them. On the other hand, consider the argument that there are no royalties for mere expectation of discovering deposits that without appropriate incentives, will not make up new reserves. Finally, there is consensus that the main reform from the perspective of fiscal regime, is the tax, with balecing of taxes on goods produced, on the income and on the different sectors.

CONCLUSION

The end of the commodity boom cycle may be the appropriate time to improve the legal, institutional and regulatory framework and within that, the tax regime governing the distribution of income from natural resources and the government take from mineral activity.

One can distinguish three periods since the enactment of CF88. At the end of the second period, given also the high price of commodities, the central government sought to govern new legal framework with increased tools for state intervention and increased government take.

Decisions or lack of, caused deleterious effect to the existing model, which had allowed the specialization of companies in research, higher risk, and project development, lower risk and more capital intensive.

The improvement of the current model, if properly conducted by the National Congress, may resume expectation and aggressiveness of entrepreneurs in the mining sector. A clear definition of rights and obligations for the parties is crucial point, as well as the strengthening of institutions responsible for implementation of mineral policy. The grant in the form of the right of priority - the first-come-first-served basis - does not appear to be an impediment to the proper functioning of the legal framework and capture income from the state.

The need to simplify the tax system, with exemption of the stages of exploration has been revealed, since this is the most delicate stage and more important to leverage sustainable development, as both product-based and profit-based and backed in the price of commodities and the size of the projects, with higher government take relapsing in world class mines. Finally, the important result is a government take that allows maximization of the gains for the host country without compromising sustainable development.

Finally, there is the opportunity of stimulus to the activity of mineral exploration, with minor exemptions, but without significant effects to the public budget.

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IMPACT ANALYSIS BY MINE DEVELOPMENT AND MINING INDUSTRY MANAGEMENT

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IMPACT ANALYSIS BY MINE DEVELOPMENT AND MINING INDUSTRY MANAGEMENT

ABSTRACT

The impacts by mine development are discussed in this study by focusing on the proposed development of the Namosi copper and gold mine in Fiji, Fiji has few options for its economic development and is experiencing difficulty in expanding its economy. The development of the Namosi mine could make a significant contribution to Fiji's economic growth. The extent and nature of the contribution is assessed. A variety of techniques are used to conduct the assessment. These include cost-benefit analysis, discounted cash flow method, sensibility analysis, input-output analysis and computable general equilibrium modeling. This paper describes with focusing on Input-Output analysis for analyzing impacts on Fiji economic structure. After introduction of analysis, the concept of "Mining Industry Management", which is the framework of JICA in mineral resources field, is introduced in Presentation.

KEYWORDS

Input-Output analysis, mine development, economic impact, economic structure, mining industry management

INTRODUCTION

Mineral resources are one of the key natural resources and the economic impact of their development is the main theme in this study. The main question is whether mineral resources development has a positive or negative impact on national economic development and growth, and whether it plays an important role in sustainable development.

With regard to mine development, both positive impacts and negative impacts have been described on many occasions; and sometimes, there has been much more emphasis on negative impacts rather than on positive impacts. This study evaluates the economic consequences of the development of mining from several different points of view.

These are:

1) Whether it results in a positive net private return.
2) Whether it shows a net social economic benefit to Fiji when Social Cost-Benefit analysis is applied.
3) Its effects on the levels of economic activity in the Fijian economy when I-O analysis is applied.
4) Its verification in regard to the occurrence of the Dutch Disease when investigated using CGE analysis.

In this study, impacts from mine development will be verified and evaluated via the existing proposal for a mine's development. Developed countries (resources user and developer) and developing countries (resources supplier) should be in win-win relations. For this purpose, developer should make consideration about developing countries' economic development and environmental conservation. Therefore, we should analyze impacts on national economy and environment by mine development. These analyses have difficulty of data acquisition. At the same time, these impacts are different in case by case, so analyses using actual example is most useful.

Fiji is a small island country in the South Pacific that faces hopes and challenges in its natural resources development. The Namosi project, a large copper-gold mine development, has been proposed and is under consideration by the Fijian government. The Fijian government is deliberating on whether natural resources should be developed as the motive force of prosperity and economic growth or alternatively conserved from the standpoint of nature and stability. The Namosi mine development project is expected to have both positive and negative impacts on Fiji's economy, society and environment. This study was conducted to assess all these impacts but focuses mainly on economic impacts including environment impacts. In this paper describes with focusing on Input-Output analysis for analyzing impacts on Fiji economic structure.

Mineral resource is a source and a trigger for economic development, and is also a strong tool for economic growth. It can prove fruitful in short term. For this purpose, sustainable mineral resources development and resource management as its executive policy is important. If resource management would be failure, problems such as resource exploitation and environment disruption will occur. On economic development's way by mining, economic diversity, stabilization, development sustainability should be tried. Therefore, the concept of "Mining Industry Management", which is the framework of JICA in mineral resources field is important, that is introduced in this time presentation.

INTRODUCTION OF MODELS FOR ECONOMIC IMPACT ANALYSIS

The purpose of this study's macroeconomic analysis was confirmed before choosing the model of analysis. Prior to performing model analysis, it is important to clarify the economic structure and features of the Fijian economy. First, qualitative investigations will be discussed, followed by a discussion on important matters and the strong points of the macro model analysis of the Fijian economy.

Mine development will bring an increase in production to the mineral sector, and indirectly impact related sectors. Macroeconomic analysis is useful for studying the changes in each sector. Macroeconomic analysis uses the Input-Output model analysis as the Partial Equilibrium model analysis.

The main purpose of the macroeconomic analysis of this study is to analyze "what changes may arise for the Fijian economy" if the development of a huge mine aimed at exports begins and develops quickly into a major industry. Rapid increases of one sector's production and exports may induce a high exchange rate, increase imports and inflation in the domestic economy. Holding other things constant, this study will examine the relationship between each industry and the change affected by one sector's increase in production.

In the Fijian economy, the sugar and tourism industries have risen to become the major domestic industries. These major industries tend to be strongly affected by foreign trends, signaling to an open economy structure. If export oriented industries are developed, the influences on the major export oriented industries that already exists will be completely different.

In Fiji, because other major export industries already exist, price fluctuation accompanied with capital outflow and inflow from overseas, such as fixing the exchange rates, has been fully taken into consideration. In this analysis, this feature of the Fijian economy should be recognized.

Another oddity of the mining industry is that the mining industry revenue is affected very much by metal grade of mine ore and by metal price. Metal prices are particularly special, because they often fluctuate and are not determined by the local or country market, but instead are determined by brokers of the London Metal Exchange. In other words, supply and demand of metal and economic conditions of the producer country are not reflected in metal prices.

The advantage of the Input-Output model is that it computes the influence generated for each industry from an increase in production of the mining sector by using the input coefficient. Additionally, other aspects are able to be observed with Input-Output table analysis.

INPUT-OUTPUT TABLE ANALYSIS FOR ECONOMIC IMPACTS

Fiji Input-Output Table Calculation

In this analysis, we used the Input-Output table analysis method to estimate the production inducement effect resulting from increased activity in a single industry. Since this product will be for the purpose of exports, we considered that the amount of F$465.473 million per year was the estimated increase in output, and the amount of F$353.923 million per year (which was output minus smelting/refining charge and freight.) of foreign currency inflow was expected every year, and considered as an exogenous variable. Therefore, the results show the impact in just one year. Concerning the expected increase, we will continue to look for better ways to get accumulated impact in further research. According to the 1997 Input-Output table, the yearly output of the mining (gold) sector was about F$73.969 million. It is expected that this project will bring an immense increase in output. The secondary effect of each industry, due to increased production in mining, was calculated using the input coefficient. The input coefficient calculated previously was also used to calculate the Leontief inverse matrix, and finally we estimated the "production inducement effect" by using that matrix.

Primary and Secondary effects

The input coefficient denotes how many units of products of "i" sector are needed as raw materials to when "j" sector produces one unit of production. The input coefficient shows the intensity of close relations between sectors. A large coefficient means a strong relationship between sectors and vice versa.

The data shows that the gold mining industry has comparatively little relation to other industries. The Fiji Input-Output table puts emphasis on agricultural products, and from the table, it can be seen that there is little relation between agriculture and mining, and that the mining industry has a weak relation to other industries.

The added value coefficient determines how many units of added value the "j" sector will produce for one unit of production. A large coefficient means that the "j" sector produces added value strongly.

The data shows that as a whole, the added value coefficient is high, with the exception of several sectors. Fijian industry sectors produce greater added value goods than the sector products themselves. In other words, the added value coefficient is bigger than the input coefficient of each sector. The gold mining sector has a high added value coefficient compared to other sectors. The informal services sector has no sector production, but instead only has "Added Value" as "waged unskilled", therefore its added value coefficient is "1."

Using the above-mentioned input coefficient, we will show the change of output in each industry due to the increased output of F$ 465.473 million from the mining sector.

The change of output is calculated by the following formula:

The change of output = Increased output of gold mining sector (465.473 million F$) ×Input coefficient of gold mining sector (column)

As a secondary effect, the increase in output of F$465.473 million generated by the mining industry at the beginning is distributed to other industries (the mining industry itself is included), as shown in the following table.

Import coefficient used in this study

Here, "1997 FIJI I-O Table" is "Non-competitive import type" (Complementary import type), therefore imports are not included in the total demand. The import coefficient means referential degree of imports to total domestic demand. A large coefficient means that imports are greater than domestic demand.

In the rice sector, textile and clothing factories (TCF) sector and other manufacturing sectors that have large amounts of imports, also have large coefficients. The import coefficient is large in the gold mining sector, because this sector has small domestic demand equivalent to imports. Total demand (production) is medium, but almost all of its production is for exports. Thus, the gold mining sector can be called an export oriented industry.

The export coefficient has not yet been defined. The export coefficient shows whether the sector is export oriented or not. The most export-oriented sector is the gold mining sector, followed by the sugar products sector, and then the ginger sector. Other export oriented groups include the TCF sector, hotels sector (tourism sector), coconuts sector and transport sector (tourism sector).

Estimation of the production inducement effect (multiplier effect)

Here we estimated what production effects will be brought about by an increase in gold mining output. Following the primary and the secondary effects already calculated, the production inducement effect, also referred to as the multiplier effect, is calculated by the following formula; and total effect estimated results are shown in the next table.

The production inducement effect = B× (Secondary effect)

At this point; Leontief inverse matrix: B

The increase in output of F$465.473 million in the gold mining industry brings an increase in output of about F$543.788 million for the industry overall. Here the increase in output of the mining industry is

overwhelmingly high, and the increase in output of about F$10 million to F$ 30 million is seen in related industries, such as the commerce, transportation, and insurance sectors. Other sectors, including finance, business and property service sectors, also experience an increase in total output. In other words, mine development brings increases in output to non-agriculture and non-manufacturing sectors. The proposed mine development is of gold and copper mines; however, existing I-O tables only include gold mine data. The proposed copper mine scale is larger than the existing gold mine and will require heavy equipment, other types of equipment and plants. Related businesses will thrive more as a result of new copper mining than existing gold mining. The expected effects of mine development are underestimated in Table 1.
The result of final output is shown in Table 2.

Although the ranking of the mining industry output rises quickly when production increases, there is no profound change in the ranking of other industries. As for the industry with the highest output, the transportation sector is still the highest after a production inducement effect. Other high output sectors include commerce, property services, manufacturing, and governmental services. Sectors with high inducement effects include commerce, transportation, insurance, and finance sectors; all of which are connected with various other sectors. Processed foods, hotels, construction and TCF (textile and clothing factories) sectors still had high output. Moreover, if the raw sugar sector (rank 13) and sugar products sector (rank 10) were combined as the sugar correlative industry, the total sum would reach over F$400 million and would be ranked number five. In addition, output of both sectors is expected to have no change caused by the change of output in the gold mining sector.

Table 1 - Production inducement effect by the increase in gold mining output

(million Fijian dollars)

	Sectors	Primary effect	Secondary effect	Production Inducement effect	Total effect
1	Raw sugar		0	0	0
2	Coconuts		0	0.005	0
3	Rice		0	0	0
4	Ginger		0	0	0
5	Dalo		0	0	0
6	Root crops		0	0	0
7	Kava		0	0	0
8	Fruits & vegetables		0	0.013	0.013
9	Other crops		0	0.001	0.001
10	Dairy		0	0.004	0.004
11	Livestock		0	0.039	0.039
12	Forestry		0.006	0.073	0.079
13	Fishing		0	0.016	0.016
14	Gold mining	465.473	0.05	0.05	465.574
15	Quarrying		0	0.006	0.006
16	Sugar products		0	0	0
17	Beverage & Tobacco		0	0.022	0.022
18	Processed foods		0	0.058	0.058
19	TCF		0	0.003	0.003
20	Other manufactures		0.019	1.246	1.265
21	Electricity & water		0.019	0.932	0.951
22	Construction		0	0.309	0.309
23	Commerce		12.699	14.124	26.823
24	Hotels etc.		0	0.696	0.696
25	Transport		6.708	10.074	16.782
26	Finance		3.65	5.277	8.927
27	Insurance		5.833	6.162	11.996
28	Property services		0.277	2.063	2.34
29	Business services		2.064	3.86	5.924
30	Other private services		0.082	1.809	1.891
31	Health		0	0.066	0.066
32	Education		0	0.001	0.001
33	Other government services		0	0	0
34	Informal services		0	0	0
	Total	465.473	31.407	46.907	543.788

Table 2 - Result of Final Output

(million Fijian dollars)

	Sectors	Output before mining sector increase	Output after mining sector increase	Total increase	Rank before increase	Rank after invrease
1	Raw sugar	165.641	165.641	0	13	14
2	Coconuts	10.125	10.13	0.005	30	30
3	Rice	7.614	7.614	0	31	31
4	Ginger	2.415	2.415	0	33	33
5	Dalo	43.907	43.907	0	25	25
6	Root crops	58.836	58.836	0	21	22
7	Kava	34.463	34.463	0	26	26
8	Fruits & vegetables	136.59	136.603	0.013	17	18
9	Other crops	1.965	1.966	0.001	34	34
10	Dairy	15.71	15.714	0.004	29	29
11	Livestock	50.346	50.385	0.039	23	23
12	Forestry	18.972	19.051	0.079	27	27
13	Fishing	86.311	86.327	0.016	19	20
14	Gold mining	73.969	539.543	465.574	20	3
15	Quarrying	3.859	3.865	0.006	32	32
16	Sugar products	237.477	237.477	0	10	11
17	Beverage & Tabacco	46.332	46.354	0.022	24	24
18	Processed foods	257.378	257.436	0.058	6	7
19	TCF	239.325	239.328	0.003	9	10
20	Other manufactures	354.689	355.954	1.265	4	5
21	Electricity & water	155.199	156.15	0.951	14	16
22	Construction	244.216	244.525	0.309	8	9
23	Commerce	522.625	549.448	26.823	2	2
24	Hotels etc.	256.713	257.409	0.696	7	8
25	Transport	876.788	893.57	16.782	1	1
26	Finance	150.671	159.598	8.927	15	15
27	Insurance	53.166	65.162	11.996	22	21
28	Property services	434.367	436.707	2.34	3	4
29	Business services	144.01	149.934	5.924	16	17
30	Other private services	179.918	181.809	1.891	12	13
31	Health	93.936	94.002	0.066	18	19
32	Education	214.405	214.406	0.001	11	12
33	Other government sei	339.263	339.263	0	5	6
34	Informal services	18.716	18.716	0	28	28
	Total	5529.917	6073.705	543.788		

* Output = Total demand = Total supply = Total Production

Index of the power of dispersion and Index of the sensitivity of dispersion

This section will discuss the power of dispersion by one sector to other sectors and the sensitivity of dispersion by one sector to other sectors. These indexes were introduced by Niida in 1992.

The index of the power of dispersion measures the degree to which one sector influences other sectors. If the index is greater than one, in relative terms the sector strongly influences other sectors. Conversely, if the index is less than one, relatively speaking the sector weakly influences other sectors.

Similar to the power of dispersion index, the index of the sensitivity of dispersion measures the degree to which one sector is influenced by other sectors. If the index is greater than one, relatively speaking the sector is influenced strongly by other sectors, and if the index is less than one, relatively speaking the sector is influenced weakly by other sectors.

The purpose and meaning of calculating these indexes is to clarify different sectors in the Fijian economy and linkages of the mining sector and other sectors, especially by degree of influence.

The calculations of those indexes are as follows:

Index of the power of dispersion: $\alpha j = cj / c$

Index of the sensitivity of dispersion: $\beta i = di / d$

At this point:

Total of column "j" element of Leontief inverse matrix: cj

Average of column element of Leontief inverse matrix: c

Total of row "i" element of Leontief inverse matrix: di

Average of row element of Leontief inverse matrix: d

Leontief inverse matrix: $\mathbf{B} = (\mathbf{I}-\mathbf{A})^{-1}$

These calculated indexes are plotted in a graph in Figure-1.

Gold mining is isolated from other sectors in the Fijian economy, which means that gold mining might be an enclave industry. The above results of final output indicate that increased output of gold mining influences a smaller number of industries. From these results, we can conclude that the gold mining industry has a high possibility of becoming an enclave industry in Fiji.

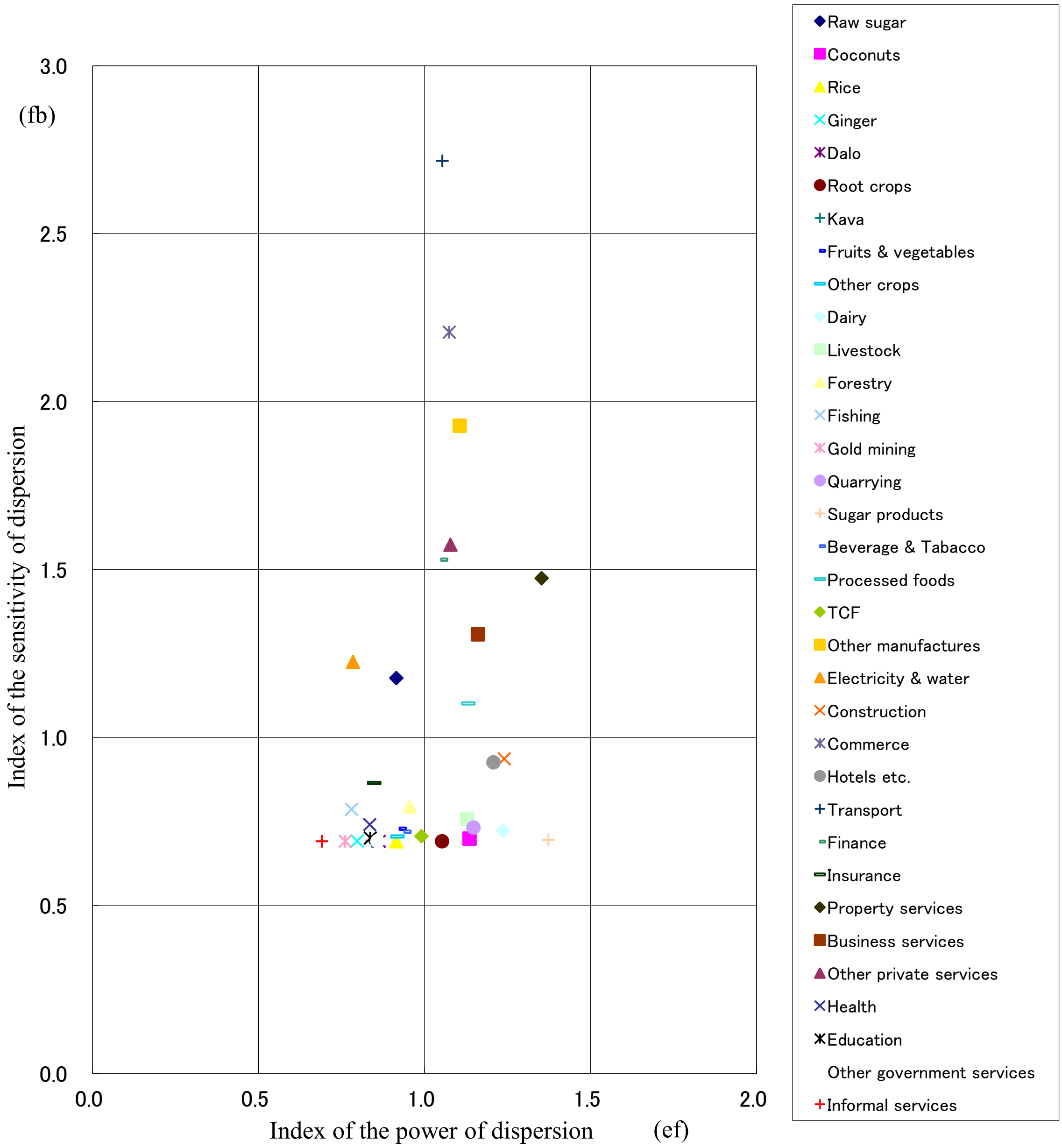

Figure 1 - Index of the power of dispersion and Index of the sensitivity of dispersion between Fijian industry sectors

SUMMARY AND CONCLUSION

In this analysis, we set up only the increase for one year as an exogenous condition. Since the Namosi mine project will be done over a 29 year course, increases of the same amount will occur every year over this period. Since these changes bring further changes in economic structure every year, it can be considered that industrial relations will also change. Therefore, although it will be several years before the mining industry surpasses other major export industries, if production increases continue in the long run, it is to be expected that industrial and export structure will change as a result of the increasing importance of the mining industry. It will be necessary to continually update data and its analysis in the future.

The Fiji Input-Output table puts emphasis on agricultural products, and confirms that there is little relation between agriculture and mining, and that the gold mining industry has weak relation to other industries. The commerce, transportation and insurance sectors have a comparatively large input coefficient, and the finance and business services sectors follow behind them in input coefficients. These sectors have close linkages with the mining sector.

The added value coefficient is high as a whole, with the exception of several sectors. Fijian industry sectors produce a larger amount of added value than sectoral products themselves. The gold mining sector has a high added value coefficient compared to other sectors.

The import coefficient and the export coefficient show that the gold mining sector is in fact an export-oriented industry. In addition, the sugar products sector and the ginger sector are export-oriented sectors.

The gold mining sector index of the power of dispersion is less than one, which means that the sector has no strong influence on other sectors. The gold mining sector index of the sensitivity of dispersion is less than one, which means that the sector is not influenced strongly by other sectors. This evidence indicates that the gold mining industry has a high possibility of becoming an enclave industry in Fiji.

The increased total output and export due to the mining industry is profound, but the mining industry has been determined to have a relatively small influence on other sectors. Therefore, the Fijian government should not be preoccupied with the negative economic influences caused by the mining industry. There is a possibility of increasing imports by mining activities, but in order to avoid this problem, Fiji should carry out industrial promotion and be able to supply required machinery domestically. Thus, a policy for managing energy resources is needed.

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ON TIME AND UNDER BUDGET? A REVIEW OF THE REASONS FOR DISAPOINTING MINING PROJECT RESULTS IN RECENT YEARS FROM A CAPITAL COST AND SCHEDULE PERSPECTIVE AND IDEAS TO IMPROVE

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ON TIME AND UNDER BUDGET? A REVIEW OF THE REASONS FOR DISAPPOINTING MINING PROJECT RESULTS IN RECENT YEARS FROM A CAPITAL COST AND SCHEDULE PERSPECTIVE AND IDEAS TO IMPROVE.

ABSTRACT

On time and under budget is a term infrequently heard in the mining industry in respect of capital projects, particularly in recent years. The boom period of 2000-2012 was particularly bad in this respect. Various reasons for this have been identified by a number of authors, including the authors of this paper. These include low productivity due in part to a shortage of experienced or appropriately qualified project personnel, increased infrastructure requirements and overall project complexity, more challenging metallurgy and the ever increasing environmental and social constraints and requirements. Besides these factors which are generally well understood and documented, the authors discuss several other main contributing factors. For instance, the quality and management of project teams, (both the engineer and owner teams) and the general lack of trust in project teams and its implications. Another important issue is the proper planning of the early phases of project development; i.e. finding the right balance between schedule and cost pressure upfront and required field & test work and engineering. The paper updates published examples of capital cost escalation and also discusses in more details the above mentioned points which lead to capex increases. The paper then advances to suggestions on how to improve the performance of projects teams to increase the likelihood of achieving the twin objectives of On Time and Under Budget.

KEYWORDS

Project management, project execution, project strategies, capital costs, schedule

INTRODUCTION

The first decade of the 21st century showed strong price increases for almost all commodities. This period, running from 2001 up to 2012, is often referred to as the commodities super cycle. During this period mining companies across the globe intensified their efforts to increase production. In doing this, large sums of capital were deployed to build new mines and expand production of existing ones.

This created a huge demand in project services (ranging from exploration through to construction), equipment and materials. The result, from an industry wide perspective, was a period characterized by substantially lower than average success in projects where many projects ran into significant capital and schedule overruns, while the resulting operations regularly also didn't perform well once finally put in operation.

In a speech to the London metals exchange in October 2015 Oscar Landerretche, president of Codelco, illustrated this fact by speaking of the 7 mining sins committed by the mining industry over this cycle. He challenged the industry to be self-critical and improve.

"The positive side of this economic slowdown in our markets, is that we look at the years of economic boom with a critical eye. It also allows us to see how we behaved and forces us to wonder if the next time we want to act in the same way or do we want to change, and if this is the case, what can we do to make it happen." (Landarretche, 2015, page 6)

One of the effects of the increased activity to develop mining projects across the globe and in almost all commodities was a very significant surge in equipment prices; for instance, the cost of trucks and rope-shovels increased by 102% and 343% respectively (Thomas & Wells, 2015). Some examples of projects that suffered significant capital cost overruns are presented in Table 1:

Table 1 – Examples of capital cost overruns

Project	Company	Country	Commodity	Approved Project Budget (BUSD)	Projected or final project costs (BUSD)	Increase (%)
Pascua Lama	Barrick	Chile-Argentina	Au, Ag	3.0	8.5	180%
Minas Rio	Anglo American	Brazil	Fe	3.6	8.8	145%
Goro Goro	Vale	New Caledonia	Ni	1.9	4.3	125%
Ravensthorpe	BHP-Billiton	Australia	Ni	1.05	2.2	110%
Éléonore	GoldCorp	Canada	Au	1.4	2.1	50%

Table 2 presents an estimate of the major factors contributing to cost escalation witnessed in the mining industry based on 2002 costs. This table is an update from the table presented in a paper by Wells, Thomas & Conca (2013).

Table 2 – Major capital cost overrun factors

	2013		**2016**	
Cost Escalation Factor	**Increase (%)**	**Impact (%)**	**Increase (%)**	**Impact (%)**
Equipment	200-300	50	100-150	25
Engineering	100-200	25	50-100	10
Construction	200-300	50	100-200	30
Location	100-200	50	100-200	50
Environmental	100	25	100	25
Community relations	50	15	50	15
Lack of experienced personnel	50-100	25	50	10
Detail required	100	20	100	20
TOTAL		**260**		**185**

The CPI over this period amounts to about 25% over this period confirming that the observed increases are caused by other factors than just inflation. Another interesting fact is that so-called "soft" factors, such as environmental, engineering hours, community relations etc. form more than half the estimated increase.

For instance, the cost increase for EPCM companies, specifically in countries like Chile and Brazil was significantly higher than Canada. Average hourly rates increased in Canada about 8% from 2008 to 2012. However, the rates in Chile increased about 15% in this same period and in Brazil 16%, double the increase witnessed in Canada.

Figure 1 presents the increase per factor for the two periods. As can be seen the current downturn is causing a reduction in some of these factors. For instance, Engineering and construction costs have decreased, mainly because Engineering or EPCM companies have been reducing their costs basis.

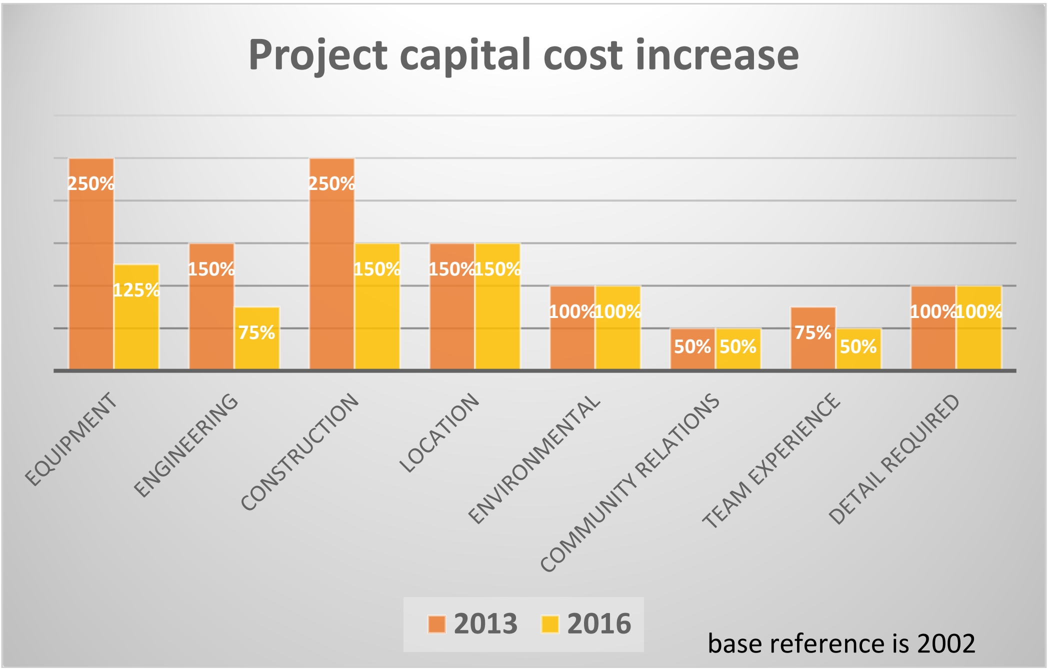

Figure 1 – Project capital cost increase factors

Several authors have dissected this cost increase and concluded the main causes can be categorized as follows (Thomas & Wells, 2015):

1. Equipment, Engineering, Construction & Labor Cost
2. Site Location; infrastructure costs
3. Increase/Improvements in Environmental Regulations
4. Community and Government Relations and Engagement (obtain social license to operate)

Figure 2 shows how the growing demands and impact of these 4 categories over the last few decades have changed the distribution of project costs dramatically.

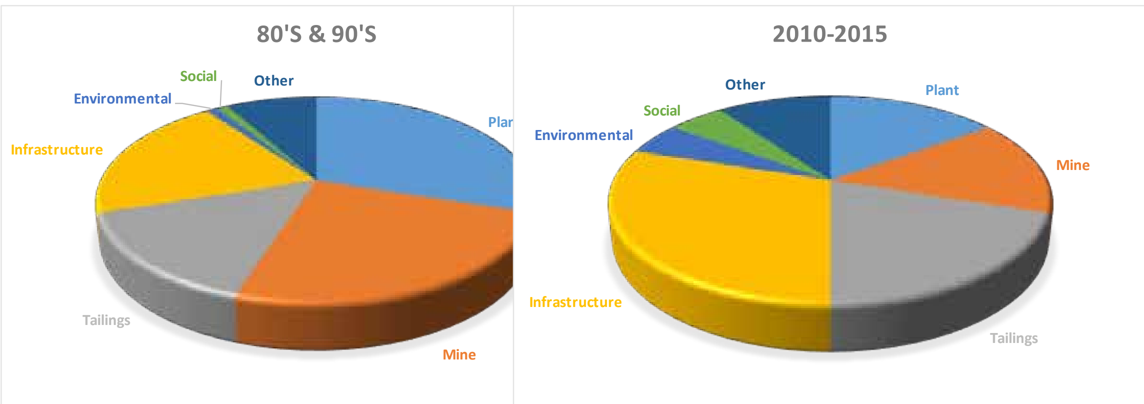

Figure 2 – Project capital cost distribution

Several papers have been dedicated to the theme of disappointing project results over the last few years. The authors of this paper intend to discuss several aspects of project development that, in the authors opinion, are substantial contributors to cost & schedule increases (often correlated/intertwined).

CAUSES

The commodities super cycle spurred a period of intensive project development around the globe and this created an extreme demand on people, materials and equipment which, as well documented, resulted in subpar project results. This section of the paper will discuss some points related to the "human factor" of project execution that contributed to generating project delays and cost overruns. We will focus on the following topics:

1. Project team quality
2. Project setup & planning
3. Project expectations

Quality of Project Teams

The project team is arguably the most important aspect that can either cause or mitigate cost and schedule increases and more often than not actually did both during the execution of projects. The complexity of creating a well-functioning team out of owner and engineer is well documented but in practice often still underestimated. Even when specific measures were taken to enhance team functioning, it often did not live up to its full potential for reasons that are beyond the scope of this paper. An interesting and insightful view on the functioning of project teams was offered in Dewhirst, Thomas & Wells (2016), where the Tuckman forming-storming- norming-performing model of team development was discussed.

Here we are focusing more on some of the underlying factors of a successful project team as shown in Figure 3.

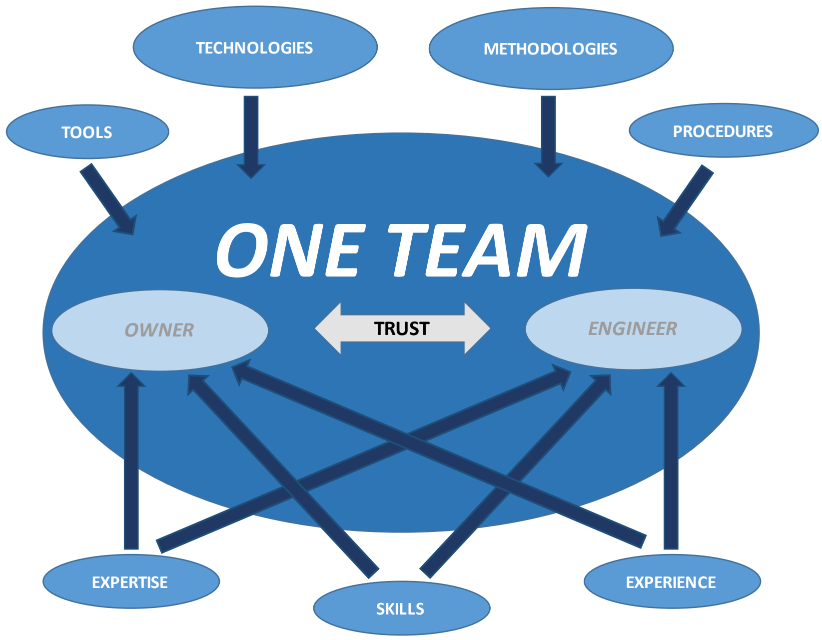

Figure 3 – Project team quality scheme

<u>One Team</u>

One of the key aspects of the project team is to generate a specific team culture that allows the team to function as one team instead of a combination of an owner team and an engineer team. This is an intangible aspect not always very well understood by the Project Managers (both client and EPCM), who generally have a technical background. However, it is a crucial contributor to achieve project goals.

One of the key points in creating this culture is to ensure the project goals and also incentives for team members are well understood and fully aligned at the start of the project. This is often one of the main objectives of the kick off meeting. However, in the experience of the authors, kick off meetings suffer regularly from insufficient planning and preparation by project management and other team members due to the short time between the project award and this essential meeting. Consequently, often the main objectives of this meeting are only partially achieved and this fact, unfortunately, often surfaces again later on in the project.

Another aspect is to ensure the team shares an office facility, this was often complicated by the fact that a lot of projects had parts of the team spread across different countries. While work-sharing across different offices and countries has becomes more and more the norm, mainly due to cost considerations, the team being in the same office is still highly relevant. Ideally the project management and key technical people from both owner and engineer are working physically in the same place, creating the project main office. If part of the work is done in remote offices, it is highly recommended leaders of the parts of the team in other offices travel regularly to the main office or at least conference to engage with the other project team members. When sharing the same office, the authors feel the team should be effectively mingled where the owner and engineer are working side by side and not each in their own corner. While some practical considerations, such as confidentiality, could argue for the latter, the productivity gain by working effectively side by side should outweigh any concerns.

Another important contributor to creating a “one team” culture can be several team building activities, preferably at project start and repeated regularly during the project execution, for instance to celebrate specific project milestones or accomplishments. This can be simple social activities and can serve as a good “thermometer” to measure the team spirit. An example experienced by one of the authors; in a certain project a first social event was organized after completion of a Feasibility Study and it was a success with almost the complete team (owner and engineer) present. However, subsequent monthly planned events were soon to be postponed by a new PM on the owner side and several months into the EPCM job, at an event to celebrate a milestone, roughly only half the team (engineer with only a few of the owner team members) was present. This was clearly a sign of strained relations at that moment.

The main objective is to create one team focused on delivering the project and achieving the set project goals by effectively working together. This is obviously very different from the “us and them” culture which is the natural state at project start up (as engineer and owner are different organizations with different specific goals and methodologies). Often a team makes a decent start at functioning as one team, but falls back to the “us and them” culture if the project faces serious challenges. When this happens it becomes even more difficult to overcome these project challenges and considerably less likely that project objectives are met.

Trust

Another key aspect of a well-functioning project team is a deep level of trust between the owner and engineer team members. This is another intangible aspect which is quickly acquired at the start of the project (or at least the appearance of trust), however, it regularly deteriorates throughout the execution of the project when complications are encountered. It is difficult to regain trust that has waned after repeated project setbacks.

Some base conditions to establish and maintain trust are to start the project with a clear and mutual understanding of the project goals and objectives and also what the particular project represents for each of the two organizations. While the latter usually differs between the engineer and owner, the overall objective of a successful project (on time and on budget) should fulfill the objectives of the two organizations and also of individual team members. Aligning these interests is a crucial foundation for the trust to grow.

Another point is a full understanding of commercial aspects of the contract to combat the often existing perception by members of the owner team that the engineer is too expensive. Transparency by the engineer towards the owner team can contribute in achieving this.

Also the Scope of Work (SOW), the methodologies to be used and the type, quantity and level of detail of the project deliverables need to be thoroughly understood and aligned. More often than not this is also only partly achieved at project start and later discussions arise on deliverables or scope, often intensifying any existing strain in the owner-engineer relationship.

The engineer PM must instill a “no surprise” mentality in the team. The engineer must deliver what has been agreed to and stick to the plan, any deviations or challenges must be communicated openly and timely to the owner to ensure proper measures can be taken to keep the project on track or to effectively recover ground that has been lost.

Unfortunately, often the level of trust between owner and engineer decreases once the project starts to face challenges which makes it even more difficult to overcome them. Once the two main parts of the team lack mutual trust it becomes more unlikely a joint plan to approach a challenge or a fully agreed and aligned recovery plan can be successfully implemented. Hence a project team can enter a vicious circle where the lack of trust complicates the execution of mitigating plans which leads to additional project challenges that undermine the remaining trust level.

Tools

While providing the right tools might sound like an obvious point of enabling a project team to be successful it is the authors opinion that this sometimes proves to be a major challenge. The difficulty arises from the fact that the team needs to effectively build a bridge between the systems of two organizations. Making the different systems communicate seamlessly requires a dedicated effort and time which is not always properly estimated nor allowed for in the project schedule.

Likewise, the proper software packages and related standards needs to be selected and usually each organization has its own standards, e.g. 3D design software. Most likely the better choice for the project is to use the engineer´s systems and software, as an efficiency loss can be expected if the majority of the design crew needs to get accustomed to new software and systems. Yet some major mining companies demand that the engineering is performed using the software they prefer.

Clear and effective project procedures need to be developed and properly studied by all team members so the PM can make sure procedures are implemented and adhered too. Unfortunately, frequently the individual team members do not take the time to familiarize themselves properly with the procedures, sometimes due to time pressures. Another potential complication is the fact that team members are used to specific procedures of their own organization and might, unconsciously, follow those which can be different from procedures for the project. Sometimes procedures from previous projects are used as a base and not sufficiently customized.

Finally, as mentioned before, it is imperative to have a thorough and aligned understanding of the SOW, the deliverables, the project schedule and the work plan for each discipline or area.

Failure to align all the above discussed tools and ensure they are applied consistently throughout the project poses a serious risk of miscommunication, engineering errors and wrong or delayed decisions. This, in turn, adds to team frustration and project delays and/or cost increases.

Continuity

Often mining companies are required by their internal governance to go out for bids for each stage of a project. This can lead to disruption and dismantling of project teams when the owner changes the engineering company from one project stage to the next. Even if the incumbent EPCM is retained, several months can elapse between completion of one stage and start of another and if the contract only covers one project phase, it is possible the EPCM reallocates some of the project team members to other projects.

In a study of project overruns presented at CIM in Oct 2014 (Haubrich, 2014), it was stated that a clear relation exists between project results and continuity of an EPCM team when a project moves from feasibility towards execution. Projects that maintained the same EPCM company showed in general lower capex overruns as projects that changed the EPCM.

Experience and Expertise

While this is yet another obvious requirement, this might be amongst the most visible issues confronted by the mining industry during the past cycle. For several reasons, such as too few new students entering mining related careers at universities, the mining industry didn't get the required level of entry of freshly formed engineers and other professionals for most of the last 2 decades. Once the super cycle really heated up this lack of fresh blood started to have an impact.

At the height of the super cycle it was extremely difficult for both owners and engineers to pick a team that had:

- People who successfully completed multiple relevant projects
- People who worked together on projects
- People who possessed the required specific technical expertise
- Well-seasoned project and engineering managers to lead the team

The boom did attract professionals from other industries to fill the requirement gaps. However, the time pressure to progress on projects sometimes prevented properly introducing these professionals to the specifics of the mining industry.

Consequently, decisional power was in the hands of people that did not always have the required experience which, together with the time pressure factor, often led to delayed and/or erroneous project decisions.

Project Development Planning

Methodology

The most common methodology currently applied by most mining companies and EPCM or engineering companies is the FEL methodology. While this methodology is widely spread it is important to understand the methodology is a guideline and therefore each company has its own interpretation. It is therefore important to ensure, at the start of a project, that the understanding of what a certain project phase entails, is aligned between the owner and the engineer. This is part of the overall alignment at project start which was already discussed above.

Figure 4 gives a schematic representation of the FEL methodology.

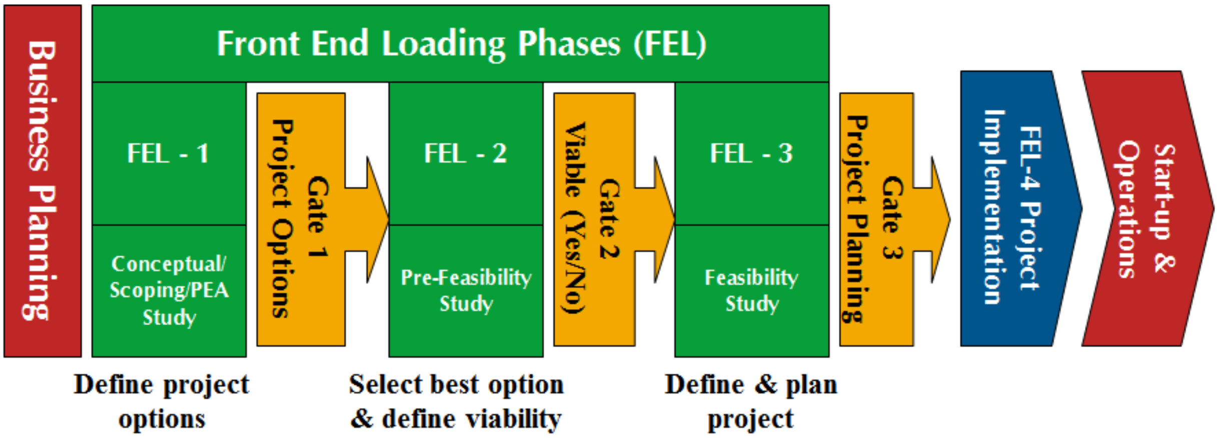

Figure 4 – FEL methodology

It should be noted that specifically for the initial stage, the conceptual/scoping studies, very experienced people are required to set the project on the right path.

While the base of the methodology is quite well defined, a common problem witnessed over the boom period is the fact that not all team members had proper experience with the methodology. As a consequence they had difficulty limiting the work or deliverables demanded (owner) or limiting the amount of detail required to finalize a certain deliverable at a certain stage (both owner & engineer).

Another common issue was the fact that lack of experience in the team created difficulty to customize the methodology to the project; i.e. the FEL methodology was used as a checklist rather than a guideline, thus creating unnecessary discussions and tensions on deliverables that might not be applicable or less relevant to a specific project.

Again, achieving a good alignment and understanding on this is part of the initial project set up. Unfortunately, this was not always fully accomplished at the project start or sometimes it was revisited during the project.

Balance Budget & Schedule

During the boom the mining companies were under a lot of pressure to show positive results and strong growth to benefit from the healthy price environment. This pressure was created mainly by the shareholders who wanted to see return on their investment.

This pressure then translated to a pressure on projects schedules and budgets and in many cases projects got off to a false start due to unrealistic budgets or schedules. This is really putting the cart before the horse and caused project teams to arbitrarily adjust the project schedule to fit with the overly optimistic expectations. This combined with project teams with inexperienced decision makers it was all but a guarantee an overoptimistic and unrealistic project schedule and/or capex was used as the base for the project.

Even more serious problems were encountered where projects, deemed relatively simple, were “fast tracked”. Often this was achieved by one of the following three actions (or lack of):

1. **Field & test work:** Often field and test work was minimized during certain project stages, for instance geotech drill programs were reduced or postponed to later stages or metallurgical test programs were reduced. Often this led to insufficient base information being available to the

designer. Examples exist where initial savings in time and money were completely wiped out multiple times by delays during the project execution phase.

2. **FEL stages:** As mentioned above the FEL methodology was widely applied, yet not always correctly. In many cases initial study phases (specifically pre-feasibility) were simplified or even skipped when projects (for instance brownfield expansion projects) were deemed relatively simple or were under excessive schedule pressure. In the authors experience many feasibility stages during the boom years included one or more significant trade off studies, supposedly defined in the pre-feasibility stage. Obviously this led to, at a minimum, delays in the feasibility study and overall project completion. This sometimes led to engineering rework and/or potential for engineering errors which needed to be corrected in the field etc. all leading to cost increases. An important contributor here is the fact that most studies did not have a proper budget and effort on risk and quality management.
3. **Environmental & Social:** The mining industry as a whole has widely recognized the importance of responsible mining. Over the last decade or even longer, the industry has dedicated considerable resources to minimize and mitigate negative impacts and maximize benefits for both environment and affected communities by the mining operations. Despite all these efforts several projects still suffered serious delays due to social disagreements that in some cases paralyzed construction activities temporarily or even, through high profile court cases, shut down projects completely. Also regularly it took longer than considered in the project schedule to obtain the required environmental licenses. In developing countries, the environmental regulations are sometimes being adjusted and the duration of the licensing process often takes longer than anticipated. In many cases this was not fully under control of the companies, yet at a bare minimum the industry needs to study these cases to ensure the project schedule does consider a realistic timeline. In some cases, where projects were fast tracked, social and environmental base work was still ongoing when, due to perceived technical maturity, the project already entered in feasibility stage. Environmental, Social and engineering activities developed in parallel but not all interactions and iterative stages were fully understood and defined and this caused delays in the licensing process and sometimes generated misinformation which in turn sometimes led to some social discontent. When setting the project schedule the work requirements and timing there off must be fully understood and implemented in the master schedule. Too often the environmental and social teams were operating in parallel and not sufficiently integrated in the overall project team. Also it cannot be emphasized enough that (greenfield) projects which engage the communities right from the earliest exploration phase have a greater chance of success.

<u>Project Complexity</u>

Another important factor contributing to the difficulties to properly plan, set up and execute projects is the fact that project complexity has increased significantly over the last few decades. This increase in complexity can be attributed to the following aspects:

1. **Low grade;** Lower grade deposits created the need to go bigger to have economies of scale. While teams and companies recognized that with larger scale comes added complexity, the authors feel this was regularly underestimated.
2. **Technical;** More deposits having more complex metallurgy or other technical challenges. Several of these projects have been studied for years, sometimes decades and during the boom were studied again or developed by applying new technology.
3. **Infrastructure;** The deposits developed over the last decade showed a very significant increase in infrastructure costs. Several factors contributed. Remote locations requiring very significant infrastructure; e.g. water supply, power supply, tailing dam location.
4. **Environment;** Increased environmental and social standards and requirements and/or changes in regulation

Especially infrastructure and location aspects have a significant effect on the project complexity as illustrated in figure 5.

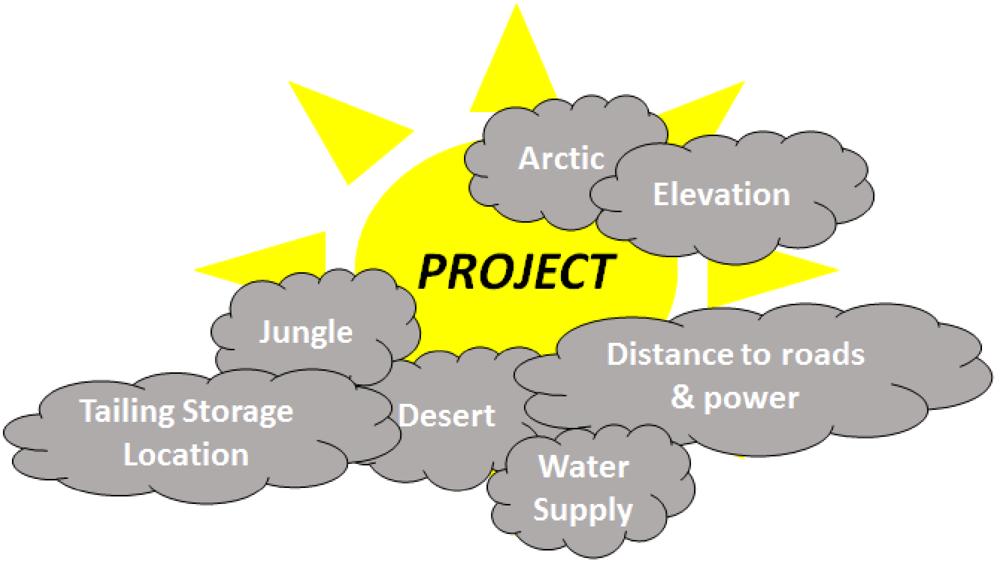

Figure 5 – Infrastructure and location aspects impact projects

Besides the complexity that each of the above 4 points bring, they often are interrelated creating an additional challenging level of complexity. This requires highly experienced project managers and planners to properly understand how an impact in one affects the progress on another point (e.g. a delay in defining whether or not to include a 3rd cleaner stage in a flotation plant can hold up environmental licensing) and how to mitigate this impact. As stated previously, the project teams often did not have enough experienced people who fully understood the subtleties and interactions of these aspects and therefore could not always properly mitigate or react to occurrences.

Project Expectations

The next point the authors want to raise is the fact that the boom period created a high level of interest from investors and subsequently a very high level of pressure for mining company executives to deliver.

This pressure often translated in mining companies focusing on aggressive growth and, looking back, it appears growth was prioritized regularly over financial results. It is the authors opinion going forward mining executives should, and likely will, focus more on financials like NPV, payback period, profitability and so on.

Also the company goals should be well defined and thoroughly applied throughout the organization including the project strategy. If for example a mining company would not be focusing mainly on the financial performance or production growth but more on long mine lives to support communities (e.g. state owned companies), then this should be well reflected in the definition, selection and approach of project execution, including setting the project goals. Also as the project progresses and some project characteristics might change, the project needs to be checked against the company goals and objectives to make sure it still meets those or, if it doesn't, the project should be stopped or divested.

The investment market required detailed information about the planned projects and the owners were required to follow reporting guidelines as defined by JORC and 43-101 regulations. Thus the results of all studies were reported in detail in the public domain. This requirement created expectations on costs and revenues. However, these were sometimes difficult to reproduce in further studies as more detailed work was done, adding to the pressures on the project teams. If significant changes or differences in costs occur between study phases, then a detailed, intense review of the project is required by both the owners and engineering teams, with perhaps an independent review by an impartial outside group. If such a review indicates that a complete re-thinking of the project is required then such a strategy, although unpalatable to all stake holders, is probably the wisest in the long run.

So here we have yet another crucial aspect that needs to be instilled in the project team culture, unconditional honesty and realism.

Although other stakeholders, for example local communities and governments, were involved, this was not always early enough or detailed enough. As a result, issues and conflicts arose, that sometimes had a major impact. The project teams, particularly inexperienced ones, did not always appreciate or understand the significant cost and schedule implications of engaging all stakeholders insufficiently or not early enough in the project.

Convergence of these Causes

A lot of projects showcased one or more of the abovementioned challenges during the development phase and more often than not, the projects encountered several of these challenges. The effects are then intensified and often the challenges proved too much for the relatively inexperienced project teams.

When some of these causes converge, the following happens:

1. **Momentum:** It becomes difficult to keep momentum in the project engineering. In Dewhirst, Thomas & Wells (2016), the different stages of the Tuckman model of team work were described as forming-storming-norming-performing. In that paper the difficulty to maintain the team on track and keep momentum going was well explained.
2. **Vicious Circle effect:** delays causing extra costs which created pressure on the budget and schedule which led to the team taking less time to properly evaluate the impact and define actions to mitigate. This then created the higher likelihood of errors and wrong decisions under the time pressure which then resulted in more delays.
3. **Finger pointing:** The complexity of adjustments required to the project planning and the successful definition and execution of a “recovery” plan would require the project team to firmly behave as one, yet at the same time creating challenges to the one team mindset. Often at these points of difficulty the “One Team” culture started to unravel.
4. **Domino effect:** Too often the project team tried unrealistic ways to recover lost ground on the schedule (as opposed to adjusting the project schedule including the effect of realistic mitigation measures) and this compromised the quality of subsequent steps such as commissioning and start up.

Once this stage was reached there was often little alternative than to continue to develop the project and accept significant budget and schedule overruns while trying to minimize the impact on overall quality of the project delivered. At this point, conflicts and tensions within and between the teams were seriously impacting morale and productivity.

SOLUTIONS AND IDEAS

In the above section we focused on circumstances, often witnessed over the last decade, which jeopardized project success.

This section will summarize and present some additional thoughts the authors feel could be beneficial in project development and enhance the chance of project success.

Project Strategies

The time required at the start of a project to define the project development strategy is clearly critical but is sometimes underestimated.

As mentioned previously it is paramount to have clearly set and realistic project goals. This starts with a proper selection of projects; which project fits the company profile best. Set proper priorities in the project pipeline. Also the project and chosen strategy to develop it must fit the company goals and strategy (and this fit needs to be confirmed throughout the project development stage). Finally, as mentioned earlier it is crucial to engage all stake holders before the project is launched to ensure the project goals reflect the company policies, incorporates the interests of all stakeholders and is well suited to the specific project conditions.

The authors suggest some alternative project strategies which can provide significant advantages given the right conditions.

Start small

Many projects developed over the last decade and today have lower grades. Also they tend to be in more remote locations which require a very significant investment in overall project infrastructure. Consequently, projects only become feasible when applying economies of scale, hence projects were developed on a very large scale. As demonstrated this did increase project complexity considerably as well as the overall time to develop the project.

An interesting option could in certain cases be to initiate production on a small scale. This concept appears to be gaining industry acceptance in recent years. So, start a project at a scale of a few percent of the overall targeted operational capacity, to jumpstart the operation quickly followed by developing the project to its full potential strengthened with information, knowledge and experience gained from the development of the project at small scale. Considering the long period currently required for development of mega projects the authors feel that, when properly planned, a two or multiple stage project development strategy does not necessarily take more time to reach full scale production and the gained knowledge, hence reduced risk, could offset the capex inefficiencies related to multiple stage project development. While a small scale project, by itself, is unlikely to be economical, there are several very significant advantages related to this strategy which may make this worth considering:

1. **Start operations quickly;** A smaller project should in many cases be considerable faster to implement. Of course certain infrastructure solutions might not be optimized at this stage (e.g. diesel generators for power supply). A smaller project should be easier, hence faster, to license and could help gain government and local support. It could increase confidence of communities in the overall project.
2. **Quick generation of cash flow;** While the modest cash flow from a smaller initial scale project will unlikely be able to fund future development to full scale, it can certainly address some development costs as well as create more confidence in the operation from an operating cost perspective.
3. **Start at a low capex and less complicated project;** A small project would be less complicated, cheaper and quicker to build. Yet it still has several project specific characteristics that apply also for the full scale project. The small project therefore offers an optimum test case and training ground for the team (if full scale development follows quickly after startup of small scale operation).
4. **Increase technical knowledge;** The small operation will help in understanding certain technical aspects of the deposit. Knowledge of metallurgical, geological, environmental, rock mechanical and other technical aspects will be bolstered by a small scale operation.
5. **Familiarise company with licensing processes;** while the small scale operation might in some aspects vary from the future full scale operations, the authors feel that the knowledge and experienced gained by the company going through the licensing process for a small plant proves highly valuable when the licensing needs to be met for the full operation. This works both ways,

the authorities will get to know the company and the operation which should increase the confidence of the authorities in the future licensing process as well.

6. **Social license to operate;** The surrounding communities will get to know the company and operations at a smaller scale where the impacts are probably much less than a full scale operation. This should help to reduce some of the fears of the nature of future impacts and provide benefits to communities from project development early on. This should also help garner trust from the communities which could be a very important intangible benefit for future project development. There is no doubt that gaining social license to operate is easier done with a small operation that, when well run and delivering on promises made, can later expand to full scale.
7. **Additional time to define the right project strategy;** In several countries a time limit exists to transfer from original exploration licenses to mining licenses. If the project possesses certain aspects that make development of the project to full scale highly complex, the company could take more time to complete additional testing and engineering work before the right project strategy and size are defined without fear of losing the licenses once a small scale operation is active.

However, if the small scale project would be considered as a standalone project with the same economic requirements, project approval could be an issue. So key to the validity of this project strategy alternative is the notion that the capital required for the small scale operation is an investment part of the full scale project and the benefits should increase the likelihood of success of the full scale project.

Recent years saw several projects being developed based on this strategy. A few examples: Achmmach tin project in Morocco (Kasbah resources), Relincho-El Morro copper project in Chile (Teck-Goldcorp), Cerro Lindo Zinc, Lead, Copper, Silver mine in Peru (Milpo) and the Pelambres copper mine in Chile (Antofagasta minerals), one of the pioneers of this approach in the early nineties.

Combining Projects

Another possible strategy is almost the opposite of the above version. In certain cases, it could make sense to combine deposits that are located close to each other to realize significant savings in infrastructure and make marginal projects work due to economies of scale. Obviously the bigger the combined project the more complex it gets and that has to be thoroughly evaluated as we have signaled earlier. Also this often requires a JV where a difficulty could arise in terms of differences in company cultures, tools, goals & strategies. Well publicised examples of this approach are the Relincho (Teck) & El Morro (Goldcorp) JV in Chile or the combination of the Los Helados & Josemaria deposits which are both owned by NGEx resources but are located on opposite sides of the Chilean-Argentinean border. The JV between Teck-Cominco/Goldcorp to jointly develop Relincho and El Morro is particularly interesting as the plan also includes a staged project development, starting the project at a capacity of a single mill line and where future expansions should be financed out of operating cash flow.

New Technology & Innovations

Another alternative to enhance certain projects can be the application of new process or equipment technologies (e.g. Ore Sorting, Chloride metallurgy or new conveyor technology) or innovative engineering & construction approach (e.g. modular design & construction, use of solar power for remote installations).

An obvious challenge lies in the fact that some new technologies or approaches are not well proven and this poses a higher risk to the project that needs to be mitigated. This can require additional tests or planning work, which can increase project schedule and could partly or wholly negate any potential benefits.

It is beyond the scope of this paper to go into detail in some of these alternatives but they can offer significant potential for project enhancement where applicable and warrant evaluation at earlier stage in the project development cycle.

Project team

Our thoughts on project teams, as discussed previously, are summarized as follows;

1. **Team selection;** The first point to address is the picking of the team. Make sure to have the right people, with the right experience and expertise at the right positions in the team structure. Preferably people that have worked together on other projects. Once more an obvious point that was far from universally applied during the boom years.
2. **Management;** Ensure the management is strong and will effectively implement the strategies to build one project team. Often, due to time pressure and possibly also lack of experience, efforts and strategies to build one team were not given enough attention.
3. **Support;** The project team must receive full support and guidance from upper management at both the engineer and owner organizations, this includes regular steering committee meetings with presence from upper management from both companies to make them effective. Once the project goals are well set and aligned with both organizations goals and cultures, strong support will keep the team aligned through the steering committee meetings. Again an obvious point that was not always rigorously applied.
4. **Team building;** As mentioned previously it is crucial to build a team at the start of the project and ensure the team spirit and culture is maintained and reinforced throughout the project to weather the eventual storms in a better way.
5. **Project Procedures;** Develop customized project specific procedures, which need to be practical and not overly elaborate and complex, and ensure all team members effectively know and apply them. Do not let completing and studying the project procedures be a “tick of the box” exercise. Do not allow the team to fall back to company specific procedures and “ways of doing things”.

It is understood that one mining company is seriously considering to modify the overall approach and plans to build a more integrated team to develop projects; an Integrated Owners Team (IOT). In this hybrid model the project team is more intimately integrated, eliminating various functions that would be doubled up in more traditional EPCM project teams. The idea behind this would be to build a team using the strength of both organizations. It will give the owner more direct control without the owner bearing full responsibility for the execution. An example would be where the project team uses specific engineering (e.g. process plant), procurement and construction management services from an engineer while the main infrastructure design, mine pre-stripping and other activities outside the engineers’ specific expertise, are directly done by the owner team members.

Such an approach has been used in the past with success. It requires a larger Owner's team. However, it is often impractical and costly for many mining companies to maintain their own large engineering team especially since it could be difficult to keep a constant workload in project development. Nonetheless, such a team could be based on short to medium term contract labour, rather than permanent employees

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Project Methodology

Several important points regarding project methodology are:

1. **Solid Base;** Ensure all field and test work is done and completed and results can be or are incorporated.
2. **Project Definition;** Several points, which have been discussed repeatedly already, are crucial to provide a solid base to allow a team off to a good start. They are; clearly defined project goals and objectives, a thoroughly defined and understood SOW, a realistic project schedule and a realistic capital cost estimate.

3. **Good start;** Allow enough time for the team to thoroughly understand the project (the scope, schedule & capex, existing and potential challenges etc.), the customized project procedures and tools and finally and also to get to know the client and other team members and "gel" as a team. In general, not enough time is spent on this; a project starts with a kick-off meeting, preceded and followed by a short period to review existing project documentation before engineering commences.
4. **Reviews;** Thorough, meaningful and fully independent reviews are required at crucial and well defined points during project development. Reviews should perhaps not be done by a team from the same or a competing engineer, nor an owner internal team. One strategy might be to establish a team composed of independent specialist consultants specifically engaged to review the project and accompany it throughout the different stages. These review committees can be formed to gather world class expertise on a specific challenging aspect of a project; for instance, tailing storage.

In short, make sure well known and established best practices are effectively implemented and consistently followed/applied.

CONCLUSIONS

Have we learned the lessons?

This paper, together with a number of other papers and presentations, has discussed some of the perceived fundamental reasons for many (but not all) mining projects failing to achieve budgets and schedules, particularly during the so-called super cycle in the first years of the 21st century. These failings are now probably better understood. This paper presents the authors thoughts on strategies that would improve project results.

A question that might be asked is whether the Super Cycle, (approximately 2000-2012) was a one off event that was not historically typical of mining projects. Although cost overruns have occurred before, the authors would characterize this super cycle as a period of unprecedented cost overruns. It was a period when demand for equipment and services were far greater than supply. The pressure on costs were thus exceptional during that period.

Since 2012, new projects have been few and far between. Suppliers of goods and services have reduced staffing levels significantly. The industry as a whole has had an opportunity to review past problems and failures. The key question for the authors is have the lessons been learned so that when the next upturn comes, mistakes will not be repeated. It is quite possible that the next upturn will not in any case be as intense as the super cycle which was driven by the reported high growth in China, (and other developing economies), and the subsequent predicted growth in demand for many commodities. Thus in the next upturn it is more likely that supply and demand for goods and services might be in better balance, as was the case for example for most of the 20th century. More competitive pricing should therefore be achieved. There are indications of projects being developed since 2012 which are benefitting from lower prices and better quality project teams.

Some of the key lessons learned outlined in this paper are the critical need to have well aligned teams in place, led by project managers who have worked on many projects, including people with decades of project experience and an aptitude to get the job done. If possible efforts should be made to maintain the same team throughout the project development cycle. One concern has to be that the current downturn might be resulting in people moving away from the mining industry or retire.

We believe that there is now a better understanding of the impact of infrastructure issues. Remote sites, high elevations, adverse climatic zones can have a huge impact on project complexity, hence its capital and operating costs. The costs of water supply, power, roads and access issues can be greater than the costs associated with developing the mine or building the plant. These infrastructure issues might be an early warning that a project might not be feasible.

Equally, the client should do an early and critical review of the possible risks associated with social, environmental and political issues. Any of these can stop or derail projects. All stakeholders need to be engaged as early as possible.

An orderly approach to project development by moving from early scoping studies, through conceptual studies, PEA's and Pre-Feasibility studies should be able to either add confidence to the suitability of a project for development or to put it on hold or reject it. Critical reviews between each stage are essential and possible better done by third parties who have no vested interest in whether the project goes forward or is terminated.

The projects objectives, challenges and expectations should be well understood and reflected in the project budget and schedule. Finally, it is crucial to define the right strategy to develop a specific project which also aligns with company goals at the outset of a project. This alignment needs to be verified and confirmed throughout the development of a project.

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OPTIMAL PROJECT SELECTION FOR OPEN PIT MINING

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OPTIMAL PROJECT SELECTION FOR OPEN PIT MINING

ABSTRACT

This work addresses the problem of choosing projects for implementing in open pit mines using formal mathematical models and optimization algorithms. Due to the interdependence among the projects for an open pit mine, classical methods for ranking projects (e.g. internal return rate, net present value and payback) are inefficient to measure individual impacts. The main result of this paper consists of a tool that returns projects to implement among many options for a given budget in order to support the decision making process, considering the interdependence among the projects since their combinations are analyzed. A side result is a mathematical model to computationally simulate an open pit mine, which can be used to understand its operation and rate its performance in terms of key performance indicators. The main benefits are the reduction of human work to select a portfolio, which can concentrate their effort in more strategic tasks, and a much likely better project portfolio choice, given that computers can analyze and explore many portfolios faster and more precisely than humans. The resulting tool is applied to a real open pit mine so that its application can be properly explored.

KEYWORDS

Open pit mining, portfolio selection, optimization, system modeling, simulation

INTRODUCTION

The optimization of an open pit mine may start since its conception, during the ore extraction planning (Dagdelen, 2001), and go through the operation itself (Burt & Caccetta, 2013) until its dismantling.

In order to define an optimal mine planning, the region to be explored is typically divided into blocks (Amankwak, 2011), over which are attributed constant model values (e.g. extraction cost, ore quality). The planning usually involves two steps: determining which blocks to explore (Picard & Smith, 2004) and in which sequence they must be explored (Bley et al., 2010).

The optimal operation of an open pit mine may be formulated using analytic models or numeric models. For instance, analytic models may be used to minimize truck maintenance cost (Topal & Ramazan, 2010), to allocate shovels in order to minimize extraction time (Michiotis et al., 1998), and to select equipment for a haulage path (Burt et al., 2011).

The approach of this paper is to use mine simulation in order to design a tool for selecting projects for improved operation, so that a vast number of mine changes can be modeled, paying the price of typically increasing the problem solution time. This type of approach has already been used to select which type of truck to use (Amirkhanian & Baker, 1992), to select which type of mining to use (Wei et al., 2003), truck-shovel productivity (Kesimal, 1998), and truck allocation and dispatch (Marzouk and Moselhi, 2004). In order to adapt to the Vale process of mine improvements, the mine changes are formulated here as projects (Markowitz, 1952).

TOOL DESIGN

The tool presented in this paper is designed to improve the productivity of an existing mine given a budget. It is fundamentally an operational problem, which comes after all the mine extraction planning is performed. Indeed, mining scheduling is an input for this problem.

Problem statement

The tool presented in this paper comes to support a routine decision in the company Vale: given a budget, which projects must be selected to implement in an open pit mine given a set of proposals in order to maximize productivity (i.e. amount of ore by time unit). Each project is associated to a cost and the overall cost of selected projects (portfolio) must fit a given budget. Figure 1 graphically represents this problem, considering that a project is a box and a portfolio of projects must fit into a hollow box (the budget).

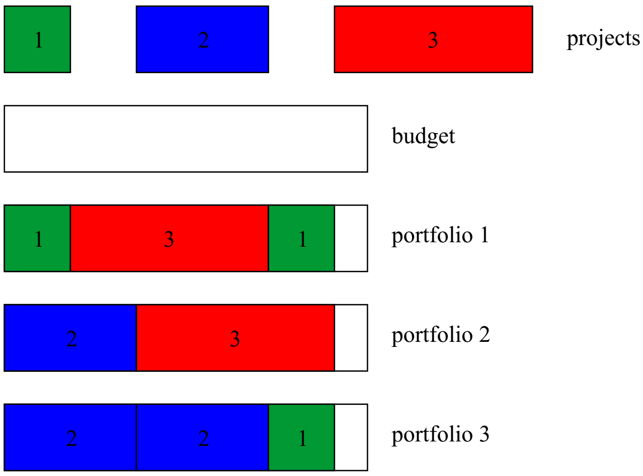

Figure 1 – Graphical representation of a portfolio selection problem. The projects 1 (green), 2 (blue) and 3 (red) are represented by boxes and sized by their respective costs, where the green box is the cheapest one and the red box is the most expensive. The selected projects must fit into a budget (represented by a hollow box). Three examples of feasible portfolios are shown, whose selected projects can be represented by a vector containing the respective count of each project (2,0,1), i.e. a portfolio composed of 2 projects 1 and 1 project 3, (0,1,1) and (1,2,0), respectively.

Modules

The tool is composed of two basic modules: simulation to evaluate the productivity related to a given portfolio of projects, and optimization to select a good portfolio of projects. They are depicted next.

Simulation

In order to evaluate the productivity of an open pit mine after implementing a given portfolio of projects, a flexible and low cost solution is to build its computational model, so that accurate simulations may approximate reality. Historical results of the mining process may be used to feed and validate the model.

The tool presented in this paper adopts a discrete event simulation (DES) approach for modeling an open pit mining process (Cassandras & Lafortune, 2008). It represents the truck cycle inside the mine, including loading at shovels, dumping at crushers, hauling through the mine and stopping (e.g. maintenances, shift changes), as shown in Figure 2. This process is characterized by timed events (e.g. a truck waits for a shovel to be available (queueing or hanging times), then it waits the loading process to finish, then it takes a time to haul to a crusher, then it waits for a crusher to be available (queueing or hanging times)…) and stochastic timings (e.g. the loading time follows a given probability distribution). The DES method used is Petri net (Ribeiro et al., 2010), which is a standard form to represent a discrete event driven process at the same time that it leads to a relatively fast simulation.

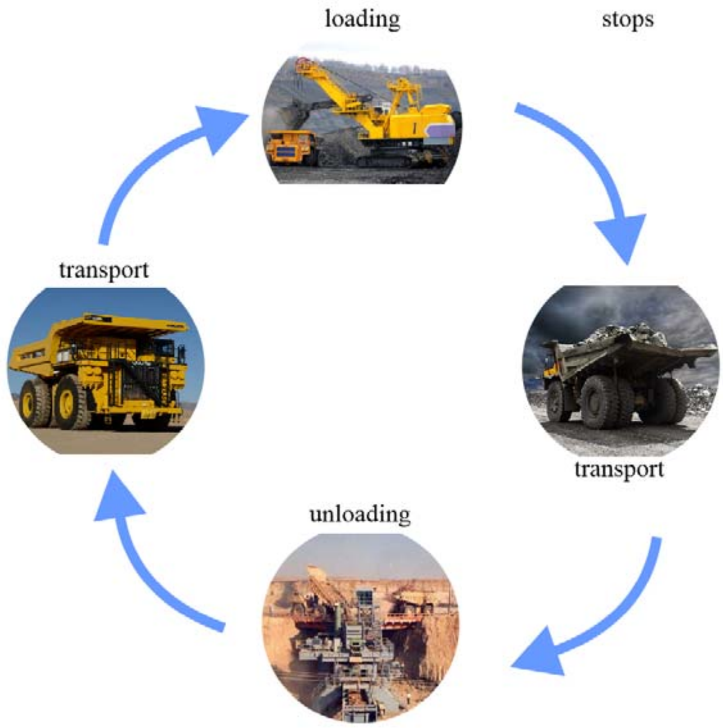

Figure 2 – Truck cycle inside an open pit mine.

With a computational mine simulator at hand, one could easily build a curve of productivity versus number of trucks in order to establish the number of trucks to keep in the mine, as shown in Figure 3. This kind of practical result may go much further by analyzing not only the number of trucks, but also many other improvement projects for the mine. This is fundamentally what the tool presented in this paper proposes to do.

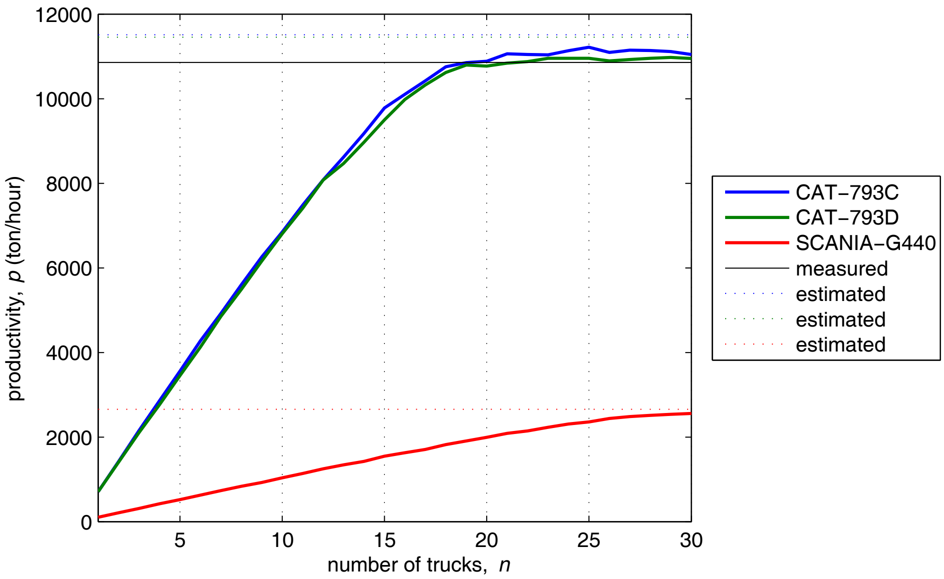

Figure 3 – The productivity of an open pit mine increases with the number of trucks until bottlenecks appear in the mining process (e.g. queues in the shovels). By this graph, about 15 to 20 trucks of type CAT-793 would be a good choice for efficiently maximizing the productivity.

Optimization

Optimization is a natural choice for the portfolio selection for open pit mining: "a set of projects must be selected to maximize the productivity under a budget constraint" is a statement of an optimization problem. A computational model to simulate an open pit mine opens the possibility to test different portfolios and choose the best one, but the number of feasible portfolios increases quickly with the number of available projects. For instance, for 30 available projects, where each one can be implemented at most once, there are about 1 billion (i.e. 2^{30}) of portfolios to compare. This number of possibilities is impossible to be analyzed by a human, and still very hard to be analyzed by a computer, claiming the development of efficient optimization algorithms.

The mine productivity depends on the implemented projects combination, where summing the individual productivity increments of implementing each project individually is typically different from the productivity increment of implementing the whole set of selected projects. This behavior makes it harder to find the problem optimal solution and justifies the development of a heuristic approach, the chosen methodology for the tool presented in this paper.

The projects available for selection already reduce the search space of changes to apply to an open pit mine while representing possible changes (i.e. design variables), which directs the decision process. In order to obtain good results, a good set of available projects must be provided. However, a given set of projects to select also defines a discrete feature to the search space: a project is implemented a number of times, which must be an integer number (e.g. acquiring half of a truck is not a valid solution).

The developed tool considers a permutative heuristic to select a portfolio of projects (at each iteration, one project is removed from the portfolio to free space to add new ones), so that the portfolio cost is kept close to the budget: an expected feature for the optimal solution. The initial guess solution is the one considering individual projects benefits and it has shown to be a good choice, since typically only a few permutations are performed to achieve the final choice in practice.

PROBLEM INSTANCE

An instance problem with 15 projects is used here to test the designed tool in practice. The projects are related to shovel bilateral loading, track improvements, dead load reduction, rock blasting, truck acquisition, treadmill acquisition, fork-lift acquisition for maintenance, preventive maintenance kits, crusher square improvements, shift change improvements, refueling improvements, automata truck acquisition, average haulage distance reduction, backlog reduction, and operator hiring. The budget is $15,000,000.00.

Results

The optimal solution indicated the acquisition of 2 trucks, hiring of 3 operators, implementation of a bilateral loading, track improvements and haulage distance reduction. The implementation of this portfolio of projects implies in an improvement of about 10% in productivity.

Accuracy

There are two main sources of error in the designed tool: modeling error and optimization error. The modeling error is estimated at around 2% using measured data to validate, as shown in Figure 3. The optimization error is related to the accuracy of the heuristic, which does not guarantee to provide an optimal solution, but, hopefully, at least close to it. In the instance of 15 projects, the optimal solution was achieved by the heuristic, which was confirmed by running an exhaustive search algorithm.

Speed

The proposed heuristic took 93 mine simulations to provide the optimal solution for the 15 projects instance, while the exhaustive search took 4,728 feasible portfolios for mine simulations among the 2^{15} = 32,768 possible combinations in order to find the optimal solution. Considering that one mine simulation takes about 5 minutes to run, the heuristic took less than 8 hours against about 16 days of the exhaustive search.

CONCLUSION

A portfolio among 15 projects could be provided by the tool presented in this paper within a few hours, which is a reasonable time for a not so often task, and still lead to productivity improvements of 10% of magnitude and an uncertainty of about 2% in the computational productivity simulation. These results economically justifies all the investments in computational models of mines and the optimization tool itself.

Some similar tools may be derived from this work. For instance, a tool could be developed to cut costs at an open pit mine, where costs should be minimized under the constraint of a minimum productivity. The cost savings of a cut in the mining process would be harder to model than pricing a project and the optimization heuristic should be changed, but we believe the ideas are quite similar and the simulation framework could be the same.

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OPTIMIZATION OF MINING OPERATIONS WITH THE USAGE OF TIME AND MOTION STUDY AND SIMULATION BY MONTE CARLO METHOD

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OPTIMIZATION OF MINING OPERATIONS WITH THE USAGE OF TIME AND MOTION STUDY AND SIMULATION BY MONTE CARLO METHOD

ABSTRACT

The article aims to present the results obtained in the characterization of mining unit operation, by conducting a study of time and motion in drilling operations, loading and transportation of gypsum in a mining operation of the Royal Gypsum Mining, located in the Araripe Plasterer Polo. The technique used is based on a stochastic method, in other words a combinatorial one, which can be implemented and solved by applying Monte Carlo algorithm. The original work has made use of a conventional method, which has its fundaments on a deterministic procedure that is based on mathematical formulas applied to the solution of time and motion studies. Comparing the results using the deterministic and stochastic technique it was concluded that both procedures work well for carrying out such a study, but it was clear that the stochastic method performed better because the amount of random numbers that can be generated and also the level of trust that can be established to optimize the entire production process from extraction until the processing of gypsum. However this paper proposes an interesting way of mining management and the development of the operating schedule of a mine.

KEYWORDS

Gypsum, time and motion study, Monte Carlo simulation, drilling and transport.

INTRODUCTION

Time and Motion Study

The time study began in 1881, at the Midvale Company plant, being FREDERICK TAYLOR its creator. Over time Gilbreth (1991) developed a parallel work to TAYLOR, adding the study of movements. The merger of these two methods, used in the analysis of the work, provided so many gains for some companies that used such a method of study. The study of time and motion has a fundamental intention of improving operational methods and working conditions, allowing analysis of the production process, activities, man-machine interface and operations in general. The control of production and operating costs is essential in the organization of an enterprise, influencing on income, working conditions, at the use of hand work and machine (Machado, 1984). The basic objective of the study of time and motion is to determine the time required to carry out a defined activity, established by rational method and performed in regular cadence by a qualified and accustomed person to a particular technique (Barnes, 1968).

Importance of Operational Efficiency of Unit Operations

In mining, as well as in various industrial activities, the final operating cost is associated with the set of activities needed to develop the product to be sold. The costs, for the most part, are generated by the execution of business processes and cost advantages arise in the implementation of these processes more efficiently than the competition. In other words operational efficiency means creating and applying procedures, so that they have a differential outcome, in order to be ahead of competitors.

Data Collection

The survey work was carried out, basically, in two distinct stages (Silva, 2013):

- The first stage consisted of a survey of excavators cycle times used to removal of overburden. From this survey we can define the average cycle time of each of the two hydraulic excavators used for the uncovering, its variability, the average unit operating time (ton / h) and the relative efficiency between the two devices used for the operation.
- The second step comprises the removal of the cycle times and distances for removing the excavated overburden material to the send-out. From this survey can define the transport distance, average speed and average cycle time to make up the transport of sterile for the send-off, its variability and the average unit operating time (ton / h).

These average cycle times can be used to perform the comparison of the efficiency between the various equipment used in the operation, performing the hourly production prediction of each device and determine the operating unit cost considering various levels of operating efficiency.

DATA SURVEY RESULTS

The Time and Motion Study

The Time and Motion study conducted in the Ponta da Serra mine is presented below in the form of charts and graphs that served to obtain the probability distribution curves of each variable analyzed (Silva, 2014).

Table 1-2: Times observed in the operation of excavation and loading of trucks with the round trip time spent on mineral uncover in Ponta da Serra Mine - Araripina / PE

Truck Load Time			
h:min:sec	**Minutes**	**h:min:sec**	**Minutes**
00:03:53	3,884	00:04:03	4,050
00:03:53	3,884	00:04:03	4,050
00:03:55	3,917	00:04:03	4,050
00:03:57	3,950	00:04:04	4,067
00:03:57	3,950	00:04:05	4,084
00:03:57	3,950	00:04:05	4,084
00:03:58	3,967	00:04:05	4,084
00:03:59	3,984	00:04:06	4,100
00:04:01	4,017	00:04:06	4,100
00:04:01	4,017	00:04:07	4,117
00:04:02	4,034	00:04:08	4,134
00:04:02	4,034	00:04:08	4,134
00:04:02	4,034	00:04:11	4,184
00:04:02	4,034	00:04:11	4,184
00:04:02	4,034	00:04:12	4,200

Round Trip Time			
h:min:sec	**Minutes**	**h:min:sec**	**Minutes**
00:04:09	4,150	00:04:16	4,267
00:04:09	4,150	00:04:16	4,278
00:04:11	4,187	00:04:17	4,289
00:04:12	4,200	00:04:17	4,290
00:04:12	4,200	00:04:17	4,290
00:04:13	4,220	00:04:18	4,302
00:04:13	4,224	00:04:18	4,302
00:04:13	4,224	00:04:18	4,302
00:04:13	4,226	00:04:19	4,321
00:04:13	4,229	00:04:19	4,325
00:04:13	4,231	00:04:20	4,335
00:04:14	4,236	00:04:20	4,347
00:04:15	4,257	00:04:21	4,361
00:04:15	4,257	00:04:22	4,368
00:04:09	4,265	00:04:23	4,384

Table 3-4: Frequency of values observed for loading trucks and the round trip time in Ponta da Serra Mine - Araripina / PE

Class Limit		Xm	Af	Rf	Acf	Class Limit		Xm	Af	Rf	Acf
3,884	3,937	3,910	3	0,100	10,00%	4,150	4,189	4,17	3	0,1000	10,00%
3,954	4,007	3,980	5	0,167	26,67%	4,210	4,249	4,23	6	0,2000	30,00%
4,024	4,077	4,050	7	0,233	50,00%	4,270	4,309	4,29	7	0,2333	53,33%
4,094	4,147	4,120	7	0,233	73,33%	4,330	4,369	4,35	7	0,2333	76,67%
4,164	4,217	4,190	5	0,167	90,00%	4,390	4,429	4,41	4	0,1333	90,00%
4,234	4,287	4,260	3	0,100	100,00%	4,450	4,489	4,47	3	0,1000	100,00%
			30	1					30	1	

Table 4-5: Mean and standard deviation for the loading time and round trip time at Ponta da Serra Mine - Araripina / PE

Mean	4,044
Standard Deviation	0,082

Mean	4,267
Standard Deviation	0,061

The first and the second graphs bellow show histograms of the absolute and accumulated frequencies of loading and round trip times respectively, it will be so important to define the kind of distribution function to do the simulation using Monte Carlo Method.

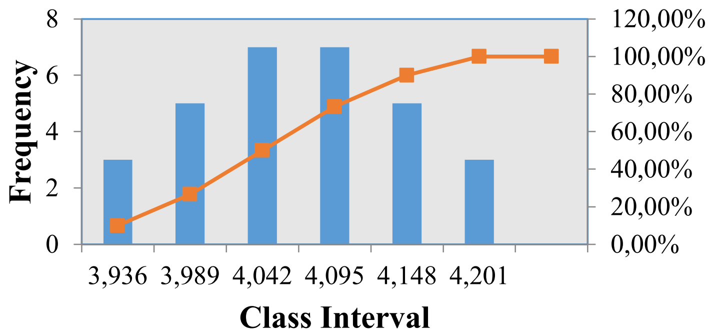

Figure 1 – Histogram indicating the distribution of loading time of trucks

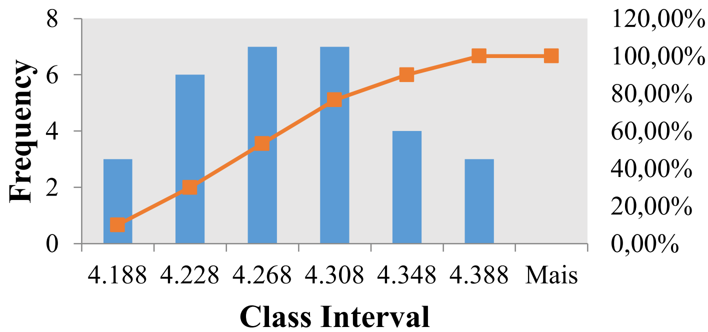

Figure 2 – Histogram indicating the distribution of round trip time of trucks

Table 6-7: Times observed in the operation of the travel time back of trucks with the dumping time spent on mineral uncover in Ponta da Serra Mine - Araripina / PE

Travel Time Back			
h:min:sec	Minutes	h:min:sec	Minutes
00:02:11	2,183	00:02:19	2,317
00:02:11	2,183	00:02:19	2,317
00:02:14	2,233	00:02:19	2,317
00:02:14	2,233	00:02:19	2,317
00:02:15	2,250	00:02:19	2,317
00:02:15	2,250	00:02:19	2,317
00:02:16	2,267	00:02:20	2,333
00:02:17	2,283	00:02:20	2,333
00:02:17	2,283	00:02:20	2,333
00:02:17	2,283	00:02:20	2,333
00:02:17	2,283	00:02:21	2,350
00:02:17	2,283	00:02:21	2,350
00:02:17	2,283	00:02:22	2,367
00:02:18	2,300	00:02:22	2,367
00:02:18	2,300	00:02:22	2,367

Dumping Time			
h:min:sec	Minutes	h:min:sec	Minutes
00:01:14	1,233	00:01:22	1,367
00:01:15	1,250	00:01:22	1,367
00:01:16	1,267	00:01:22	1,367
00:01:18	1,300	00:01:22	1,367
00:01:18	1,300	00:01:23	1,383
00:01:18	1,300	00:01:23	1,383
00:01:18	1,300	00:01:23	1,383
00:01:18	1,300	00:01:24	1,400
00:01:20	1,333	00:01:25	1,417
00:01:20	1,333	00:01:25	1,417
00:01:21	1,350	00:01:25	1,417
00:01:21	1,350	00:01:25	1,417
00:01:21	1,350	00:01:27	1,450
00:01:21	1,350	00:01:27	1,450
00:01:21	1,350	00:01:28	1,467

Table 8-9: Frequency of values observed for the travel time back and the dumping time of the trucks in Ponta da Serra Mine - Araripina / PE

Class Limit		Xm	Af	Rf	Acf
0,1840	0,2240	0,20	2	0,0667	6,67%
0,2340	0,2740	0,25	4	0,1333	20,00%
0,2840	0,3240	0,30	7	0,2333	43,33%
0,3340	0,3740	0,35	8	0,2667	70,00%
0,3840	0,4240	0,40	6	0,2000	90,00%
0,4340	0,4740	0,45	3	0,1000	100,00%
			30	1	

Class Limit		Xm	Af	Rf	Acf
0,234	0,274	0,254	3	0,1000	10,00%
0,294	0,334	0,314	5	0,1667	26,67%
0,354	0,394	0,374	7	0,2333	50,00%
0,414	0,454	0,434	7	0,2333	73,33%
0,474	0,514	0,494	5	0,1667	90,00%
0,534	0,574	0,554	3	0,1000	100,00%
			30	1	

Table 9-10: Mean and standard deviation for the travel time back and dumping time of the trucks in Ponta da Serra Mine - Araripina / PE

Mean	2,298
Standard Deviation	0,048

Mean	1,357
Standard Deviation	0,058

The graphs bellow show histograms of the absolute and accumulated frequencies of the travel time back and dumping time for the trucks, with all these parameters it is possible to manipulate them, statistically, in order to discover if the stochastic method presents batter than the classic one.

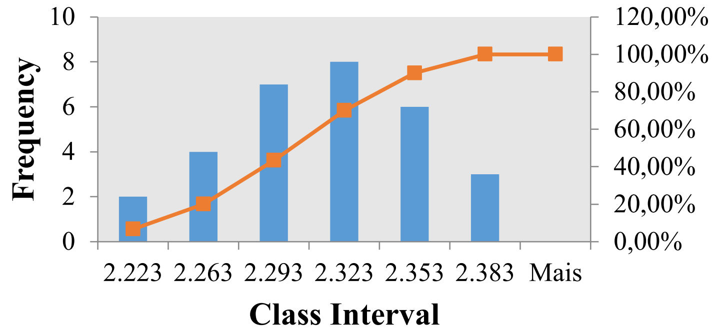

Figure 3 – Histogram indicating the distribution of the travel time back of trucks

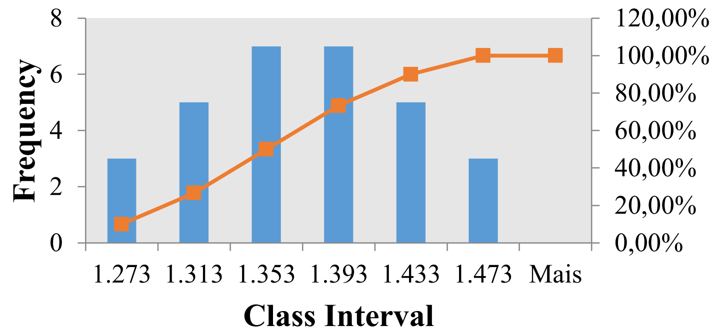

Figure 4 – Histogram indicating the distribution of the dumping time of trucks

The graphs above show histograms of the relative and accumulated frequencies of the travel time back and the dumping times respectively. Once these data are well established, it is possible to work them applying both deterministic and stochastic one.

METHODOLOGY AND DISCUSSION OF RESULTS

The Monte Carlo Method

This is a process that makes use of operations with statistical models to deal experimentally with variables described by probabilistic functions, in other words, it is a method that aims to address problems that would be extremely laborious solve them analytically, because we would have several functions that possibly would not be so easy to find out its training laws; hence the need to adapt a model that presents well to the application of the method of Monte Carlo, whose real goal experimentally evaluate the combined effects of random variables associated with the system.

To define the average transport times were used the parameters obtained in the study of times and movements performed in the pit of the company, being considered at first the average times without the inclusion of the variability of these parameters. This variability and its reflection in the fleet dimensioning calculations will be performed through the Monte Carlo simulation technique.

The time required to define the transport cycle (travel time) are Loading Time, round trip time, dumping time and travel time back. The values of the times that were used in the calculation of fleet

dimensioning were the arithmetic average obtained from the processing of the data collected in the field for each variable analyzed. Once these values are all calculated it can proceed the calculation of the number of trucks by the classic method, so:
LT = 4.04 min
RTT = 4.27 min
DT = 1.36 min
TTB = 2.30 min

$$\textbf{Total Cycle Time} = \mathbf{11.97 min/cycle} \cong \mathbf{12 min/cycle} \quad (1)$$

Assuming the truck bucket volume used in the sterile transport of $12m^3$ and applying a filling coefficient of the bucket 90%, the liquid volume transported by truck is about $10.8m^3$/cycle.

Thus, using the formulation proposed by Souza, J. C. (2002) may define the hourly production of each transport unit as:

Hourly production = Volume transported/cycle x number of cycles/h x transport efficiency
Hourly production = 10.8m³/cycle x (60'/12') x 0.85 = 45.9 m³ / hour / truck (2)

Note: it is considered a transport system efficiency of 85%

Defining a working scheme of 6 hours/day and 22 days month, it has that each truck employed in removing the overburden may perform the transportation of:

45.9 m³/h x 6 h/day x 22 days/month = (6,058.8x0.9) => 5,500 m³/month (3)

Given that the average movement of waste material of the cover is about 45,000 tons/month and the average density of local clay is near of 2.55 ton/m³, it has that the total volume to be transported month amounts to:

Monthly Demand volume = 45,000 ton/month/2.55 ton/m³ = 17,647 => 18,000 m³/month (4)

This is the volumetric need of cover sterile to be carried by the mine monthly, one can determine the number of trucks which will be needed to work in the uncover of the deposit of gypsum as follows:

Number of trucks = 18,000 m³/month/5,500 m³/month = 4 units (5)

Soon it is concluded that the number of trucks needed to transport sterile gypsum deposit coverage in the Ponta da Serra mine is 4 units of 12 m³ volume capacity bucket in operating conditions presented above. But we have to emphasize that this is a point estimative, so once it is generated some random numbers to treat it with a more realistic approach it may have some different results that will be shown below.

To perform this simulation it is considered the stochastic variables the total cycle time and the total volume, once it is associated to them some probability distribution function, it can be possible to estimate for this two variables the normal distribution for the first and uniform for the second one, once the real objective is to see the behavior of the possible scenario when these parameters oscillate, and with it understand the real necessity of equipment to attend the mine operation.

Table 11: Distribution of the random numbers and the monthly demand volume

Number Quantity	Random Numbers	Hourly Production	Monthly Production	Monthly Demand Volume	Number of Trucks
1	10.87	54.36	7174.96	17939.63	2.50
2	9.36	46.81	6179.04	16775.54	2.71
3	13.40	66.99	8842.25	16329.11	1.85
4	10.49	52.46	6925.06	18927.95	2.73
5	13.59	67.97	8972.51	17022.74	1.90
6	12.88	64.38	8498.58	18055.12	2.12
7	11.63	58.17	7678.28	16036.87	2.09
8	9.66	48.28	6372.63	19767.33	3.10
9	9.46	47.32	6246.62	18812.71	3.01
10	12.43	62.14	8203.13	19175.51	2.34
11	12.07	60.37	7968.63	18962.49	2.38
12	9.54	47.68	6293.38	18857.02	3.00
13	9.75	48.74	6433.79	17764.46	2.76
14	10.90	54.50	7193.95	18195.99	2.53
15	13.20	65.99	8711.33	16656.39	1.91
16	11.47	57.36	7571.09	18359.69	2.42
17	13.59	67.95	8969.46	18947.48	2.11
18	15.18	75.89	10017.10	19238.26	1.92
19	11.38	56.90	7510.79	16764.06	2.23
20	10.08	50.42	6655.50	17310.59	2.60
21	12.40	62.00	8183.53	17343.18	2.12
22	11.01	55.04	7265.50	19093.84	2.63
23	13.75	68.77	9077.15	17701.10	1.95
24	7.07	35.34	4665.21	16089.60	3.45
25	12.04	60.20	7946.10	18931.85	2.38
26	12.95	64.77	8550.06	16465.59	1.93
27	13.36	66.79	8816.01	19431.62	2.20
28	11.35	56.76	7491.67	16587.18	2.21
29	13.08	65.42	8635.97	18691.98	2.16
30	12.47	62.34	8229.12	18465.65	2.24
31	11.14	55.70	7352.40	18472.85	2.51
32	10.52	52.62	6945.33	17691.34	2.55
33	13.18	65.89	8697.71	16641.13	1.91
34	12.40	62.01	8185.07	16996.73	2.08
35	14.27	71.35	9418.65	17250.65	1.83
36	10.99	54.95	7253.83	19720.08	2.72
37	14.06	70.32	9282.24	19038.91	2.05
38	13.93	69.67	9196.86	17642.02	1.92
39	9.36	46.78	6174.94	19932.62	3.23
40	8.54	42.70	5636.78	17423.02	3.09
41	11.55	57.75	7623.42	17879.33	2.35
.	.	.	.	.	.
.	.	.	.	.	.
29996	11.98	59.91	7908.54	19512.92	2.47
29997	11.37	56.85	7503.79	17844.78	2.38
29998	14.48	72.41	9558.12	18446.00	1.93
29999	13.05	65.25	8613.49	16529.31	1.92
30000	10.56	52.80	6969.05	16584.86	2.38

This stochastic table shows that the simulation with these two variables – Total Cycle Time and Monthly Demand Volume – is possible to measure efficiently the number of equipment to attend with security the transport of this mine. The probability distribution functions of this two parameters, based on the simulation carried out is presented in the following figures.

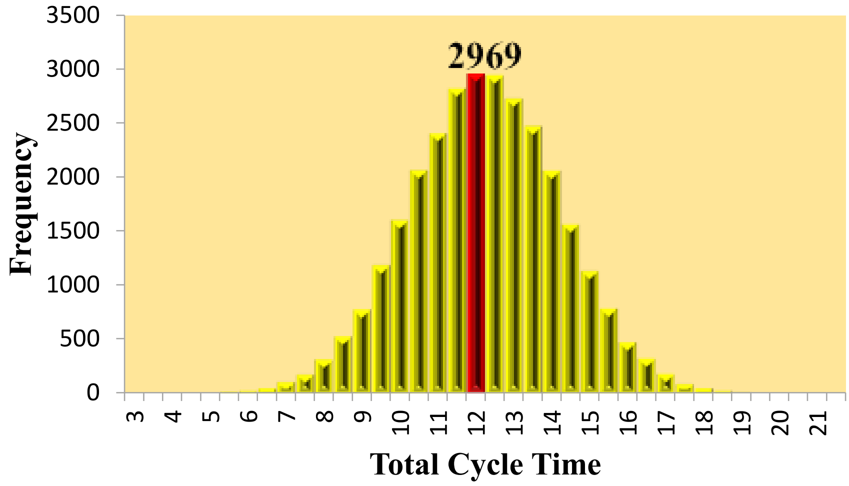

Figure 5 – distribution of the random numbers

The figure above presents the variable Total Cycle Time simulated by Monte Carlo Method, and the red line is the average of this variable.

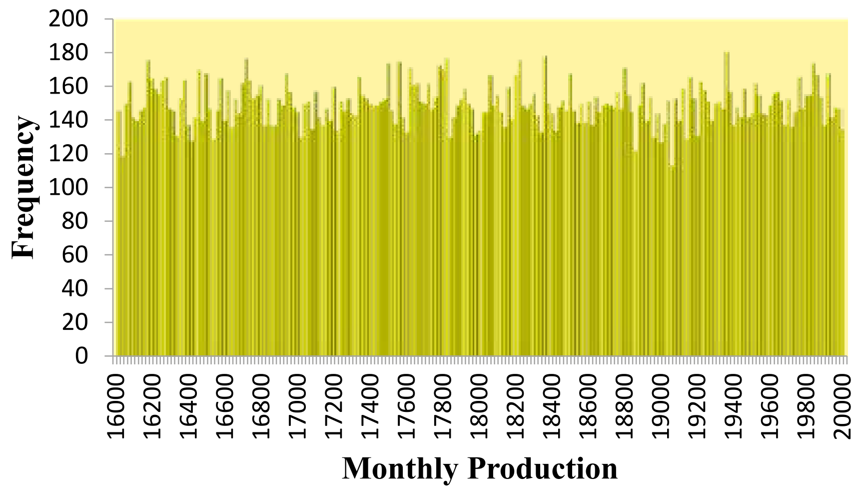

Figure 6 – Distribution of the monthly production

This figure above is the variable Monthly Production simulated using the Monte Carlo Method. It was chosen a uniform distribution because there is no deed to see the behavior out of this established range.

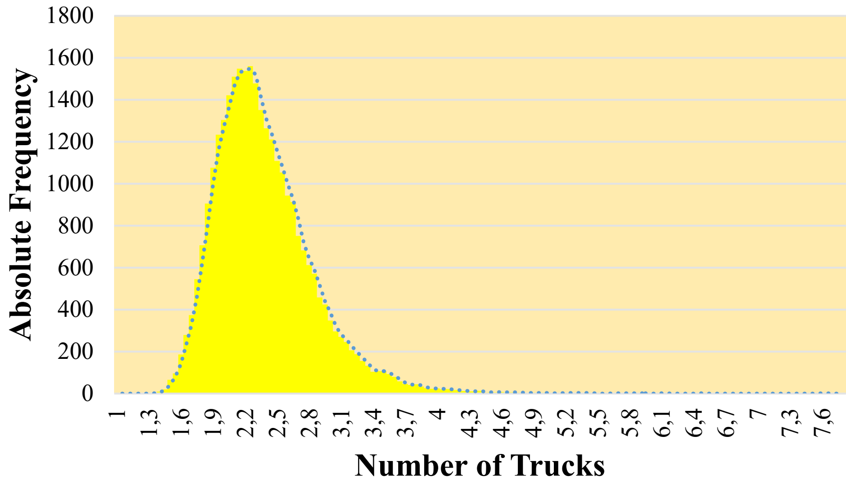

Figure 7 – Absolute frequency of the number of trucks

This figure above show us the absolute frequency for the number of trucks used to operate the mine.

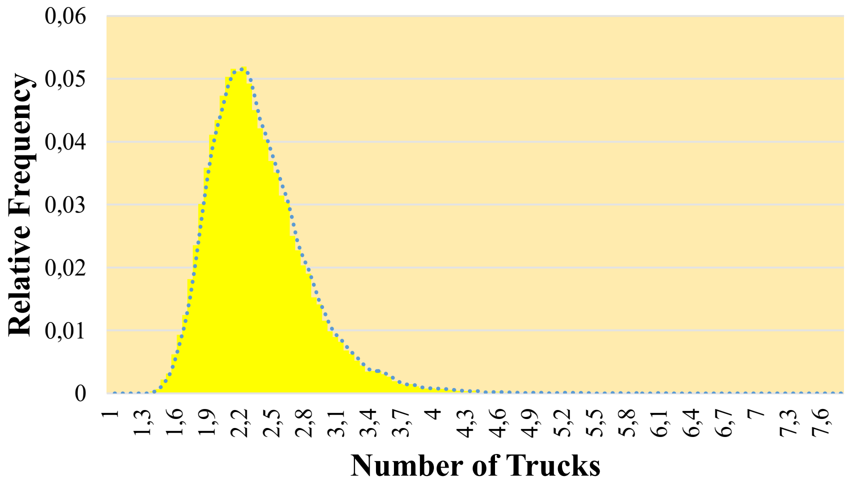

Figure 8 – Relative frequency of the number of trucks

This figure above show us the relative frequency for the number of trucks used to operate the mine. Based on this parameters showed on the figures above it was possible to calculate, stochastically the minimum necessary number of trucks needed to make the wished sterile uncover of the study mine as show in the histogram below.

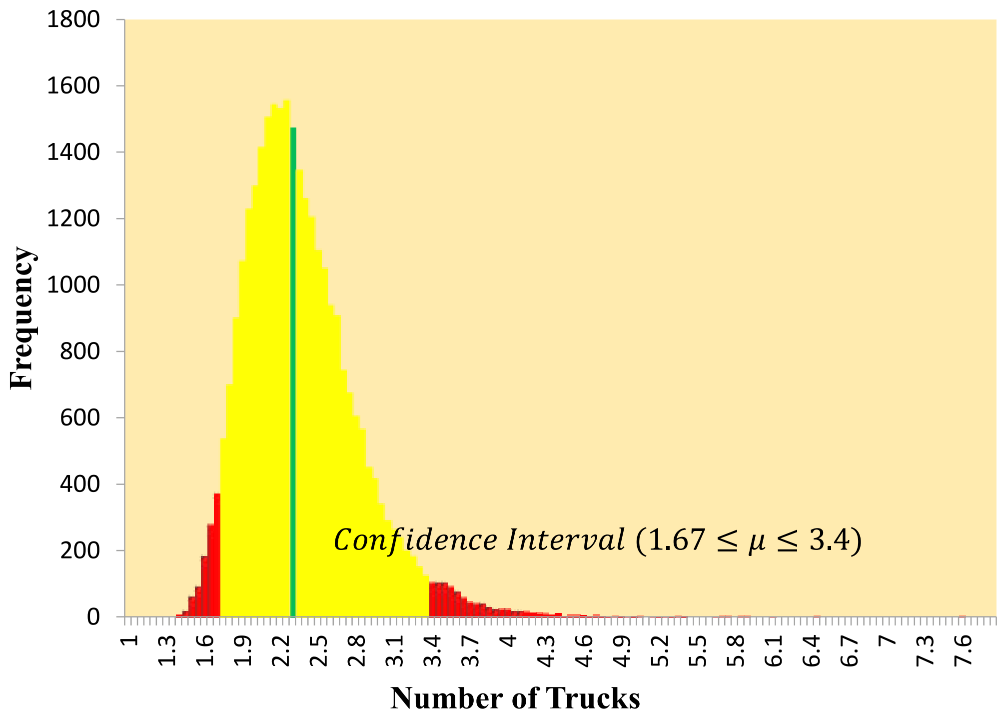

Figure 9 – Simulated quantity of the number of truck

Therefore, the results of this distribution shows that, through this simulation it is possible to reach the correct quantity of equipment to attend this operation. We can see above, with a trust rating of 95% that the operation comfortably assisted using tree trucks. Which is a reduction of 25% only for the expenses of operating trucks, so it is clear that we have many others possibility to find out better conditions of changing the work for the better, this is one.

The results of the minimum fleet sizing necessary to carry sterile capping using the classical method is 4 trucks and applying the stochastic one it was possible to observe a great possibility of reducing one truck, which is a significant reduction in the necessary investment. Once it is working with larger fleet truck this method of simulation presents an optimal option to dimension not only the amount of trucks needed to attend the mine operation efficiently, but all the mine operation which implies in a better income to the company.

CONCLUSIONS

The time and motion study gives us a tremendous advantage in regard to the statistical treatment of operational data, because by using this method it is possible to have the possibility of getting accurate information for many system of operation at any kind of enterprise or company; in our case we applied it to find out the best operational configuration for the sterile transport of a gypsum mine. And it is clear that it was very useful to accomplish the efficient results for the company.

The idea of applying the Monte Carlo Simulation was very useful, once we had the possibility of finding out the necessary number of trucks to attend the mine without having some extra expenses, that is, we were able to reduce the number of operations equipment and at the same time increase the revenue, what is so important in the business world.

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OPTIMIZATION ON LONG TERM SUPPLY OF INDONESIAN COAL TO DOMESTIC MARKET

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OPTIMIZATION ON LONG TERM SUPPLY OF INDONESIAN COAL TO DOMESTIC MARKET

ABSTRACT

Coal is a vital mineral resource for Indonesia, be it at present and in future. Domestic coal demand is expected to increase along with the government policy to increase the proportion of coal in the energy mix. On the other hand, the Indonesian coal supply is also estimated to increase. Although the supply can satisfy the domestic demand, there is one big issue on domestic coal supply allocation due to the fact that Indonesia is an archipelago country with 5 major islands and 30 smaller groups of total 17,508 islands. Indonesian coal is mainly supplied by two major islands, i.e. Sumatra and Kalimantan, with its diverse quality variations. Meanwhile, the coal is needed and consumed in all regions over Indonesia. This paper will evaluate the allocation of Indonesian domestic coal supply in the future by developing a coal transaction model and optimize such supply allocation using a linear programming method. An optimum supply is achieved by minimizing the logistic cost derived from coal transaction network.

KEYWORDS

Indonesian coal, optimization on supply, coal transaction model;

INTRODUCTION

Coal is one of the vital energy resources for Indonesia. From 1990 to 2013, coal consumption has grown significantly, of 10% per year. Coal usage for the domestic needs are mainly for electricity generation, cement industry, and processing industry. The highest portion of consumption was for electricity generation, reaching 60% of the total national consumption. In the future, coal consumption is expected to keep on increasing along with the government policy to increase the proportion of coal in the energy mix. In the supply side, coal production has also increased significantly. Its production growth during the last 20 years was 17% per year, around 7% higher than the growth percentage of domestic consumption. The main reason of such a significant production growth is to also fulfill the demand from the international coal market.

The increase in domestic coal demand is not a problem for Indonesia due to its abundant coal reserves. According to data from Geological Agency of Ministry of Energy and Mineral Resources, the total coal reserves in 2013 is 30 billion tonnes. Such reserves can be maintained for 75 years of production assuming that the annual production is 400 million tonnes per year, the coal production in 2013.

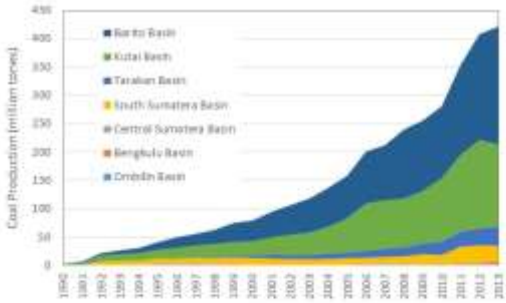
One major issue in Indonesian domestic coal supply is about the allocation of coal from producers to consumers due to the fact that Indonesia is an archipelago country having 17,508 numbers of island. Coal is mainly supplied by two major islands of Sumatra and Kalimantan, but it is needed and consumed in almost all the regions in Indonesia. Thus, this paper will evaluate the allocation of Indonesian domestic coal supply in the future by developing a coal transaction model and optimizing it to achieve the minimum logistic cost.

CURRENT CONDITION OF INDONESIAN COAL MINE

Indonesian coal basins spread all over Indonesia, from western to eastern part of Indonesia. The distribution of Indonesian coal basins is shown in Figure 1a. Coal basins having a huge resource are those located in the western part of Indonesia, i.e. in continental margin basins of Kalimantan (Kutai, Tarakan and Barito basins) and foreland basins of South Sumatera (Ombilin, Bengkulu, South Sumatera, and Central Sumatera basins).

Indonesia's coal production has increased significantly since early 1990. In 2013, the total coal production reached 420 million tonnes. Kutai and Barito basins, the two basins with the highest reserves in Kalimantan, contributed around 83% of total coal production. On other hand, foreland basins of South Sumatera have not yet provided significant contribution to the total national production (only 6% of), ,even though it has high reserves. Historical data of coal production by economic basin is plotted in Figure 1b.

a. Distribution of coal basin in Indonesia



b. Coal production based on coal basin

Figure 1 – Coal basin in Indonesia and its production level

In the demand side, only around 20% of total coal production is utilized domestically. It was mostly utilized by the power plants and cement industries. If the coal production is divided according to the economic coal basin, coal consumption shall then be divided according to its geographical location. The geographic of Indonesia is given in Figure 2a. Mainly around 81% of the domestic coal is consumed in Java Island. The details of coal consumption by geographical regions are shown in Figure 2b.

a. Geographical distribution of coal consumer

b. Historical data of coal consumption

Figure 2 – Indonesian domestic coal consumption

METHOD OF EVALUATION

Evaluation of the logistic cost on long term supply of coal will be carried out by developing coal transaction model which describes the coal flow from producer to consumer. Coal are produced from coal basin or coalfield with certain type of quality. Such coal are mined, processed, stockpiled, and transported to consumer based on the quality requested by consumer.

The main objective of coal supply process is to minimize the logistic cost. The logistic cost consists of two main components: coal purchasing cost and transportation cost. Formulation of the objective function is given in Equation 1.

$$Min\ f\ = Min\ \sum_{i=1}^{m} \sum_{j=1}^{n} c_{i,j}\ x_{i,j} \quad (1)$$

Note:

- c = logistic cost in USD, consists of purchasing cost and transportation cost
- x = coal quantity in tonnes
- m = coal basin / coal field
- n = coal consumer
- i = 1, 2, 3, …, m
- j = 1, 2, 3, …, n

In addition to the objective function, there are several more constraints that need to be accommodated in the model, such as;

- Supply constraint

  Supply constraint is given to prevent the total coal supply from certain coal basin/coalfield to the consumer not to exceed the production capacity of such a coal basin/coalfield.

  $$\sum_{j=1}^{n} x_{i,j} \leq a_i \quad (2)$$

- Demand constraint

  Demand constraint is given to limit the total coal consumed by the consumer from all producers not to be less than the total coal demand.

  $$\sum_{i=1}^{m} x_{i,j} \geq b_j \quad (3)$$

- Non-negative constraint

  Non-negative constraint makes sure all the variables of $x_{i,j}$ having positive values.

  $$\sum_{i=1}^{m} x_{i,j} \geq 0 \quad (4)$$

Note:

- a = coal production in a coal basin/coalfield in tonnes
- b = coal demand in a region in tonnes

COAL TRANSACTION MODEL AND ITS OPTIMIZATION

Component of Coal Transaction Model

Coal transaction model shows coal flow from producer to consumer. There are 3 main components of coal transaction model; producer, consumer, and logistic cost.

Coal Producer

Coal producer in the transaction model is defined as coal basin/coalfields which currently produce coal, as shown in Figure 1. Production in each coal basin, assigned as a_i value in supply constraint in Equation 2, will be forecasted by Gompertz curve. Production forecasting by Gompertz curve assumes that when the non-renewable resources are subjected to physical limitation, production level will therefore start from zero and end at zero.

The Gompertz curve forecasts the future production based on time series data of the cumulative production of the previous years. The time series data of cumulative production will show a particular growth trend. That data will then be smoothed into a growth curve as shown in Equation 5 and iteration procedure is needed to get the constants of the curve equation. From the growth curve, a level of saturation can be obtained. The future production can therefore be forecasted by extending the graph using the obtained curve equation.

$$y(t) = URR \times e^{-e^{-k(t-t_0)}} \quad (5)$$

Note:

- $y(t)$: cumulative production in time function t
- URR : ultimate recoverable reserves
- k : constant
- $t - t0$: duration of forecast

The forecasting of Indonesian coal production in each coal basin will be carried out by URR data in year 2013 and production data year 1990 – 2013. Result of production forecasting to 2025 is given in Table 1.

Table 1 – Forecasting of Indonesian coal production

Basin	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Ombilin	1.02	1.05	1.08	1.11	1.14	1.17	1.20	1.23	1.25	1.28	1.30	1.33
Bengkulu	1.17	1.15	1.13	1.10	1.07	1.04	1.00	0.97	0.93	0.89	0.85	0.82
Central Sumatra	3.42	3.86	4.33	4.82	5.32	5.83	6.35	6.87	7.39	7.90	8.40	8.89
South Sumatra	26.57	28.34	30.18	32.07	34.01	35.99	38.02	40.09	42.20	44.34	46.50	48.69
Tarakan	30.92	32.60	34.08	35.36	36.41	37.25	37.88	38.28	38.48	38.49	38.31	37.97
Kutai	150.63	160.26	169.59	178.56	187.08	195.11	202.58	209.46	215.71	221.31	226.23	230.47
Barito	163.73	167.79	170.73	172.60	173.42	173.27	172.21	170.32	167.70	164.42	160.58	156.27

Coal Consumer

The coal consumption forecasting for each region will be carried out by a multi-variable linear regression method. The dependent variable, in this case the coal consumption, is defined as a linear function of some influencing factors which act as independent variables, i.e. Gross Domestic Regional Product (GDRP), population, and time. The general equation for forecasting of the coal consumption is given in Equation 6.

$$Cons = a + b\ GDRP + c\ Pop + d\ Time \quad (6)$$

Note:

- Cons : Coal consumption
- GDRP : Gross Domestic Regional Product
- Pop : Population
- Time : Time
- b, c, d : Coefficient

There are four main steps in forecasting the coal consumption. First step is to determine the coefficient value (constant) for each independent variable of Equation 6 according to the historical data. Second step is a statistical analysis to check the significance of each independent variable with respect to its effect to the dependent variable. If the independent variable does not significantly affect the dependent variable, such an independent variable will then be withdrawn from Equation 6. Third step is to estimate the future value for each independent variable. Last but not least, the fourth step is to forecast the coal consumption based on a linier regression function obtained from the first and second steps by inputting the estimated future value of the independent variables obtained from the third step.

In this study, the coal consumption forecasting for each region will be carried out by using historical data of independent variables between year 2009 to 2013. The results of the multivariable linear regression model for each region of consumer and the estimated amount of consumption are given in Table 2. The estimated coal consumption for each region will therefore be assigned as b_j value in the demand constraint of Equation 3.

Table 2 – The estimated Indonesian coal consumption of year 2014 to 2025

Region	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Northern Sumatra	2.59	2.97	3.41	3.97	4.66	5.43	6.28	7.26	8.37	9.56	10.86	12.29
Southern Sumatra	4.65	5.05	5.44	5.84	6.23	6.62	7.02	7.41	7.81	8.20	8.59	8.99
Western Java	32.99	36.68	40.36	44.05	47.73	51.42	55.10	58.78	62.47	66.15	69.84	73.52
Eastern Java	30.73	33.31	35.89	38.47	41.05	43.63	46.21	48.79	51.37	53.95	56.53	59.11
Northern Kalimantan	0.14	0.17	0.20	0.25	0.30	0.35	0.42	0.50	0.58	0.67	0.78	0.89
Southern Kalimantan	2.73	3.34	4.05	4.84	5.72	6.69	7.78	8.95	10.21	11.58	13.06	14.63
Northern Sulawesi	1.06	1.42	1.85	2.34	2.89	3.52	4.22	4.99	5.82	6.74	7.73	8.80
Southern Sulawesi	2.84	3.26	3.69	4.12	4.56	5.00	5.45	5.91	6.36	6.83	7.30	7.77
Nusa Tenggara	1.06	1.34	1.63	1.93	2.26	2.60	2.96	3.34	3.73	4.15	4.58	5.03
Maluku and Papua	1.44	1.79	2.16	2.56	2.97	3.42	3.90	4.40	4.92	5.48	6.08	6.70

Logistic Cost

Logistic cost is derived from the coal purchasing cost and the transportation cost. Each components of the logistic cost will be forecasted using different forecasting method. Purchasing cost is estimated using a trend analysis of the historical data. On the other hand, the transportation cost will be estimated based on Environmental Protection Agency (EPA) study.

The trend analysis is carried out to find general tendency of historical data of the coal price as a function of time. The general tendency can be either linear, logarithm, or exponential. The trend function obtained will then be extrapolated for forecasting the future coal price.The forecasting of Indonesian coal price by trend analysis is carried out using historical data year 1998 to 2013 as plotted in Figure 3. It is shown that and the tendency of the available historical data follows a linear trend function. The extrapolation of the coal price trend to 2025 is given in Table 3.

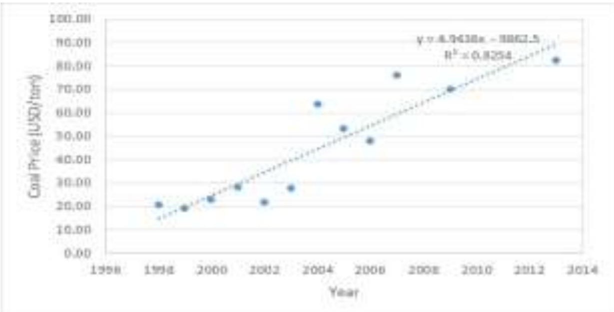


Figure 3 – Indonesian coal price in 1998 to 2013

Table 3 – The estimated Indonesian coal price of year 2014 to 2025

Year	Estimated Indonesian Coal Price (USD/ton)
2014	94.31
2015	99.26
2016	104.20
2017	109.14
2018	114.09
2019	119.03
2020	123.98
2021	128.92
2022	133.86
2023	138.81
2024	143.75
2025	148.70

The coal price listed in Table 3 is applicable for coal with a calorific value of 6600 Kcal/kg. Such coal price needs to be adjusted based on the specific calorific value of each coal basin to get the coal price of a specific coal basin. The estimated coal price per basin in year 2014 to 2025 is given in Table 4.

Table 4 – Estimated Indonesian coal price per basin in year 2014 to 2025

Basin	Calorific Value	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Ombilin	6600	77.0	82.4	85.2	89.0	93.8	97.7	100.9	105.0	109.5	113.2	116.7	120.8
Bengkulu	7000	69.0	73.8	76.3	79.8	84.1	87.6	90.5	94.1	98.1	101.5	104.6	108.3
Central Sumatra	6275	56.2	60.8	63.1	66.4	70.5	73.8	76.5	80.0	83.8	87.0	89.9	93.4
South Sumatra	5950	55.8	60.4	62.8	66.1	70.2	73.6	76.3	79.8	83.6	86.9	89.8	93.4
Tarakan	6000	48.9	52.9	55.0	57.9	61.5	64.4	66.8	69.8	73.2	76.0	78.6	81.7
Kutai	5250	54.9	59.4	61.7	65.0	69.0	72.3	75.0	78.4	82.2	85.3	88.2	91.7
Barito	5875	57.5	62.2	64.6	67.9	72.2	75.6	78.3	81.9	85.8	89.1	92.1	95.7

The second component of logistic cost is transportation cost. It is calculated as transportation distance (between mine barge port to consumer port) multiplied by unit transportation cost (in which the barge used is less than 270 ft long). The data of transportation distance from producer to consumer are given in Appendix. The unit transportation cost formula is given in Equation 7. The variations of the calculated transportation cost are presented in Table 5.

$$Barging\ cost = 0.0221 \times 1.852 \times Distance\ in\ Km \qquad (7)$$

Table 5 – Variations of transportation cost from producer to consumer in 2013 (unit in USD per ton)

		Consumer Location									
		Northern Sumatra	Southern Sumatra	Western Java	Eastern Java	Northern Kalimantan	Southern Kalimantan	Northern Sulawesi	Southern Sulawesi	Nusa Tenggara	Papua
Producer Location	Ombilin	0.0	15.7	14.5	24.3	32.7	30.2	44.9	35.3	37.3	53.7
	Bengkulu	11.2	0.0	10.0	19.8	28.1	25.6	40.3	30.7	32.7	49.1
	Ctr Sumatra	0.0	0.0	14.5	19.9	31.0	24.8	43.2	29.9	31.9	48.3
	Sou Sumatra	17.9	0.0	7.1	16.9	25.2	22.7	37.4	27.8	29.8	46.2
	Tarakan	41.9	32.3	31.1	21.1	13.0	16.7	14.8	19.0	22.9	37.3
	Kutai	32.7	23.0	21.8	11.9	0.0	7.4	15.9	9.7	13.7	29.8
	Barito	30.2	20.5	15.7	11.9	6.6	0.0	18.8	8.8	10.8	28.8

The transportation cost in future is estimated based on a study conducted by Environmental Protection Agency (EPA) as a reference. It points out that the transportation cost in future can be obtained by applying escalation factor to the transportation cost of a reference year. The study also evaluates the influencing components of the transportation cost, i.e. fuel, labor, equipment, and productivity. For the foreseeable future, EPA estimates the average escalation factor of the influencing components is -0.2% per year. But for Indonesia, escalation factor of -0.2% per year may not be applicable due to its high inflation rate. Therefore in this study a conservative value of 0% escalation factor per year will be applied.

By summarizing the coal price (Table 4) and the transportation cost (Table 5), the total logistic cost from producer to consumer can therefore be obtained. Logistic cost will be assigned as $c_{i,j}$ value in the objective function given in Equation 1.

Optimizing Coal Transaction Model

The linear programming problem on coal transaction model (Equations 1 to 4) is solved using GAMS (General Algebraic Modeling System). The output of the transaction model is the selling quantities of a specific coal basin to a consumer in the specific location ($x_{i,j}$) which produced the least total logistic cost (Table 6).

Under an optimum condition, the domestic coal consumption in Indonesia will be supplied by 5 coal basins; Central Sumatra and South Sumatra basins in Sumatra Island, and Barito, Kutai and Tarakan basins in Kalimantan Island. The analysis shows that to achieve an optimum condition, coal consumption in Sumatra, western part of Java, and southern part of Kalimantan Island shall be supplied by Central Sumatra, South Sumatra and Barito basins. The coal consumption for the other regions in Indonesia shall then be supplied by Kutai and Tarakan basins. The total logistic cost under the optimum condition of year 2014 to 2025 is USD 140.33 Billion.

Table 6 – The selling quantities per coal basin under an optimum condition in year 2014 to 2025

		Consumer Location									
		Northern Sumatra	Southern Sumatra	Western Java	Eastern Java	Northern Kalimantan	Southern Kalimantan	Northern Sulawesi	Southern Sulawesi	Nusa Tenggara	Papua
2014	Ombilin	0.32									
	Ctr Sumatra	3.42									
	Sou Sumatra		6.07	20.5							
	Tarakan							0.3			1.44
	Kutai				27.14	0.17			1.86	1.06	
	Barito			9.42			1.95				
2015	Ctr Sumatra	3.86									
	Sou Sumatra		6.83	21.51							
	Tarakan							0.32			1.79
	Kutai				28.51	0.19			2.27	1.34	
	Barito			10.72			2.18				
2016	Ctr Sumatra	3.97	0.36								
	Sou Sumatra		7.21	22.97							
	Tarakan							0.35			2.16
	Kutai				29.88	0.21			2.73	1.63	
	Barito			11.46			2.4				
2017	Ctr Sumatra	4.08	0.74								
	Sou Sumatra		7.56	24.51							
	Tarakan				31.24			0.37		1.19	2.56
	Kutai					0.24			3.23	0.74	
	Barito			11.98			2.62				
2018	Ctr Sumatra	4.19	1.13								
	Sou Sumatra		7.88	26.13							
	Tarakan				32.61			0.4		0.43	2.97
	Kutai					0.28			3.79	1.83	
	Barito			12.3			2.83				
2019	Ctr Sumatra	4.31	1.52								
	Sou Sumatra		8.18	27.81							
	Tarakan				33.41			0.42			3.42
	Kutai				0.57	0.32			4.39	2.6	
	Barito			12.42			3.04				
2020	Ctr Sumatra	4.42	1.93								
	Sou Sumatra		8.45	29.57							
	Tarakan				33.54			0.44			3.9
	Kutai				1.81	0.38			5.05	2.96	
	Barito			12.33			3.24				
2021	Ctr Sumatra	4.53	2.34								
	Sou Sumatra		8.69	31.4							
	Tarakan				33.41			0.47			4.4
	Kutai				3.3	0.45			5.75	3.34	
	Barito			12.03			3.43				
2022	Ctr Sumatra	4.64	2.75								
	Sou Sumatra		8.92	33.28							
	Tarakan				33.07			0.49			4.92
	Kutai				5.01	0.54			6.51	3.73	
	Barito			11.53			3.63				
2023	Ctr Sumatra	4.76	3.14								
	Sou Sumatra		9.15	35.19							
	Tarakan				32.49			0.52			5.48
	Kutai				6.96	0.66			7.31	4.15	
	Barito			10.87			3.81				
2024	Ctr Sumatra	4.87	3.53								
	Sou Sumatra		9.36	37.14							
	Tarakan				27.11			0.54		4.58	6.08
	Kutai				13.71	0.8			8.18		

	Barito			10.01			3.99				
2025	Ctr Sumatra	4.98	3.91								
	Sou Sumatra		9.56	39.13							
	Tarakan				25.67			0.57		5.03	6.7
	Kutai				16.51	0.99			9.09		
	Barito			8.97			4.16				

DISCUSSION

The domestic coal supply from the producer to the consumer is significantly affected by the coal price rather than the total logistic cost. The total coal purchasing cost, obtained by multiplying the selling quantity and the coal price, is estimated to be around 89% of the total logistic cost. The estimated total logistic cost of year 2014 to 2025 is plotted in Figure 4.

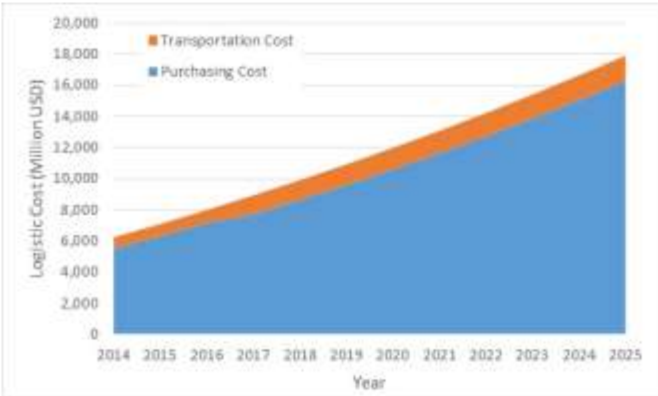
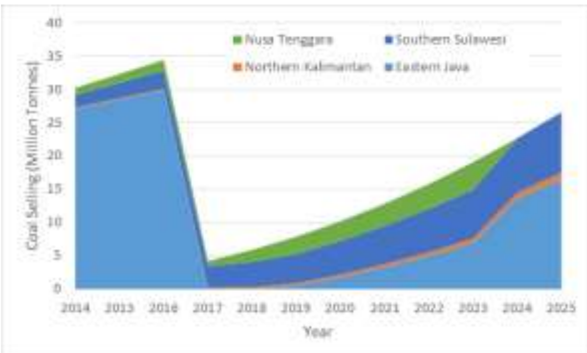
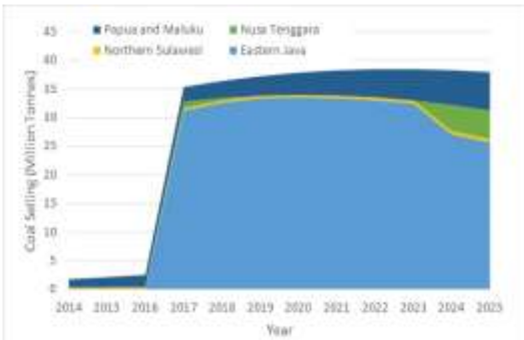


Figure 4 – Estimated total logistic cost of year 2014 to 2025

Effect of coal price on the allocation of domestic coal supply can be monitored from the coal supply to the following regions: Eastern Java, Nusa Tenggara and Maluku, and Papua. Coal supply to these areas for a short period time is fulfilled by Kutai basin, but in the long run will be fulfilled by Tarakan basin. The main reason for such condition is due to the coal price difference between the two coal basins. Kutai basin has a higher selling price than Tarakan basin due to its higher calorific value. Coal selling of Kutai and Tarakan basins with respect to its consumers are plotted in Figure 5.



a. Coal selling of Kutai basin



b. Coal selling of Tarakan basin

Figure 5. Coal selling of Kutai and Tarakan basins w.r.t consumer

CONCLUSION

Based on the aforementioned study, two conclusion are drawn and summarized as follow;

- Optimization on long term supply of Indonesian coal is greatly affected by coal price rather than the transportation cost.
- To achieve an optimum condition, the coal consumption in Sumatra, western part of Java, and southern part of Kalimantan Island shall be supplied by Central Sumatra, South Sumatra and Barito basins. The coal consumption for the other regions in Indonesia shall therefore be supplied by Kutai and Tarakan basins.

Considering the importance of coal price in determining an optimum coal supply condition, future study on a scenario analysis may need to be carried out to forecast the coal price using some other forecasting methods, i.e. econometrics and ARIMA method.

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APPENDIX

Coal Consumption by Region (in Million Tonnes)

Location	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Sumatra North	1.94	3.24	2.80	2.83	2.78	3.48	3.33	2.78	3.27	3.16	2.42	2.53
Sumatra South	0.82	0.94	0.96	1.05	0.95	1.15	0.94	2.41	3.65	3.53	4.46	5.36
Java West	8.96	10.08	10.36	11.55	11.89	14.18	13.93	16.43	17.45	19.35	22.59	31.91
Java East	11.33	12.92	13.05	14.56	16.46	19.24	18.51	20.76	16.62	22.12	24.77	29.37
Kalimantan North	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.19	0.11	0.16	0.13	0.17
Kalimantan South	0.09	0.11	0.17	0.18	0.21	0.29	0.34	1.06	1.05	1.07	1.58	1.68
Sulawesi North	0.00	0.00	0.00	0.00	0.00	0.09	0.09	0.11	0.06	0.11	0.19	0.25
Sulawesi South	0.58	0.54	0.51	0.60	0.71	0.97	1.01	1.07	0.53	0.44	1.25	1.55
Nusa Tenggara	0.01	0.01	0.01	0.01	0.01	0.02	0.04	0.07	0.05	0.49	0.74	0.69
Papua	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.65	0.99
Total	23.74	27.84	27.86	30.77	33.00	39.43	38.34	44.90	42.80	50.67	58.79	74.51

Source: Directorate of Energy and Mineral Resources, Republic of Indonesia

Coal Production by Basin (in Million Tonnes)

Year	Ombilin	Bengkulu	Ctr Sumatra	South Sumatra	Tarakan	Kutai	Barito
1990	0.00	0.37	0.00	0.00	0.00	2.44	0.45
1991	0.54	0.13	0.00	0.00	0.00	4.19	2.22
1992	0.45	0.00	0.00	7.10	0.00	9.98	4.37
1993	0.60	0.04	0.00	7.37	0.00	12.21	6.70
1994	0.99	0.34	0.00	6.71	0.30	13.55	9.06
1995	2.76	1.54	0.00	7.98	0.71	14.96	13.41
1996	2.52	0.60	0.00	9.23	1.09	17.75	18.69
1997	2.85	0.96	0.00	9.97	1.87	19.66	20.71
1998	2.30	1.24	0.00	9.86	2.38	22.33	24.82
1999	2.01	1.50	0.00	11.21	3.43	23.51	33.50
2000	0.99	0.69	0.00	11.75	4.99	24.41	36.65
2001	0.99	0.45	0.00	10.93	7.05	30.35	44.90
2002	0.79	0.38	0.00	10.28	7.57	35.39	52.08
2003	0.12	0.33	0.00	10.78	7.79	38.97	60.11
2004	0.27	0.70	0.09	10.46	9.71	46.92	68.76
2005	0.68	0.50	1.07	10.68	10.34	60.10	74.83
2006	0.30	0.81	2.35	10.48	12.18	83.43	91.43
2007	1.04	0.55	2.36	11.27	14.70	85.19	97.01
2008	0.48	0.81	1.46	13.31	16.19	85.85	121.81
2009	1.25	1.46	1.54	16.07	18.84	92.34	124.20
2010	0.33	0.32	2.30	15.51	23.74	111.56	126.86
2011	0.50	2.78	1.57	28.60	27.02	134.74	158.55
2012	0.50	3.19	1.70	30.35	30.01	155.79	186.44
2013	0.00	6.76	2.26	25.82	33.94	144.82	207.83

Source: Directorate of Energy and Mineral Resources, Republic of Indonesia

Population by Region (in Million)

Region	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Sumatra North	25.74	26.21	26.69	27.16	27.64	28.11	28.59	29.07	29.54	30.11	30.69	31.27
Sumatra South	19.04	19.29	19.55	19.81	20.06	20.32	20.58	20.83	21.09	21.38	21.68	21.98
Java West	54.43	55.54	56.65	57.76	58.86	59.97	61.08	62.19	63.29	64.64	66.01	67.41
Java East	69.97	70.39	70.81	71.23	71.64	72.06	72.48	72.90	73.32	73.76	74.21	74.66
Kalimantan North	2.67	2.78	2.89	3.00	3.11	3.22	3.33	3.44	3.55	3.71	3.88	4.05
Kalimantan South	9.15	9.28	9.42	9.56	9.69	9.83	9.96	10.10	10.23	10.39	10.55	10.71
Sulawesi North	5.24	5.33	5.42	5.51	5.59	5.68	5.77	5.86	5.95	6.05	6.15	6.26
Sulawesi South	10.19	10.34	10.50	10.65	10.81	10.96	11.12	11.27	11.43	11.60	11.79	11.97
Nusa Tenggara	11.51	11.70	11.90	12.09	12.29	12.49	12.68	12.88	13.07	13.31	13.54	13.78
Maluku and Papua	4.60	4.80	4.99	5.19	5.38	5.58	5.77	5.97	6.17	6.45	6.75	7.06

Source: Bureau of Statistics, Republic of Indonesia

GDRB by Region (in Billion IDR)

Region	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Sumatra North	213.70	249.48	255.01	263.01	276.96	289.62	303.55	312.57	329.50	349.06	367.97	385.93
Sumatra South	92.47	97.23	101.87	106.60	112.10	118.73	125.15	131.11	138.95	148.30	157.72	167.47
Java West	517.34	543.34	572.10	605.47	641.38	682.50	724.63	758.33	806.40	859.63	914.55	969.98
Java East	356.61	373.87	394.66	416.87	440.02	465.81	492.79	517.60	550.32	587.39	627.82	667.10
Kalimantan North	87.85	89.48	91.05	93.94	96.61	98.39	103.21	105.56	110.95	115.49	120.09	121.99
Kalimantan South	53.00	55.12	57.91	60.65	63.85	67.70	71.76	75.47	79.81	84.77	89.84	95.27
Sulawesi North	22.69	23.78	25.14	26.76	28.58	30.64	33.47	36.07	38.92	42.11	45.68	49.50
Sulawesi South	37.42	39.59	41.83	47.56	50.83	54.23	58.56	62.33	67.60	73.02	79.44	85.44
Nusa Tenggara	41.37	42.98	45.24	46.98	49.06	51.72	54.17	58.09	61.50	63.54	66.09	69.95
Maluku and Papua	30.18	30.65	26.48	33.01	29.75	31.27	31.77	37.23	39.05	40.84	43.52	48.45

Source: Bureau of Statistics, Republic of Indonesia

Transportation Distance between Producer and Consumer Location (in Nautical Mile)

Basin	Sumatra North	Sumatra South	Java West	Java East	Kalimantan North	Kalimantan South	Sulawesi North	Sulawesi South	Nusa Tenggara	Maluku and Papua
Ombilin	land	539	487	932	1,309	1,197	1,861	1,427	1,517	2,259
Bengkulu	338	land	282	726	1,103	991	1,655	1,221	1,311	2,053
Central Sumatera	land	land	489	733	1,233	955	1,785	1,185	1,275	2,017
South Sumatera	639	land	151	595	972	860	1,524	1,090	1,180	1,922
Tarakan	1,727	1,290	1,237	787	418	584	498	688	868	1,520
Kutai	1,309	872	819	369	land	166	552	270	450	1,180
Barito	1,197	760	542	369	130	land	682	230	320	1,135

SOUTH AMERICA MINING COMPETITIVENESS

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THE BRAZILIAN MINING COMPETITIVENESS IN SOUTH AMERICA

ABSTRACT

Competitiveness should be understood as a consistent advantage over one's competitors, usually substantiated by a better economic performance. On the other hand, mining is known as one of the most important economic activities for most Latin American countries. It is an important source of wealth generation as evidenced by indicators such as their share in the nations GDP, the positive contribution to the importing/exporting balance and the improvement of quality of life, among others. Over the last decades, most Latin America countries have shown increasing efforts to attract capital to the mining industry. In turn, investors seek countries that offer better competitive conditions characterized by systematic, structural and internal aspects. This paper intends to make a comparative analysis of the competitiveness of the Brazilian mining industry against the mining industry of some countries such as Peru, Chile, Colombia and Argentina.

KEYWORDS

Competitiveness, Brazilian Mining Industry, South American Mining.

INTRODUCTION

The competitiveness of a given country can be broadly defined as its ability to technologically self-develop and sustain benefits such as efficient production and low operating costs enabling, therefore, to face competition. It may also be understood as its ability to be economically successful in the international market where competition exists (Mariotto, 1991). This ability can be compared to a business model that is conditioned by a wide range of internal and external factors (Porter, 1990).

In addition, according to Porter, competitive strategy seeks to establish a profitable position acquired by a sustainable supremacy against other competitive countries. The challenge for a given country is to choose or create a government context in which the skills and natural resources can actually result in an advantage over other countries.

Mining is one of the earliest activities in the world. The continuity and development of mankind is highly associated to mining activity (Candia, 2015). Basically, this activity consists of finding and removing mineral substances with economic value from the earth's crust and preparing these minerals for further use. Over the years, this activity has become a major source for people´s income and a significant influence on local development wherever mining projects are installed.

Socio-economic growth implies in higher consumption of mineral commodities. Hence, it is important to ensure the availability and supply of these resources, answering to the internal society requirement and, in the event of a surplus, allowing exports which results in the generation of foreign exchange. Studies show that there is a direct relationship between economic development, quality of life and consumption of mineral (DNPM, 2012).

In all South American countries taking into account in this study, mineral resources belong to the State who grants the exclusive right of exploiting them to companies in return of tax payments, indemnities, compensations, etc. All of this statutory payments influence the country´s competitiveness. This paper presents data and relevant information about the competitiveness and economic development of

South American countries (Argentina, Brazil, Colombia, Chile and Peru), mostly regarding the mining industry.

Although most of the nations in South America have developed mining in a rather intensive manner, the countries considered here are potential competitors, presenting similar industrial characteristics. This study shows an overview of the mining industry competitiveness conditioned by structural and systemic factors already discussed in earlier studies (Mendo, 2009a). Mining data and economic information such as exports, share in the national GDP, investment in infrastructure, and so on, allow to understanding the true importance of mining at each considered country, with emphasis on Brazil.

Boosting economic growth and the slowdown in the current context of the world economy implies large challenges for the region. One of the most important of these challenges highlights the necessity to strengthen the domestic demand favoring the dynamic of investment. It would affect positively on the productivity and competitiveness of such economies.

This research was based on published literature and on exploring specialized sites that address the issue of competitiveness. Material produce by government agencies and non-governmental organizations was use to compare the competiveness among all select countries Data gathered in physical and digital formats were compiled and analyzed using software such as Microsoft Excel®. The outcomes show a descriptive characteristic raised from a systematic review of articles and technical reports in forms of graphics and tables.

SOUTH AMERICAN MINING OVERVIEW

South American countries have established competent institutions to identify opportunities and to promote the economic growth taking into account the exploitation of its mineral resources. These institutions have stimulated investment attraction, offering specialized programs in the management of mineral resources, improving productivity programs and seeking contacts with mineral industry business entities worldwide.

The establishment of Department of Mines and Energy subordinate bodies in each country, holding specific administrative roles in the mining sector, resulted in a better organization of production and the intensification of geological research in their respective territories. A better administration shown by the governments of these countries, with some exceptions, has promoted higher credibility by international investors.

It is important to mention that these countries began, in the mid-90s, to formulate basic guidelines on economic policy aiming at promoting investment. These economic policies have shown similarities among the South American countries. Albeit some exceptions, as they agreed on the same ideological basis that seeks: a) economic stability, b) state downsizing, c) privatization and deregulation of the economy, d) market opening and international integration, e) product quality and competitiveness, f) reform of financial systems, g) review of labor and social security regulations, as well as h) tax reform.

South American Mining Competitiveness Analysis

The Gross Domestic Product (GDP) is the sum, in monetary values, of all final goods and services produced in a particular country, or region, for a given period. GDP is one of the indicators most commonly used in macroeconomics, and has the main objective of measuring economic activity. "The wealth of a nation can scarcely be estimated by the measure of national income" (Kuznets, 1937).

Mining, as an economic activity, represents a significant GDP share of the countries considered in the study as shown on Table 1. It should be noted that in the last decade the GDP of the countries here considered exhibited a negligible growth. It can be also seen in the Table 1 that Brazilian GDP, in absolute terms, are significantly higher than the other´s. One can argue that Brazil holds more than 50% of South America GDP. Historically, mining represents about 4% of Brazilian GDP. If one considers mining as a supplier of semi-manufactured and/or manufactured products, mining contribution to GDP reach values of 14% and 40%, respectively (Candia, 2015).

The mining industry is a key driver for the economy in many countries. In Chile, this activity contributed 15.2% to the national GDP and represented a 56% of Chilean exports. It also corresponds to over 10% of the Colombian economy (ECLAC, 2015). If the current investment trend continues over the next decade, mining will reach the value of 12.5% of GDP in Colombia. In Argentina, the mining sector has attracted $ 11 billion in investments in the last ten years. This amount represents 3.2% of its GDP. In Peru, mining accounts for approximately 13.6% of the GDP and is usually more than 50% of Peruvian exports (Candia, 2015). In 2012, Brazilian mineral production raised $ 51 billion and in 2013 the sector reached 5% of the national GDP (DNPM, 2014), as shown in Table 1.

Table1 – Mining Share in GDP of South American Countries

Countries	Argentina	Brazil	Chile	Colombia	Peru
GDP (10^6 US$)	540.16	2353.03	257.97	384.90	29.70
Mining(%)	3.2%	5%	15.2%	10%	13.6%

Source: International Monetary Funds - MREC/ECLAC/MENDO (2015).

Despite the economic similarities seen in the countries analyzed, it can be observed that the mining has not yet reached its real importance in the Brazilian economy as compared to Chilean. Brazil, taking into account its geological profile could increase the investment in mineral production and overcome some South American countries, concerning GDP share, allowing this activity to contribute more significantly to the wealth generation.

Internacional Trade

The South America countries potential for mineral exports is doubtless slarge. Looking at the mineral production of these countries it is possible to note:

- Argentina is an important producer of copper concentrates, refined tin and silver concentrates.
- Brazil stands out as producer of iron, bauxite; primary aluminum, tin concentrate, refined tin, nickel concentrates, concentrates of iron, refined nickel, gold, zinc concentrates and refined zinc.
- Colombia stands out as nickel concentrates producer, refined nickel and coal.
- Chile is an important producer of copper concentrates, refined silver and gold.
- Peru deserves mention in copper concentrates production, refined copper, tin concentrates, refined tin; gold, silver, lead concentrates, refined lead and zinc concentrates.

Table 2 shows the international trade of mineral commodities, not including oil and gas. It can be seen that the South America countries trade reached a total of US $ 165.3 billion. Exports achieved 67% of this total, representing a surplus of US $ 66.9 US $ billion.

Table 2 - South America mineral commodities international commercial exchange (in billions)

Countries	Exports	Imports
Argentina	4.898,66	4.345,60
Brasil	34.118,62	29.129,71
Colômbia	13.800,55	1.993,05
Chile	44.556,60	9.730,52
Peru	18.768,75	4.019,23
Total:	116.143,18	49.218,11

Table 3 shows the amount of imports - goods and services, from 2004 until 2012 by all five countries. From 2011 on it can be seen a sharp decline on import values. It, in one hand, might indicates an internal increase in production capability but, most probably, this decline is an adverse effect of the economic deterioration experienced in the world. It is important to note that the data of goods exports shown in Table 3, are accounted for all exports, demonstrating that other areas were responsible for the those higher numbers.

Table3–South American countries goods and services imports from 2004 to 2012

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012
Peru	9,558	10,870	13,062	21,352	24,063	-16,747	26,069	11,645	11,326
Chile	18,411	17,175	11,802	14,280	11,224	-16,168	25,869	15,618	4,972
Brazil	13,304	8,470	18,449	19,874	15,357	-7,598	35,836	9,749	0,202
Colombia	10,272	11,902	19,968	14,046	10,476	-9,149	10,845	21,487	8,947
Argentina	40,122	16,085	10,813	21,918	13,521	-19,335	34,979	19,759	-4,736

Source: International Monetary Funds

International Commodities Trade Status

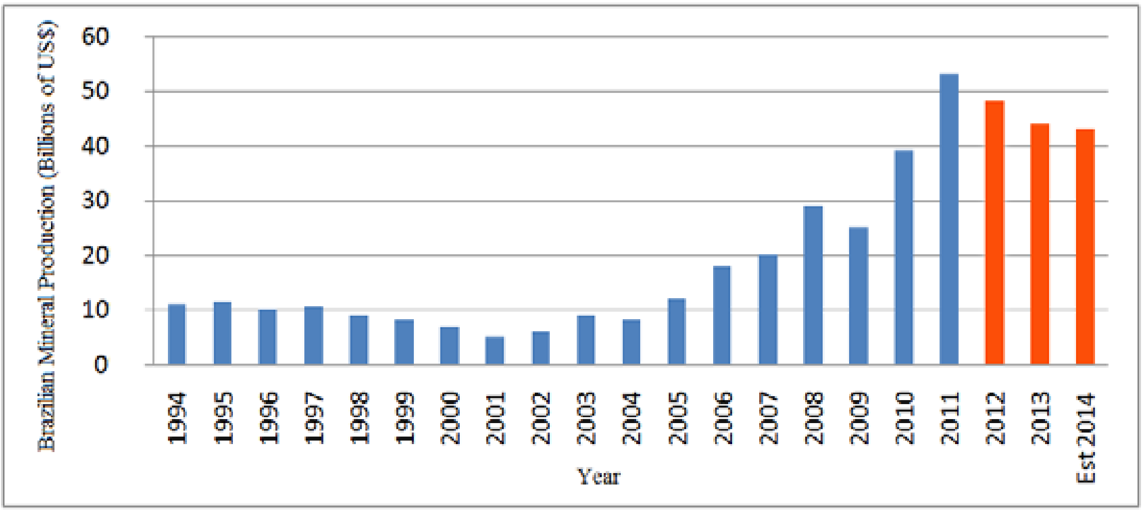
Even though the exports from the five countries showed an up and down movement during the last two decades, the GDP growth, from 7 to 10%, in average between 2005 and 2008, demonstrate a certain stability. The year of 2009 evidences the vulnerability of the South American international regarding the foreign trade. All countries were affected by the crisis known as the Great Recession (WESSEL, 2010). After some recovery in 2010, the growth rate of international trade was hit again by a “new” financial crisis, mostly in China and Europe, enhanced by natural disasters and civil conflicts, in 2011 and 2012.

As the mining industry represents a large share of these countries exports (global business), the global downwards of the economyserious affected the mining affairs. Investors’ confidence was shaken and the South American countries experienced a drastic reduction on capital inflow. This trend was also true concerning domestic investments. Figure 1 depicts the effect of 2009-2012 crisis in the Brazilian mineral production reverting the upwards curve experienced the later years.

Infrastructure

Infrastructure is undoubtedly very significant as the mining activities increasingly depend upon the sector´s competiveness. Precarious infrastructure compromises the mining productivity. Such problems require the development of new technological advances such as in capacity of handling and hauling equipment as well as in managing process focusing in increasing efficiency of logistic systems, reducing operating costs and, consequently, improving competitiveness.

Figure 1 –Brazilian Mineral Production in billions of US$



Source: IBRAM, 2015

Table 4 compares some infrastructure indicators observed in the five South America countries. Particular attention should be given to Energy and Logistic.

Table 4–Infrastructure Indicator of South American Countries

Infrastruture type	Unit	Argentina	Brazil	Chile	Colombia	Peru
Per Capita GDP	US$ 1,00	14.760	11.208	15.732	7.826	6,660
Area	10^6 km²	2,8	8,5	0,76	1,1	1,3
Population	10^6inhabitants	40	194	17,5	46,5	29
Electrical Energy Consumption	Kwh per capita	87,95	61,40	83,63	33,77	29,59
Energy Generation Capacity	10^9kw/hour	127,92	537,61	66,89	57,81	39,07
Thermoelectric	10^9kw/hour	90,16	70,97	40,21	10,15	16,55
Hydroelectric	10^9kw/hour	28,99	411,19	19,96	47,11	21,83
Railways	10^3 km	32	29	5,5	-	2
Roadways	10^3 km	242	1.581	77	214	129
Paved Roadways	total%	32,2	13,5	23,8	11,9	13,3
Waterways	10^3 km	11	50	-	18	9
Main Ports	-	18	19	12	6	6
Airports	-	1.150	4.176	357	991	202
Pipelines	10^3 km	38	25	2	14	3

Adapted from Mendo, 2009a

Argentina`s road and railway networks, 242 thousand km and 32 thousand km, respectively, are relatively good. It's power generation capacity is around 128 billion kw/h. Brazil has 1.5 million km of highways and 29,000 km of railroads. The country is the world tenth largest energy consumer and the third largest within the Western Hemisphere, behind US and Canada. The Brazilian energy matrix is based on renewable sources, mainly hydroelectric power and ethanol. From the total electricity generation capacity (537.61 billion kw/hour), the hydroelectric power represents as much as 74%.

The average cost of an MWh produced in Brazil is about R$ 388/MWh (CCEE, 2015), approximately four times higher than in Argentina. The Brazilian cost surpasses in 12% the average cost practiced in 28 countries investigated by FIRJAN (Rio de Janeiro State Industries Federation). Energy power costs in Colombia are even higher than in Brazil, reaching values 2.4 higher than in the United States. Brazil figures in the 24th position in the world ranking of competitiveness in the sector, needing costs reduction of, at least, 35% to achieve the so-called "competitive zone." (FIRJAN, 2015).

The Chilean rail system is around 5500 km long and reasonably reaches the main mining areas. The road system has about 80,000 km (24% paved). The power supply in Chile has deteriorated in terms of generating capacity and energy costs. Imported fossil fuels accounts for 60% of the electricity production in the country. The remaining energy is virtually supplied by hydroelectric plants. Only 4% of the electricity consumed by Chile comes from, so-called, clean sources such as solar, geothermal, wind and waves.

Eighty percent of the cargo transported in the Colombia, about 80 million in 2000, circulated on the highways. There are known problems of insufficient network and poor maintenance in this country. However, much of the coal activities has road and rail access to the Caribbean Sea or to the Pacific Ocean. The existing energy generation capacity (data updated as of 2013) experienced an improvement of 57.81 Billion kW/hour) due to a large increase in the construction of hydroelectric power plants, which account for nearly 80% of energy production.

Peruvian thoroughfare system accounted for, approximately, 129,000 kilometers of highways in 2013, 13.3% paved and 2000 km of railway. It also benefits from about 9000 km of waterways in tributaries of the Amazon River, and 208 km on Lake Titicaca. The electric power generation capacity is 39.07 billion kW/hour, 76% from hydroelectric plants and 24% fossil fuels.

According to recent data on the main aspects of its infrastructure, Chile has shown a steadily increase on power supply, from an energy production of around to 47 billion KWh in the mid-2000s to about 66.89 billion kWh presently, not enough to become self-sufficient. This energy profile prompts an ever increase energy cost, impairing the competitiveness of the Chilean mineral industry.

The other South American countries suffer from the same sort of problems in transportation logistics. The ports appear to be forgotten in what concerns investment, the railways are privileged of some companies that end up enslaving a production flow model that, besides somewhat efficient, needs urgent expansion. Brazil, a continental country, has a railroad network of 29,000 kilometers mostly used for themineral production transportation. Nevertheless, it requires new investments to expand since it is already operating at full capacity. Argentina, in contrast, is a country with an area smaller than Brazil, but has a larger railroad network and in good conditions.

The constant energy exchanging between Brazil and Argentina demonstrate that both experience a vulnerable generation system. Brazil, beyond the problems on the transport system, such as roads extension, relegation of the railway system and structure of waterways, also faces the prospect of energy shortages and rising costs. Although it is considered a clean power generation system the hydropower is highly depend on the weather conditions. Hence, some projects are being forced to reduce the production during peak hours, rather preferring to reduce production and sales to operatingon negative margins. Others are being induced to invest in poorer financially and environmentally alternatives such as the installation of diesel generator plants.

Taxation

Taxation in Brazil is very complex even to the mining sector. The same can be said for the other four countries cited in this study. However, most of the countries have made major changes in tax regulation to keep up with the economic changes. These regulations aim on exemptions, simplifying the taxing systems and reducing the amount due.

Revenue taxes and fees, although with different denominations (value-added tax - VAT) is quite noticeable in four of the South American countries. It varies from the minimum of 15% in Peru and a maximum of 32% in Brazil as shown in Table 6. In addition to the tax based on revenues, most of the countries have other conjugated fees, for instance Argentina's with 24% (21% VAT + 3% provincial "royalty").

Table 6 – Mineral Production Taxation

Country	VAT	Tax Over Profit	Tax Over Remitted Dividend
Argentina	21%	30%	-
Brazil	until 30,25	33%	15%
Chile	18,5% a 23%	15%	20%
Peru	16%	37%	10%

Adapted from Mendo, 2009b

The Brazilian Constitution of 1988 brought important changes in the taxation system (Brasil, 1988). However, there is a clear necessity for simplification on taxing procedures and an urgent definition of the *royalty ad valorem*, which is typically applied at the time of the transaction. The Brazilian tax values are strongly influenced by the foreign trade and taxation regime that continues to grow nowadays in Brazil.

According to the CPRM (Brazilian Geological Agency) the current Brazilian taxation, mainly federal taxes, are the foundation to financing social security as exemplified by the following contributions:

- COFINS: Contribution to Social Security Financing (3% of the monthly gross income, exempt exports;
- PIS/PASEP: Social Integration Program/Public Staff Asset Formation Program (0.65% of the monthly revenues, exempt exports, - private and public companies)/
- CSLL: Social Contribution on Net Income (12% rate on the net income)
- CFEM: Financial compensation for the exploitation of mineral resources (varies from 2% to 3% of the net revenues from the mineral production sale, depending upon the substance exploited)

Of the amount collected by CFEM, 65% are transferred to municipalities where the production is located, 23% to the state(s) and the Federal District, and 12% to DNPM (Brazilian Mining Agency). DNPM, in turn, will allocate 2% of its share to IBAMA (Brazilian Environmental Agency). Finally, the royalty and compensation to land owners, when not object to private negotiation among the stakeholders corresponds to 50% of CFEM.

In the year of 2013, President Dilma Roussef forward to the congress a bill outlining the new Mining Regulation – Bill No. 5807 of 2013. If approved the bill will replace the current Mining Code, Decree-Law No. 227. It has been argued that, if approved as is, the new regulation will discourage potential investments by reducing its remuneration and will prevent new proposals of mineral exploration (Alberto, 2014).

Looking at the possible net profitability under this new framework, it becomes clear the perception that there is an intention of the government to increase the municipalities share in the revenues, through CFEM. The contribution, once 3% at most, will be 4%. As the total costs are already getting near to the international commodities price, take Iron Ore as an example, the possible outcome of this new taxation (CFEM), will implies lower mineral investments; projects closure and layoffs. At the government view, the new bill will bring higher tax collection and, therefore, wealth generation, based on the premise of rich geology and new production technologies. Even with the current law, CFEM has showing a sharp rising from R $ 140 million in 2003 to R $ 2.4 billion in 2013, around a 1600% increase (Alberto, 2014).

Recent studies show that Brazil's position, regarding the taxation applicable to mining, is certainly beneficial to promote the investment by the mineral industry, although it can be improved with regard to the excessive taxes levied on income. These studies also show that there are no special regimes for mining ventures worldwide. The policy applied is, in general, the same observed for other industrial activities. The main difference is the incidence of specific charges referred to as *royalties* that varies from country to country. As in other taxation regimes, such differences hider a comparison among countries a difficult task.

CONCLUSION

This study allowed us to infer some conclusions about the mineral industry competitiveness on the South American countries here considered. Brazil mineral production is directed to domestic and international markets. To increase the mining sector competitiveness, the country should direct great efforts to improve its infrastructure, mineral legislation and taxation. Regarding internal market, it is also essential to boost the vertical integration in the chain production increasing the mining share in the GDP. Although a higher domestic consumption would alleviate the mineral industry dependence on exports it is a consensus that the industry will continue to depend upon the external demand, mainly Asian.

With regard to South American countries, there is a need for the economic policies envisioning to strengthen domestic consumption that minimizes the vulnerability and dependence on exports of mineral products. Mining is a global industry, from production to marketing, controlled by major's mineral economies outside South America. The development of geostrategic commercial agreements signed by these South American economies may strength each individual country against possible crises.

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THE BRAZILIAN GUIDE FOR EXPLORATION RESULTS, MINERAL RESOURCES AND MINERAL RESERVES: A NEW MEMBER OF THE CRIRSCO FAMILY

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THE BRAZILIAN GUIDE FOR EXPLORATION RESULTS, MINERAL RESOURCES AND MINERAL RESERVES: A NEW MEMBER OF THE CRIRSCO FAMILY

ABSTRACT

Public reporting of exploration results Mineral Resources and Mineral (Ore) Reserves now benefits from considerable international conformity of terminology and practices, thanks to the efforts of the national resources and reserves reporting committees of Australia, Canada, UK / Western Europe, South Africa, USA, Chile, Russia, Mongolia and most recently Brazil and of the international umbrella organization CRIRSCO (Committee for Mineral Reserves International Reporting Standards).

The recently created "Comissão Brasileira de Recursos e Reservas" (CBRR, Brazilian Commission for Resources and Reserves) is focused on establishing, promoting and managing efforts to promote and develop the Brazilian mineral sector through the dissemination of international best practices in engineering, exploration, geological modelling and mineral resources and mineral reserves delineation.

Two key pieces for this are the announced ***CBRR Guide for Exploration Results, Mineral Resources and Mineral Reserves*** and the ***adoption of a Qualified Professional***, both aligned with the CRIRSCO guidelines.

This paper provides a comparative overview of the Brazilian, Canadian, American and Australian reporting standards, emphasizing their main similarities and differences.

INTRODUCTION

Public reporting of exploration results Mineral Resources and Mineral (Ore) Reserves now benefits from considerable international conformity of terminology and practices, thanks to the efforts of the national resources and reserves reporting committees of Australia, Canada, UK / Western Europe, South Africa, USA and Chile, under the auspices of the international umbrella organization CRIRSCO (Committee for Mineral Reserves International Reporting Standards). Russia and Mongolia were accepted into CRIRSCO in 2011 and 2014 respectively, while the most recent member, Brazil, joined in November 2015. Mining companies listed on stock exchanges that use CRIRSCO-type reporting standards account for over 80% of the listed capital of the world's mining industry.

The Brazilian Commission for Resources and Reserves (Comissão Brasileira de Recursos e Reservas - CBRR) was established in 2015 by the Brazilian Association of Mineral Exploration Companies (Associação Brasileira de Empresas de Pesquisa Mineral - ABPM), the Brazilian Agency for Mineral Technology, Research and Development (Agência Brasileira de Desenvolvimento Tecnológico da Indústria Mineral - ADIMB) and the Brazilian Mining Institute (Instituto Brasileiro de Mineração - IBRAM). Building on the CRIRSCO Reporting Template, it developed the *Brazilian Guide for Reporting of Exploration Results, Mineral Resources and Mineral Reserves*, the first edition of which was released in May 2016.

This paper includes a comparison of the Brazilian Guide with the three most important Resource / Reserve reporting standards worldwide, (1) the Australasian JORC Code (Joint Committee of the Australasian Institute of Mining and Metallurgy, Australian Institute of Geoscientists and Minerals Council of Australia, 2012), (2) the Canadian National Instrument 43-101 (Canadian Securities Administrators, 2011), and (3) the USA Securities and Exchange Commission's Industry Guide 7. The JORC Code is generally recognized as the earliest and most influential of the modern reporting standards, while Canada enjoys a reputation as the capital market of choice for exploration and mining companies, with its NI 43-101 being followed by an increasing number of companies worldwide. The USA is acknowledged as a highly influential global capital market where many of the major international mining and exploration companies have a single or dual listing. However, its Mineral Reserve reporting standard, Industry Guide 7 is over 30 years old, and does not conform to modern-day reporting standards or to CRIRSCO guidelines.

It is important to note that other laws, policies and regulations apply to the reporting of exploration results, Mineral Resources and Mineral (Ore) Reserves in each country (for example, Sarbanes-Oxley in the USA, National Policy 51-201 and National Instrument 51-102 in Canada, and sections of Australian Securities Exchange listing rules in Australia). Reporting companies and Competent / Qualified Persons need to ensure they are familiar with all reporting requirements, not just those summarized in this paper.

This paper is based in part on a paper by a P R (Pat) Stephenson prepared for the 2015 Expomin Conference in Acapulco, Mexico. That paper drew in part from a presentation prepared for the 2011 Annual Meeting of the North West Mining Association by Pat Stephenson, Dr H (Harry) Parker, Consulting Mining Geologist & Geostatistician, Amec Foster Wheeler, and Chairman of the USA Resources and Reserves Committee of the Society for Mining, Metallurgy and Exploration, Inc (SME Resources and Reserves Committee), and P T (Peter) Stoker, Principal Geologist of AMC Consultants Pty Ltd and past-Chairman of JORC (now Deputy Chairman). That presentation drew in part from a paper prepared in 2008 by Pat Stephenson, Peter Stoker, and Dr Jean-Michel Rendu, who was then Chairman of the SME Resources and Reserves Committee.

OVERVIEW OF INTERNATIONAL RESOURCE/ RESERVE REPORTING STANDARDS

Table 1 presents a summary of the main CRIRSCO and non-CRIRSCO national and international reporting standards for exploration results, Mineral Resources and Mineral (Ore) Reserves.

Table 1 Overview of national and international Resource / Reserve reporting standards

	Australasia	Canada	South Africa	UK/W Europe	Chile	USA – SME	USA - SEC	Russia	Mongolia	Brazil
Adoption of CRIRSCO-type standard	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Reporting standard recognized by National Regulator	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	No
Competent or Qualified Person requirement	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Reporting of Mineral Resources allowed	Yes	Yes	Yes	Yes	Yes	Yes	No*	Yes	Yes	Yes
Inferred Resources allowed in economic studies	Yes	No*	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
At least pre-feasibility level study required for Mineral Reserves	Yes	Yes	Yes	Yes	Yes	Yes	No*	Yes	Yes	Yes
Commodity price process specified by Regulator	No	No	No	No	No	No	Yes	No	No	No
RPO-type reciprocal system	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes

* Conditional

Comparison between Canadian, Australian, American and Brazilian reporting standards

Canada

In Canada NI 43-101, together with Companion Policy 43-101CP and Form 43-101F1 which sets out the required content of a NI 43-101 Technical Report, was released by the Canadian Securities Administrators (CSA) in 2001, replacing National Policies 2-A and 22. An updated version of NI 43-101 was released in December 2005 and the most recent version in June 2011 (Canadian Securities Administrators, 2011). CSA is a forum for the 13 Canadian provincial and territorial securities regulators to coordinate and harmonize regulation of the Canadian capital markets. National Instruments have legal status, an important point for companies also listed in the USA or that file registrations statements with the SEC, as is discussed later. While the CSA is primarily responsible for coordinating the development of National Instruments, it is up to each of the provincial / territorial securities regulators to adopt (or not) the Instrument. If adopted, enforcement of the Instrument is the responsibility of the provincial / territorial regulator. All members of CSA have adopted NI 43-101.

The Investment Industry Regulatory Organization of Canada (IIROC) is a separate securities regulator in Canada. It was created by CSA and TSX when TSX became listed on its own stock exchange. Amongst its other responsibilities, IIROC plays an important role in real-time regulation of news releases and share trading activity by listed companies.

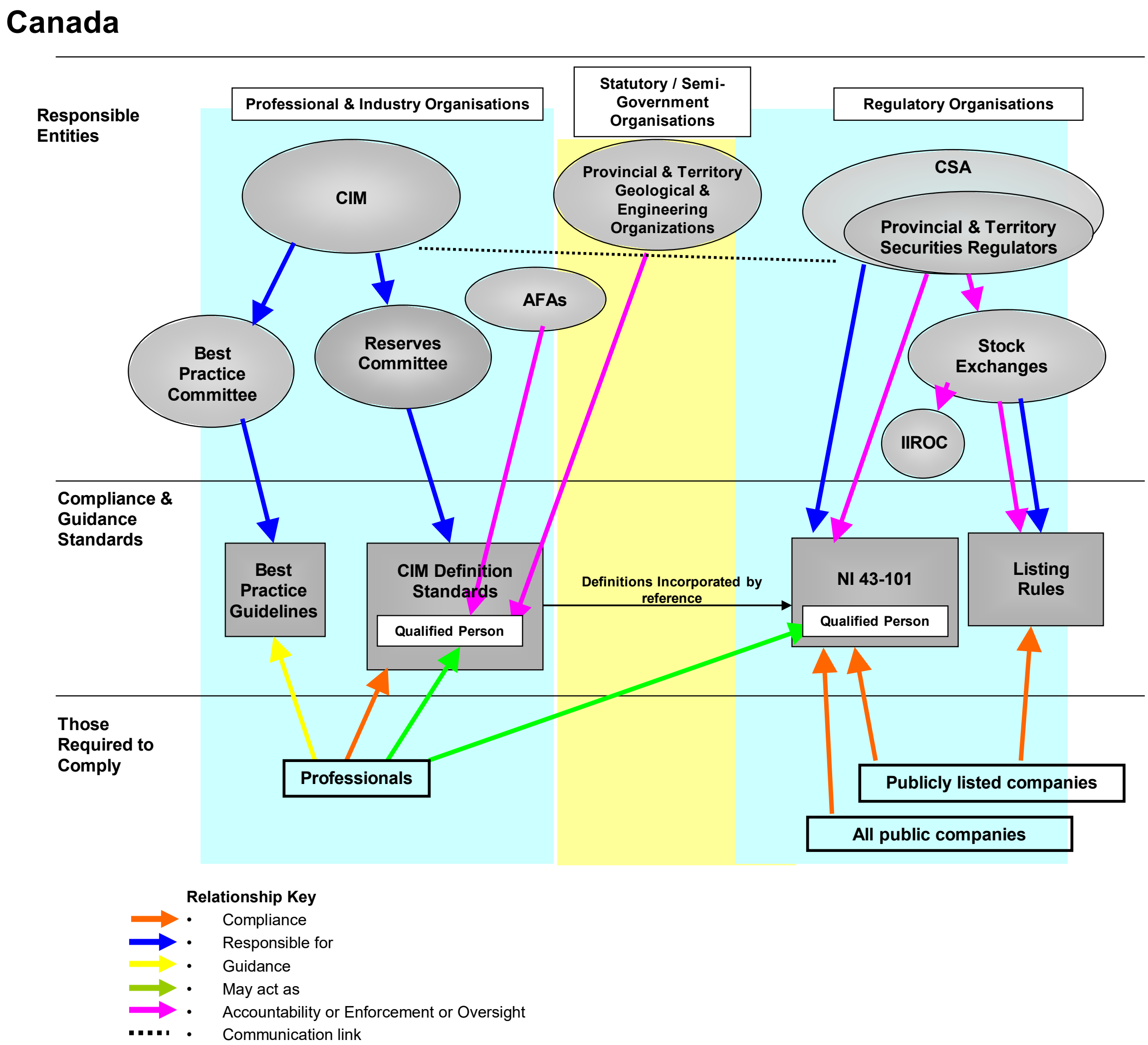

Figure 1 Reporting environment in Canada

NI 43-101 incorporates by reference ten of the definitions in the 2014 CIM Definition Standards for Mineral Resources and Mineral Reserves (CIM Definition Standards), developed by the CIM Standing Committee on Reserve Definitions. The CIM Definition Standards set out definitions and guidelines for reporting of Mineral Resources and Mineral Reserves in Canada. NI 43-101 includes a definition for a Qualified Person and also specifies a number of requirements and guidelines for Qualified Persons, who must belong to one of the provincial / territorial geological, geoscientific or engineering organizations or to an Accepted Foreign Association (AFA) listed in Appendix A to Companion Policy NI 43-101CP. In addition to the Definition Standards, CIM has published best practice guidelines for general exploration, diamond exploration and estimation of Mineral Resources and Mineral Reserves. NI 43-101 references these documents as guidance that Qualified Persons should follow.

USA

In the USA, the equivalent to NI 43-101 / CIM Definition Standards and the JORC Code is the Society for Mining, Metallurgy and Exploration Inc (SME) Guide for Reporting Exploration Results, Mineral Resources and Mineral Reserves, 2014 edition (Society for Mining, Metallurgy and Exploration Inc, 2014) (SME Guide1). The SME Guide is adopted as best practice by professionals, but is not mandatory. However, public disclosure of Exploration Results, Mineral Resources and Mineral Reserves in the USA is regulated by the Division of Corporation Finance of the SEC. The SEC does not formally recognize the SME Guide or similar CRIRSCO-style reporting standards, instead requiring mining companies to comply with its Industry Guide 7 (United States Securities and Exchange Commission, undated), and the SEC staff interpretations of this Guide.

Figure 2 Reporting environment in USA

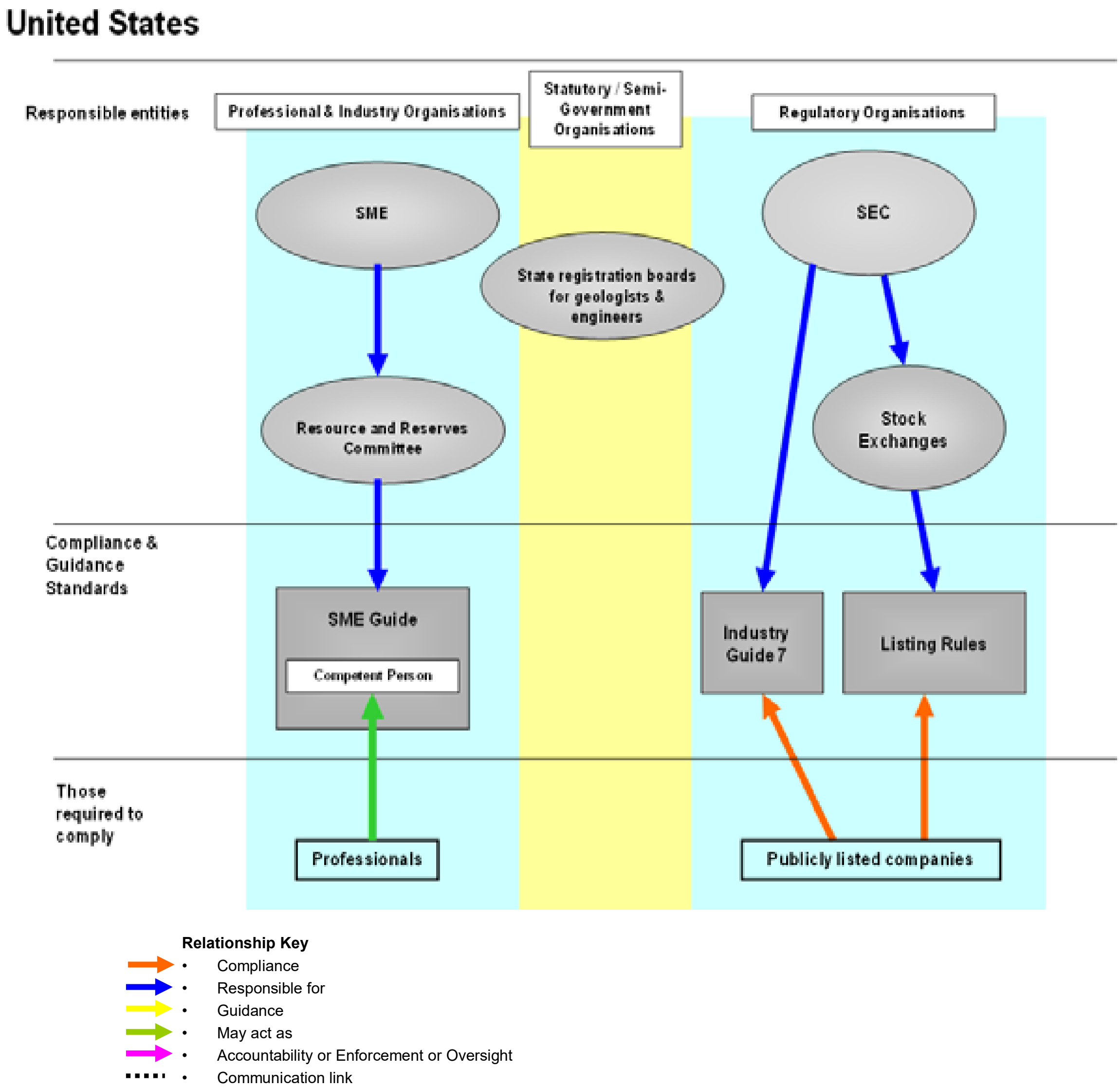

Figure 2 Reporting environment in USA

Industry Guide 7 (and subsequent SEC staff comments), first published more than 30 years ago and not since updated, differs significantly from CRIRSCO-style reporting standards in that it:

[1] In 2005, the SME Board of Directors approved the establishment of the Registered Member, a category that has the enables its members to act as Competent / Qualified Persons subject to satisfactory relevant experience.

- Does not permit the reporting of Mineral Resources, instead requiring any non-reserve material that could be considered Indicated or Measured Resources to be reported as "other mineralized material" (an exception is when a company is required by foreign or state law to report Mineral Resources, as is the case with Canada, but not Australia).
- Requires the use of commodity prices that do not exceed the average prices of the last three years or on a contract price if the commodity is sold under contract (this is an SEC staff requirement not specified in Industry Guide 7). In CRIRSCO-style reporting standards, management's reasonable and supportable forward looking prices may be used.
- Requires at least a Feasibility Study to have been undertaken to allow the publication of Mineral Reserve estimates for new projects[2] (this is also an SEC staff interpretation of Industry Guide 7). CRIRSCO-style reporting standards require at least a study at Pre-Feasibility level.
- Requires that a report be signed, but does not recognize the Competent / Qualified Person concept.

Industry Guide 7 is a short (three pages) and relatively simple document. It therefore requires considerable interpretation by SEC staff to cover the wide variety of situations found in the mining industry.

Since 2005 the SEC's comment letters in connection with their review of disclosure filings began to be publicly released. They can be found at SEC's EDGAR database: *http://www.sec.gov/edgar.shtml*.

The staff's comments are in response to their review of a company's filings with the SEC and other public information and are based on the staff's understanding of that company's facts and circumstances. Although these letters set forth staff positions and do not necessary constitute an official expression of the SEC's views, they are often used by filers and their advisors as guidelines to fill the gaps left by the IG7.

Australia

In Australia, there is only one securities regulator, the Australian Securities and Investment Commission (ASIC) and one national stock exchange, the Australian Securities Exchange (ASX), although small regional and specialist stock exchanges have set up in recent years.

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[2] Where Mineral Reserves are being incremented thorough a brownfields extension, the SEC considers a Pre-Feasibility Study as the minimum acceptable support for publication of Mineral Reserves

Figure 3 Reporting environment in Australia

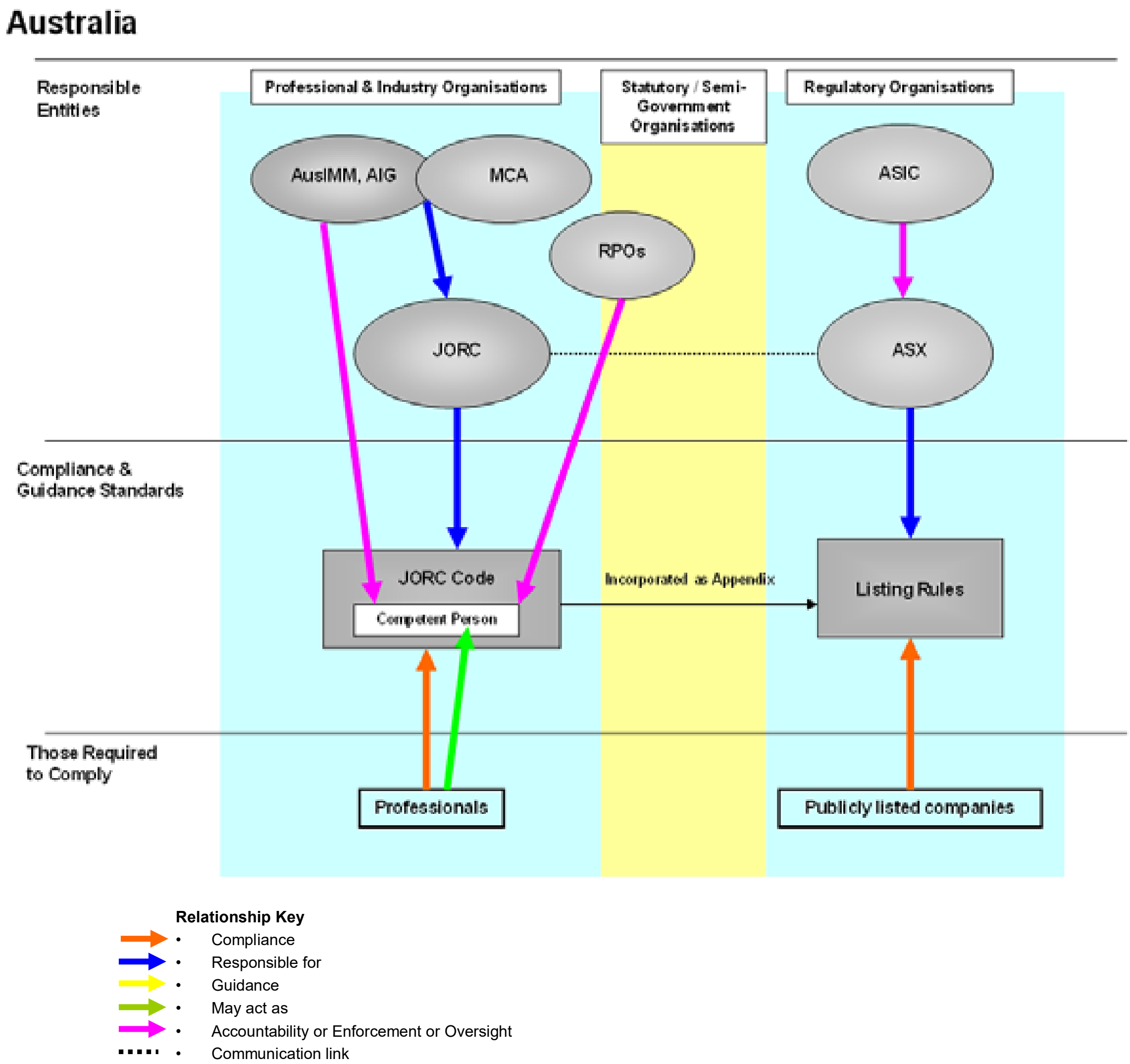

Figure 3 Reporting environment in Australia

The JORC Code has been incorporated as an appendix to the listing rules of ASX since 1989 and of the New Zealand Stock Exchange since 1992, making compliance with the JORC Code compulsory for listed companies in both Australia and New Zealand.

The JORC Code is the responsibility of the Joint Ore Reserves Committee (JORC), established in 1971 and a joint committee of The Australasian Institute of Mining and Metallurgy (AusIMM), Australian Institute of Geoscientists (AIG) and Minerals Council of Australia (MCA) with representation from ASX and Financial Services Institute of Australasia.

ASIC oversees the operation of ASX and administers the Federal Corporations Act. While stock exchange listing rules are not part of law in Australia, ASIC can require listed companies to comply with ASX listing rules, giving them a degree of legal status in certain situations. When ASX listed on its own stock exchange in 2006, it placed its operational supervisory functions in ASX Markets Supervision, since renamed ASX Compliance Pty Limited, and a subsidiary of the ASX Group.

A Competent Person must be a Member or Fellow of The AusIMM, AIG or a ”Recognized Professional Organization” (RPO) included in a list prepared from time to time on advice from JORC and available on ASX and JORC websites. RPOs are similar to Canada's AFAs, but with more stringent recognition conditions. Both RPOs and AFAs may be self-regulatory professional organizations or statutory / semi-government organizations.

Brazil

Figure 4 Reporting environment in Brazil

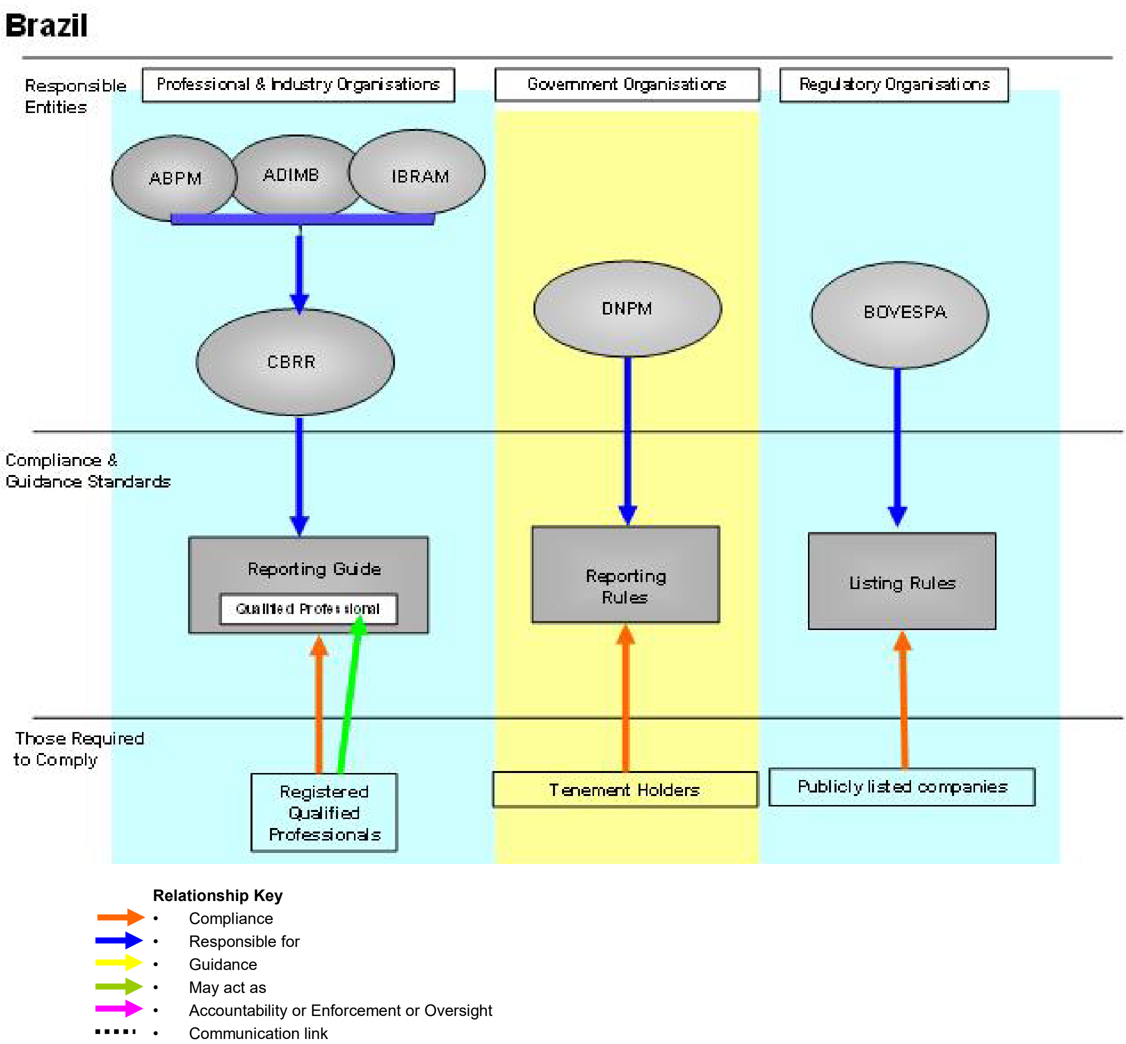

Figure 4 Reporting environment in Brazil

In Brazil, there is currently no relationship between the technical reports presented for the National Department of Mineral Production (DNPM) and the information provided to the stock exchange. The DNPM uses the Brazilian Mineral Code, which is based on a version of the USGS from the 60´s. There is no distinction between resources and mineral reserves, and there is no possible correlation between reported reserves within this code and standards proposed by CRIRSCO or the SEC.

There are only three mining companies listed with BOVESPA (Sao Paulo Stock Exchange, the largest in Brazil), and they normally use the same standard of information submitted to the international stock exchanges, usually NYSE (SEC).

The CBRR Guide for Reporting Exploration Results, Mineral Resources and Mineral Reserves seeks industry self-regulation, and its proposal is to be adopted as a reference by BOVESPA and domestic investors. This guide is aligned with the minimum standards recommended by CRIRSCO, and, like the JORC Code, NI 43-101 / CIM and SME, it recognizes the importance of the Qualified Professional role.

Contrary to the situations in Australia, Canada and USA, professionals who wish to be recognized as **"***Qualified Professionals***"** must register with the CBRR and provide evidentiary documentation of professional experience. The *Qualified Professionals* must observe a code of professional ethics and are subject to penalties, including expulsion in the case of serious breaches.

The Guide states: *"A Qualified Professional registered with the CBRR must have at least 10 (ten) years of professional experience and a minimum of 5 (five) years of relevant experience in the style of mineralization and type of deposit under consideration and in the activity which that person is undertaking, including at least 3 (three) years in a Position of Responsibility."*

Table 2 Summary comparison

	Canada	**Australia**	**USA-SME (2014)**	**USA-SEC**	**Brazil - CBRR**
Technical report	Requirement to publicly lodge a Technical Report to support certain technical / scientific disclosure on mineral deposits	No requirement to publicly lodge a technical report. However, where Exploration Results, Mineral Resources or Ore Reserves for a significant project are being reported for the first time, or when those estimates have materially changed from when last reported, a brief commentary on each of the criteria in Table 1 must be provided and a Technical summary based against Table 1 criteria on an "if not, why not" basis should be presented as an appendix to the Public Report"	No requirement to publicly lodge a technical report. However, the 2014 Guide requires a Prefeasibility or Feasibility Study must have been completed in order to publicly report Mineral Reserves	No requirement to lodge a Technical Report, but a Feasibility Study (Greenfields) or Life-of-Mine Plan must have been completed to publicly report Mineral Reserves	No requirement to lodge a technical report, but a Feasibility Study (Greenfields) or a Life of Mine Plan must have been completed to publicly report mineral reserves
Legal status	Have the force of law	Do not have the force of law (although ASX Listing Rules can be enforced under law)	Do not have the force of law; however SEC Staff uses SME Guide on an informal basis in staff comment letters	Effectively have the force of law when taken in conjunction with other USA regulations	Do not have the force of law and is not a currently requirement for the Stock Exchange
Reporting Mineral Resources and Reserves	Inclusive or exclusive	Inclusive or exclusive	Exclusive is preferred; inclusive is permitted	Mineral Resources may not, with certain exceptions, be reported, although Measured and indicated mineral resources may be reported as "mineralized material"	Inclusive or exclusive
Inferred Resources	May not, with certain exceptions, be used in economic studies	May be used in scoping studies with an appropriate warning. May not be used to support detailed planning in prefeasibility or feasibility studies	May be used in scoping, but caution should be exercised	Inferred Resources may not, with certain exceptions be reported	May be used in Scoping Studies with cautionary language.
Aggregation of Resources	Inferred may not be aggregated with Measured and Indicated	Inferred may be aggregated with Measured and Indicated	Inferred may not be aggregated with Measured and Indicated	Indicated and Measured Mineral Resources may be reported as mineralized material	Inferred may not be aggregated to Measured and Indicated

	Canada	Australia	USA-SME (2014)	USA-SEC	Brazil - CBRR
Conversion from Mineral Resources to Reserves	At least a pre-feasibility study	At least a study at pre-feasibility level	Completion of Pre-feasibility or Feasibility Study	Feasibility study for new projects; Pre-feasibility study or life of mine plan for brownfields extensions or satellite deposits	At least a study at pre-feasibility level; Feasibility level for specific cases
Commodity prices	Based on management's reasonable and supportable expectations	Based on management's reasonable and supportable expectations	Based on management's reasonable and supportable expectations	Maximum of three-year trailing average or other variation as approved by SEC staff	Based on management´s reasonable and supportable expectations
Naming of Qualified / Competent Person	Required in public reports	Required in public reports	Required on request	No Qualified / Competent Person requirement, but report must be signed	Required in Public Reports
Qualified / Competent Person experience	At least 5 years' experience and experience relevant to the particular situation	At least 5 years' experience relevant to the particular situation	At least 7 years' experience relevant to the particular situation, with 3 years in a position of responsibility	No Qualified / Competent Person requirement	At least 10 years' of professional experience, at least 5 years relevant to the specific situation, and at least 3 years in a position of responsibility

CONCLUSIONS

Brazil became the latest member of CRIRSCO in December 2015, when CBRR published the first edition of the *Brazilian Guide for Reporting of Exploration Results, Mineral Resources and Mineral Reserves*, based on the CRIRSCO Reporting Template. Brazil has also adopted a Qualified Professional system, which has a requirement for ten years of professional experience, with at least five years relevant to the specific situation being reported upon, and at least three years in a position of responsibility. While the Brazilian reporting regime is consistent with other CRIRSCO countries, it has more similarities to the JORC Code than to NI 43-101 in that there is no requirement to publish a Technical Report and the Brazilian Guide does not have the force of law.

Currently, the Brazilian Guide is not a requirement for reporting to domestic stock exchanges, however CBRR is working with the largest of the exchanges, BOVESPA, to introduce the Guide and Qualified Professional system. This will bring Brazil into alignment with other CRIRSCO countries, whose stock exchanges account for over 80% of the listed capital of the world's mining industry.

ACKNOWLEDGEMENTS

One of the authors, Pat Stephenson, gratefully acknowledges the contributions of Peter Stoker, Dr Jean-Michel Rendu and Dr Harry Parker to earlier co-authored papers, from which this paper draws some content. All authors thank Dr Parker and Mr G Gosson, Technical Director Geology & Compliance, Mining & Metals Consulting, Amec Foster Wheeler, for their detailed review of a draft of this paper.

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THE ROLE OF BAUXITE ADDED VALUE DEVELOPMENT IN INDONESIAN ECONOMY: INPUT-OUTPUT ANALYSIS

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THE ROLE OF BAUXITE ADDED VALUE DEVELOPMENT IN INDONESIAN ECONOMY: INPUT-OUTPUT ANALYSIS

ABSTRACT

Government of Indonesia implemented the raw mineral material export ban policy effectively in early 2014. One of the purposes of this policy is to encourage the mineral added value development in Indonesia. The aim of this paper is to analyze the impact of the bauxite added value development to the Indonesian economy using input-output analysis. Our methodology contains three stages and each stage contains more detailed steps. Firstly, the projection of Indonesian Input-Output Table for the year 2005 to 2035 by including alumina refinery as a new classification was conducted. Secondly, we conducted the linkages and multiplier analysis of the sector in Indonesian economy. Lastly, we also conducted output impact analysis with three scenarios. The results indicate that alumina refinery sector has high backward linkage and low forward linkage. Moreover, multipliers of alumina refinery sector generally show higher average values than other sectors especially income and employment multiplier. Output impact analysis show that the scenario 3 (all of bauxite ores are processed domestically) gives the largest total output, while scenario 1 (all of bauxite ores are exported) gives the smallest. Our findings confirm the necessity of bauxite added value development. The result from this paper could help in choosing the optimum option in utilizing mineral resources for the welfare of the people especially in Indonesia.

KEYWORDS

Bauxite, input-output analysis, added value, linkages, multipliers

INTRODUCTION

Bauxite is one of the back-bone mining commodities for supporting Indonesian economy beside coal, nickel, copper and gold as an export commodity. Indonesian bauxite ores production grew fast in the recent year especially in 2013 before the implementation of the raw mineral material export ban policy (see Fig. 1). Unfortunately, before this implementation, all of bauxite ore productions are exported because there are no alumina refineries or other bauxite processing facilities in Indonesia. Meanwhile, Indonesia's bauxite resources and reserves are not very abundant compare to other bauxite ores exporter country (see Fig. 2). Therefore, to get optimum benefit of bauxite, it is necessary to develop bauxite added value by encouraging bauxite mining permit holders to process bauxite domestically.

Bauxite added value development or bauxite beneficiation can be done in several ways. Bauxite can be processed as calcined product, special products, chemical products, cement products and alumina production (Hill & Sehnke, 2006). Almost 85% of mined bauxite is converted into aluminium metal while 10% goes to nonmetal uses in various forms of alumina and the remaining 5% goes to non-metallurgical-grade bauxite application. The market for non-metallurgical-grade bauxite is mature and only consumes five million tons of these products. On the other side, the market for alumina production still grows significantly. For example, in 2015 the world aluminium production which needs alumina grew from 50 million tons to 58 million tons (US Geological Survey, 2016). This amount of aluminium production approximately needs about 116 million tons of alumina. Based on the aforementioned demand, it is suggested to build alumina refinery in order to beneficiate bauxite.

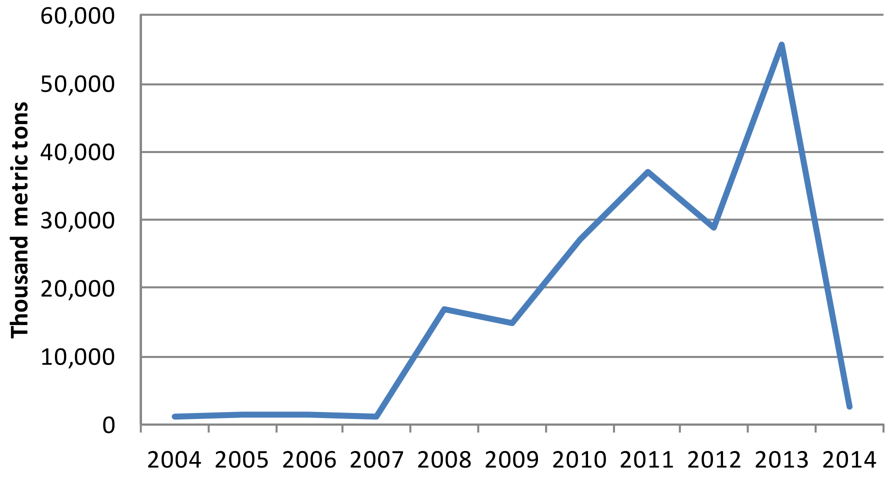

Figure 1 – Indonesia's bauxite ores export and production 2004-2014 (US Geological Survey, 2016)

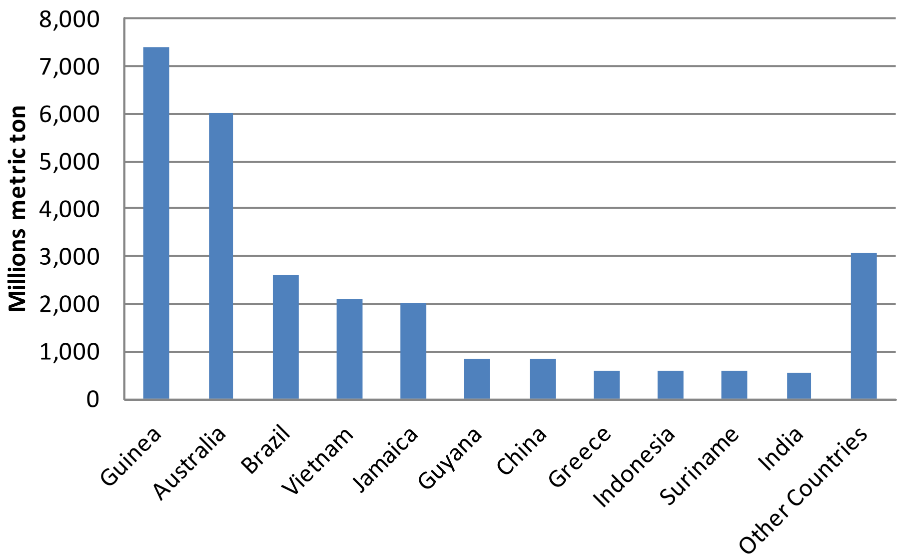

Figure 2 – World bauxite reserves (US Geological Survey, 2014) and (Center for Geological Resources, Indonesia, 2014)

RESEARCH METHOD

The aim of this paper is to analyze the impact of the bauxite added value development to the Indonesian economy using input-output analysis. The analysis is based on Indonesian Input-Output Table for 2005, 175x175 sectors, domestic transactions on the basis of producer prices (Badan Pusat Statistik Indonesia, 2006). Moreover, this table is aggregated and added with alumina refineries as a new sector into 26 x 26 sectors. Thus, this table is projected until the year 2035 by using the assumptions that the economic growth is 5.5%. The output of alumina refineries is the result of processing 20 million metric tons of bauxite production. Meanwhile, the inputs of alumina refineries sector are based on the summary of the feasibility study report of alumina refinery from Ministry of Energy and Mineral Resources of Indonesia.

Input-output Analysis

The relationship between the entries in Input-Output Table and GDP are as follows:

$$\sum_{j=1}^{n} x_{ij} + F_i = X_i + M_i \quad (1)$$
$$\sum_{i=1}^{n} x_{ij} + V_j = X_j \quad (2)$$

And $X_i = X_j$ then the formula can be written as follows:

$$\sum_{j=1}^{n} x_{ij} + F_i - M_i = \sum_{i=1}^{n} x_{ij} + V_j \text{ or } F_i - M_i = V_j \quad (3)$$

Where:
xij = transaction from i sector to j sector; Mi = imports of i sector.
Fi = final demand of i sector; Vj = primary input (value added) of j sector
Xi = total output of i sector; Xj = total input of j sector

The proportion of intermediate input from i sector to the total input of j sector is referred as coefficient of intermediate input (Miller & Blair, 2009) and obtained by the formula:

$$a_{ij} = \frac{x_{ij}}{X_j} \quad or \quad x_{ij} = a_{ij}.X_j \quad (4)$$

By substituting equation (4) into equation (1) with imports (M_i) is excluded, the equation becomes as follows:

$$\begin{aligned} a_{11}X_1 + a_{12}X_1 + \ldots + a_{1n}X_1 + F_1 &= X_1 \\ a_{21}X_2 + a_{22}X_2 + \ldots + a_{2n}X_2 + F_2 &= X_2 \\ \ldots + \ldots + \ldots + \ldots + \ldots &= \ldots \\ a_{n1}X_1 + a_{n2}X_2 + \ldots + a_{nn}X_1 + F_n &= X_n \end{aligned} \quad (5)$$

If the composition of the equation (4) is simplified into matrix form, it is obtained:

$$\begin{aligned} \mathbf{AX + F = X} \\ \mathbf{X - AX = F} \\ \mathbf{(I - A)X = F} \end{aligned} \quad (6)$$

The output can be calculated as the effect of final demand induction, as follows:

$$\mathbf{X = (I - A)^{-1}F} \quad (7)$$

where:
I = the identity matrix of size n × n
F = final demand matrix of size n x 1
A = matrix of input coefficients / technical of n x n

Matrix $(I - A^d)$ -1 is a matrix multiplier which is suitable for measuring changes in domestic output, due to the change in domestic final demand. This matrix is also known as Leontief inverse matrix (Bulmer, 1982).

Linkage Analysis

Linkages analysis is used to calculate the output impact of the fact that basically the industrial sectors in the economy affect each other (Nazara, 2005). There are two types of linkages, namely backward linkage and forward linkage. The calculation of forward linkage can be done in two ways, namely by using Leontief inverse matrix and Ghosian inverse matrix.

Forward (and backward linkages indexes using Leontif inverse matrix are calculated as follows:

$$\propto_j = \frac{(1/n)\sum_i b_{ij}}{(1/n^2)\sum_i \sum_j b_{ij}} \qquad \beta_i = \frac{(1/n)\sum_j b_{ij}}{(1/n^2)\sum_i \sum_j b_{ij}} \tag{8}$$

Forward linkage/supply multiplier using Ghosian inverse matrix is calculated as follows:

$$SuM_j^I = \sum_{j=1}^{n} \vec{b}_{ij} \tag{9}$$

<u>Multiplier Analysis</u>

Basically, multiplier analysis is used to describe what happens to the endogenous variables, namely sectors output, if there is a change in exogenous variables, such as final demand, in the economy (Nazara, 2005). The multipliers analyses are calculated as follows:

$$OM_j^I = \sum_{j=1}^{n} b_{ij} \quad IM_j^I = \frac{\sum_{j=1}^{n} b_{ij} I_j^T}{I_j^T} \quad EM_j^I = \sum_{j=1}^{n} \frac{l_j b_{ij}}{l_j} \tag{10}$$

$$VM_j^I = \frac{\sum_{j=1}^{n} v_j b_{ij}}{v_j} \qquad KM_j^I = \frac{\sum_{j=1}^{n} k_j b_{ij}}{k_j} \qquad SM_j^I = \frac{\frac{\sum_{j=1}^{n} v_j b_{ij}}{v_j}}{\sum_j^n k_j b_{ij}}$$

where:

b	:	Leontief inverse matrix (Type I);	$\vec{b}$	:	Ghosian inverse matrix
OM	:	Output multiplier;	IM	:	Income multiplier;
EM	:	Employment multiplier;	VM	:	Value added multiplier;
KM	:	Investment multiplier;	SM	:	Surplus multiplier;
l	:	Coefficient of salary;	v	:	Coefficient of value added;
k	:	Coefficient of capital			

Output impact analysis is used to compare the economic benefits of some condition or export control scenarios, namely: (a) all raw materials of mineral are exported, (b) raw materials partially are processed domestically and (c) all materials of mineral are processed domestically. The scenarios are based on the assumptions as follows: the production are twenty million metric tons of bauxite ores per year, selling price of bauxite ore is US$ 28/metric tons, selling price of smelter-grade alumina (SGA) is US$ 380/tons, and selling prices of chemical-grade alumina (CGA) are US$ 455/tons for CGA commodity and $ 971/tons for CGA specialty.

RESULT AND DISCUSSION

Table 1 shows the result of linkage analysis among sectors in the Indonesian economy the year 2035. The base-metal industry sector has the largest backward linkage index, while oil and gas mining sector has the smallest. The sectors with the yield of backward linkage above the average (> 1) will give enormous effect through investment on the economy. Moreover, service and unspecified services sector has largest forward linkage index, while alumina refinery has the smallest. The sectors with the yield of forward linkage above the average (> 1) will be more stimulated by the economy than other sectors. Alumina refinery's backward linkage index ranking is 7 and its forward linkage index ranking is 26. This small forward linkage index of alumina refinery sector can be explained by the lack of its downstream sector. The output of this sector is only used by two sectors, base-iron industry sector and other metal industry. In addition, linkage analysis using supply-side or also knows as supply/input multiplier shows alumina refinery sector ranking is 21. We can notice that this sector has important position in Indonesian economy. Based on the range of backward and forward linkage index's ranking, we can classify alumina refinery sector as intermediate primary production because of its large backward and small forward linkage indexes (Lixon, Thomassin, & Hamaide, 2008). Figure 3 shows the sectoral linkage pattern of alumina refinery sector.

Table 1 - Backward and forward linkage, and supply multiplier among sectors in the Indonesian economy in the year 2035

Nr.	Sectors	Backward Linkages	Rank	Forward Linkages	Rank	Supply Multiplier	Rank
1	Agriculture	0.8568	20	1.3528	5	2.0041	10
2	Coal Mining	0.8160	22	0.8504	16	1.6306	15
3	Oil & Gas Mining	0.6991	26	1.3866	3	2.0803	7
4	Tin ores	0.7644	24	0.7713	18	2.7145	1
5	Nickel ores	0.7294	25	0.6876	25	1.3248	24
6	Bauxite ores	0.9173	18	0.7195	22	2.5406	2
7	Copper ores	0.9236	17	0.7237	21	1.1872	25
8	Gold & Silver ores	0.8677	19	1.1423	8	2.5169	3
9	Iron ores	1.0319	13	0.7426	20	1.3501	23
10	Other Mining	0.8312	21	0.7189	23	2.1564	6
11	Food and Beverage Ind.	1.2399	2	1.0182	10	1.5511	19
12	Textile Industry	1.2189	3	0.9345	13	1.5058	20
13	Wood Industry	1.1703	6	1.0061	12	1.9533	11
14	Chemical Industry	1.0039	15	1.0846	9	2.0114	9
15	Oil & Gas Refinery	0.7918	23	1.3439	6	2.0177	8
16	Rubber Industry	1.1099	8	0.8594	15	1.7840	13
17	Base-iron Ind.	1.0808	10	0.7807	17	2.1857	5
18	Base-metal Ind.	1.2712	1	0.7110	24	1.5805	16
19	Alumina Refinery	1.1134	7	0.6647	26	1.4997	21
20	Other Metal Ind.	1.0892	9	0.7556	19	1.8807	12
21	Manufacturing	1.0359	11	1.1740	7	1.4759	22
22	Electricity, Gas & Water	1.2137	4	1.0116	11	2.2629	4
23	Construction	1.1711	5	0.8876	14	1.1036	26
24	Trade, Hotel & Restaurant	1.0358	12	1.5029	2	1.5738	18
25	Transportation & Com.	1.0253	14	1.3843	4	1.7268	14
26	Services & Unspecified S.	0.9914	16	1.7853	1	1.5776	17

Table 2 describes the output, employment and income multiplier among sectors in the Indonesian economy. The sector's rankings in output multiplier are the same with backward linkage indexes. Meanwhile, alumina refinery sector has the largest yield both in employment and income multipliers. Oil and gas refinery has the smallest employment multiplier, while oil and gas mining has the smallest income multiplier.

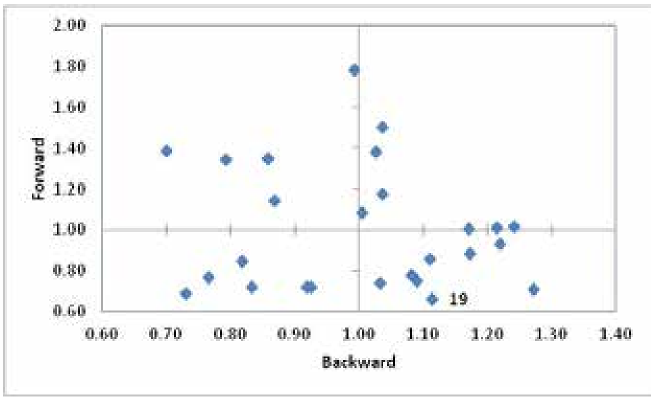

Figure 3 – Sectoral linkage pattern of alumina refinery sector (no. 19 is the alumina refinery sector)

Table 2 - Output multiplier, employment multiplier and income multiplier among sectors in the Indonesian economy in the year 2035

Nr.	Sectors	Output Multiplier	Rank	Employment Multiplier	Rank	Income Multiplier	Rank
1	Agriculture	1.3416	20	1.1218	25	1.2994	20
2	Coal Mining	1.2777	22	1.8450	17	1.2848	21
3	Oil & Gas Mining	1.0947	26	1.1740	24	1.1109	26
4	Tin ores	1.1969	24	1.4180	22	1.2057	22
5	Nickel ores	1.1421	25	1.2315	23	1.1234	25
6	Bauxite ores	1.4364	18	3.9107	4	1.8008	12
7	Copper ores	1.4463	17	3.7111	8	1.8555	10
8	Gold & Silver ores	1.3586	19	1.9557	16	1.4344	18
9	Iron ores	1.6157	13	2.5129	10	1.5354	17
10	Other Mining	1.3015	21	1.5990	19	1.1762	23
11	Food and Beverage Ind.	1.9415	2	10.7869	2	2.6780	3
12	Textile Industry	1.9087	3	2.8291	9	2.1011	7
13	Wood Industry	1.8324	6	3.9014	5	2.1125	6
14	Chemical Industry	1.5719	15	2.3916	13	1.7333	13
15	Oil & Gas Refinery	1.2398	23	1.0974	26	1.1464	24
16	Rubber Industry	1.7380	8	4.0492	3	2.0289	8
17	Base-iron Ind.	1.6924	10	3.7877	7	3.1336	2
18	Base-metal Ind.	1.9905	1	2.4086	12	2.6854	4
19	Alumina Refinery	1.7435	7	10.9506	1	3.8333	1
20	Other Metal Ind.	1.7056	9	2.0358	15	1.7001	14
21	Manufacturing	1.6221	11	2.3398	14	1.8267	11
22	Electricity, Gas & Water	1.9004	4	3.8683	6	2.2379	5
23	Construction	1.8338	5	2.4576	11	1.9843	9
24	Trade, Hotel & Restaurant	1.6220	12	1.5561	20	1.5836	16
25	Transportation & Com.	1.6055	14	1.5243	21	1.6763	15
26	Services & Unspecified S.	1.5523	16	1.6529	18	1.3407	19

Table 3 describes the value-added, investment and surplus multiplier among sectors in the Indonesian economy. The base-metal industry sector has the largest value added multiplier, while oil and gas mining sector has the smallest. Moreover, construction sector has the largest investment multiplier, while oil and gas mining sector has the smallest. Food and beverages sector has the largest surplus multiplier, while tin ores sector has the smallest. Alumina refinery sector's rankings are 10, 18, and 23 in value-added, investment and surplus multiplier.

Table 3 - Value-added multiplier, investment multiplier and surplus multiplier among sectors in the Indonesian economy in the year 2035

Nr.	Sectors	Value Added Multiplier	Rank	Investment Multiplier	Rank	Surplus Multiplier	Rank
1	Agriculture	1.2432	21	1.8205	11	38.3997	2
2	Coal Mining	1.1978	22	1.3958	19	18.0183	17
3	Oil & Gas Mining	1.0894	26	1.1050	26	31.1624	4
4	Tin ores	1.1626	24	1.1452	24	6.3115	26

5	Nickel ores	1.1111	25	1.1474	23	17.1560	19
6	Bauxite ores	1.3418	17	1.9902	8	20.3688	12
7	Copper ores	1.3292	19	1.5782	16	19.7399	14
8	Gold & Silver ores	1.3041	20	1.3844	20	18.4713	15
9	Iron ores	1.5507	15	1.9507	9	17.4320	18
10	Other Mining	1.1924	23	1.2198	22	12.3381	24
11	Food and Beverage Ind.	2.5923	3	2.3740	2	45.4056	1
12	Textile Industry	2.1125	8	2.2119	4	23.3423	10
13	Wood Industry	2.0713	9	2.1288	6	24.1911	9
14	Chemical Industry	2.2759	6	1.7245	12	29.6993	6
15	Oil & Gas Refinery	1.3393	18	1.1201	25	16.2356	21
16	Rubber Industry	2.2812	5	2.0042	7	28.7711	7
17	Base-iron Ind.	2.5242	4	2.1816	5	31.0147	5
18	Base-metal Ind.	3.6287	1	2.2193	3	33.6039	3
19	Alumina Refinery	1.9420	10	1.4187	18	13.1388	23
20	Other Metal Ind.	1.8930	11	1.9183	10	21.4863	11
21	Manufacturing	1.7995	12	1.7187	13	20.1820	13
22	Electricity, Gas & Water	2.6964	2	1.4845	17	13.3828	22
23	Construction	2.1865	7	2.4538	1	27.5311	8
24	Trade, Hotel & Restaurant	1.5558	14	1.6915	14	18.2859	16
25	Transportation & Com.	1.6697	13	1.2818	21	8.6620	25
26	Services & Unspecified S.	1.4658	16	1.5862	15	17.0281	20

Table 4 shows the result of output impact analysis based on three scenarios. Scenario 2 gives the largest total output, while scenario 1 gives the smallest. Meanwhile, scenario 3 gives almost two times higher than scenario 1 but less than half of scenario 2. This result confirmed the advantage of bauxite added-value development through alumina refinery sector.

Table 4: Output impact analysis of three scenarios (in million US$)

		Scenarios		
Nr.	Sectors	1	2	3
1	Agriculture	4.45	49.08	17.19
2	Coal Mining	0.36	196.61	60.13
3	Oil & Gas Mining	9.20	40.70	17.01
4	Tin ores	0.35	5.61	1.89
5	Nickel ores	0.01	0.07	0.02
6	Bauxite ores	541.88	229.38	340.88
7	Copper ores	0.08	1.05	0.36
8	Gold & Silver ores	0.19	1.00	0.40
9	Iron ores	0.00	0.03	0.01
10	Other Mining	0.75	34.31	10.83
11	Food and Beverage Ind.	3.46	12.79	5.63
12	Textile Industry	3.97	4.14	3.25
13	Wood Industry	10.60	17.73	10.71
14	Chemical Industry	9.15	150.79	50.55

15	Oil & Gas Refinery	34.46	45.47	31.09
16	Rubber Industry	2.95	17.24	6.73
17	Base-iron Ind.	0.68	4.25	1.64
18	Base-metal Ind.	0.33	1.72	0.69
19	Alumina Refinery	0.01	1,940.87	591.83
20	Other Metal Ind.	1.44	10.07	3.79
21	Manufacturing	26.15	77.97	36.85
22	Electricity, Gas & Water	3.81	18.10	7.42
23	Construction	11.85	105.92	38.22
24	Trade, Hotel & Restaurant	26.93	52.53	29.48
25	Transportation & Com.	53.96	174.14	80.08
26	Services & Unspecified S.	28.58	192.09	72.86
	Total Output	775.60	3,383.66	1,419.57

CONCLUSION

This paper has applied input-output analysis for examining the role of bauxite added value development in Indonesian economy. Bauxite added value development was performed by adding alumina refinery as a new classification sector. The alumina refinery sector's backward linkage's rank is high relative to other sectors especially bauxite ores sector. Meanwhile, its forward linkage's rank is very low relative to other sectors indicating the lack of downstream sector linkage. In addition, its supply multiplier analysis gave better result. Based on the composition of backward and forward linkage, this sector can be classified as intermediate primary production.

Multipliers of alumina refinery sector generally show higher average values than other sectors especially income and employment multiplier. These values indicate that this sector has the potential to create new output capable of driving the Indonesian economy. Output impact analysis show that the scenario 3 (all of bauxite ores are processed) gives the largest total output, while scenario 1 (all of bauxite ores are exported) gives the smallest. This result confirms the necessity of bauxite added value development.

The results from this paper give valuable information and could help in choosing the optimum option in utilizing mineral resources for the welfare of the people in Indonesia. To further our research, we intend to optimize the sectors in the input-output table to get the optimum GDP using linear programming. Moreover, we also plan to concentrate the analysis to one region using regional input-output modeling system (RIMS).

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THERMOPLASTIC POLYMER APPLICATION ON THE BEARINGS OF CONVEYOR BELTS AVOIDING CONTAMINATION OF THE BEARINGS AND AVOIDING PRODUCTION DOWNTIME

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ABSTRACT

In the mining industry, the effects of corrosion, contamination by mineral powder and humidity, have been for many years a factor that increases the OPEX in the segment of mining. Bearings of conveyor belts and of other equipment has history of exposure to contaminants, therefore reducing significantly the life of the bearings. Historical of mining industries reveal that the time bearing life exposed to contamination in many cases resist few days or weeks, reducing the availability of equipment and generating costs to each intervention. On application of the thermoplastic polymer, all surfaces of bearing and of shaft in the region near to the bearing is encapsulated, on the end of shaft a clamp is placed efficiently avoiding that the contaminant reaches the bearings. This coating does not adhere to the surface and thus the shaft rotates freely without damaging the package. This characteristic is due to the presence of polymer has a corrosion inhibitor oil which does not allow adhesion to the substrate. Since 2009, this coating has been applied and proved that exponentially increases the bearing life compared to previous records to utilization. In time of low mineral prices, it is an effective tool to reduce production costs.

KEYWORDS

Contamination of bearings, Bearing life, Thermoplastic polymer, Production downtime, Bearings protection

INTRODUCTION

The aim of this work is show how and why the utilization of thermoplastic polymers is an excellent option to protect bearings of conveyor belts and any other complex shaped equipment, metallic or not of any size, against contamination by mineral powder, humidity and corrosion that contaminates the equipment as well increasing the costs of maintenance and reducing the production. The work also shows a cost analysis and experiences of application in the mining industries of iron mine. Later application of thermoplastic polymer, the life of bearing is increasing for two years, while without the application the life stands for just some days or weeks.

ACTION PRINCIPLE

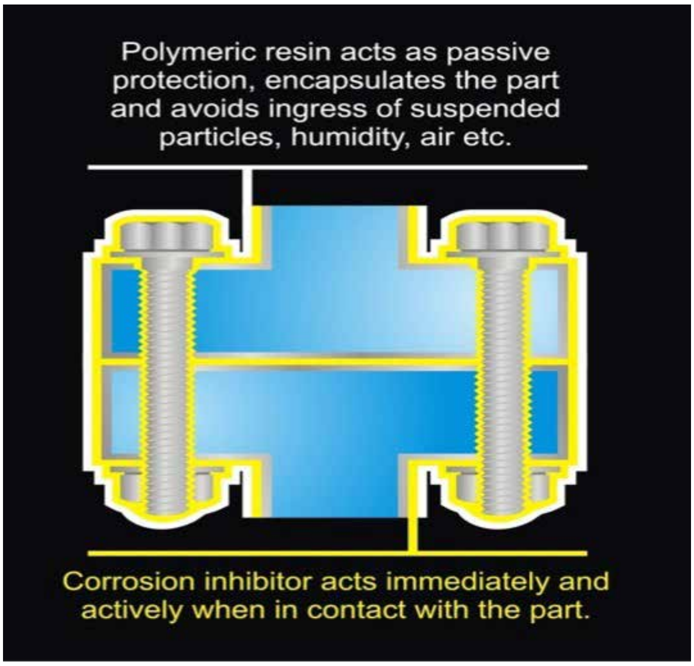

Figure 1: Illustration of action principle of thermoplastic polymer applied to an equipment.

EXAMPLES OF APPLICATIONS

1. Application on the bearings contaminated due to constant contact with the mineral powder

1.1. About the service:

Sealing the bearings with polymer resin at the pelletizing plant, before the application the bearings were contaminate with high level by mineral and contamination in the wax see Figure 2. During the work, just surface preparation with brush of steel for removing impurities like Figure 3 and better adherence of the product.

1.2. Pictures about work:

Figure 2: Contamination in the wax by mineral powder before application.

Figure 3: Later surface preparation and sealing, ready to apply the polymer.

Figure 4: Later application of thermoplastic polymer on the bearings.

Notice on the Figure 4, that the rotating movement of shaft does not damage the application of thermoplastic polymer, because the polymer does not adhere to the surface, this characteristic is due to the presence of polymer has a corrosion inhibitor oil which does not allow adhesion to the substrate, therefore the shaft can rotate freely.

2. Application of coating to protect roller bearings against penetration of particles and moisture

2.1. About the service:

The applications of thermoplastic polymer were make for testing in two roller bearings and a gearbox. The bearings and the gearbox are in an area subject to moisture penetration that reduces the estimated useful lives.

2.2. Bearings:

Contamination by dust in the crushing, before the service of application the bearing was found with high level of contamination, like Figure 5:

Figure 5: Bearing without protection with high level of contamination by dust and moisture.

2.3. Later washing, the bearing was placed on shaft of conveyor belt see Figure 6:

Figure 6: Bearing after washing and placed on shaft.

2.4. Later application of thermoplastic polymer, like Figure 7:

Figure 7: Later application of thermoplastic polymer on the different bearings.

COST ANALYSIS

A comparative study was making comparing different costs before application of thermoplastic polymer and later application. In historical of mining industry related is replace of bearing and also sleeves for few days like three days, one week or three months, this cost also includes discard of lubricants and labor of exchange. After application of thermoplastic polymer, the historical related by two years without replace the bearings. Therefore increasing the profit in the operations and decreasing the costs of maintenance, labor of exchange and the costs of lost production. Below is present a comparative table of costs.

Table 1: Maintenance cost of bearing.

Mine of production of iron ore					
Bearing type	Type of sleeve	Cost of bearing	Cost of sleeve	Average of exchange in the year	Total cost (without cost of lost production)
23144 CCK W33	H3144	R$ 3,590.24	R$ 1,431.97	4	R$ 51,115.47
23152 CCK W33	H3152	R$ 7,039.86	R$ 2,268.77	4	R$ 69,531.78

In times of low prices iron ore, the application of polymer demonstrated quite effective, protecting the bearings against contamination during two years, during this time the intervention in the bearing is not necessary leaving the equipment in full operation, below is demonstrated the average of cost application of thermoplastic polymer on the same bearings related above.

Table 2: Maintenance savings in two years after applying the thermoplastic polymer.

Cost application of thermoplastic polymer on the same bearings			
Bearing type	Cost of maintenance in two years	Cost application on the pair of bearing of thermoplastic polymer	Economy in two years with application of thermoplastic polymer
23144 CCK W33	R$ 102,230.94	R$ 12,166.00	R$ 90,064.94
23152 CCK W33	R$ 139,063.56	R$ 16,720.00	R$ 122,343.56

CONCLUSIONS

The applications with thermoplastic polymer to protect the bearings, demonstrated quite effectiveness against penetration of dust, moisture and other impurities. To prove the efficiency, before application of thermoplastic polymer, less than 6 months in operation the maintenance team opened the bearing and found lots of particles and contaminants on it, like Figure 8:

Figure 8: Bearing in regular operating conditions without protection with less than 6 months of use. Note how contaminated the grease becomes.

For the bearing protected by thermoplastic polymer the maintenance team waited approximately 1 year and opened the unit to find the internals clean and no dust ingress to be evident, see the Figure 9:

Figure 9: The grease inside the unit protected by thermoplastic polymer was clean and the bearing was in great operational condition.

The maintenance team was delighted with the outcome of applications that provided substantial costs savings to their annual operating budget. The thermoplastic polymer is now extensively applied throughout the facility. After application on shaft, the movement of rotating does not damage the polymer and the protection, because the product does not adhere to the surface. In the mine industries is related exchange of bearings sometimes in few days or weeks, later application with polymer the bearings can resist for two years operating under conditions extremely contaminant, reducing the costs with maintenance, time of lost production and cost with exchange. For many years, this coating has been applied and proved that exponentially increases the bearing life compared to previous records to utilization. In time of low mineral prices, it is an effective tool to reduce production costs.

TRENDS AND DETERMINANTS OF HARD COAL EXPORT AND IMPORT IN POLAND IN RETROSPECTIVE AND PROSPECTIVE VIEW

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TRENDS AND DETERMINANTS OF HARD COAL EXPORT AND IMPORT IN POLAND IN RETROSPECTIVE AND PROSPECTIVE VIEW

ABSTRACT

The main aim of the article is to present the trends and determinants of hard coal export and import in Poland based on historical data (retrospective view) and results of expert survey (prospective view). The historical analysis includes the dynamics and structure of import and export of hard coal in Poland in the years 2004-2013. The projections cover the years 2015-2030 and they have been developed according to the experts' opinions obtained from survey research conducted in 2014. They concern the volume of import and export forecast and their determinants, grouped in five categories: industrial, economic, technological, socio-demographical and political. At the end of the article the conclusions for Polish coal mining and Polish mining enterprises are stated. The methodology used in the article includes descriptive statistics and survey research.

KEYWORDS

hard coal import and export in Poland in the years 2004-2013, hard coal import and export projection in Poland

INTRODUCTION

For years Poland has been one of leading manufacturers of hard coal in the world. However, in the last eight years its role in the manufacturing and trade of this resource has been systematically decreasing. The main reason for this unfavorable trend is a visible decrease of the price competitiveness of the resource mined in the Upper-Silesian Coal Basin, due to a sudden drop of hard coal prices on the global market and the increase of the unit production cost in Polish mines. Concomitance of those unfavorable trends causes the decrease of export and increase of import in Polish coal industry. This, in turn, constitutes a threat to the existence and development of Polish mining enterprises.

Taking the aforementioned circumstances into account, the objective of this paper is to assess the current and predictable trends in the area of export and import of hard coal in Poland. The assessment in the ex post perspective is conducted based on the historical data covering the years 2004-2013. The assessment from the ex ante perspective was performed based on expert survey research conducted in the year 2014. The projection of import and export created in such a way extends up to the year 2030. Apart from the quantitative analysis, the key determinants of the net export balance in hard coal trade are presented in the paper.

HARD COAL IMPORT AND EXPORT IN POLAND IN THE YEARS 2004-2013

The total volume of export in the analyzed period is presented in table 1, from which it can be seen that in the period of ten years export of Polish hard coal decreased almost twice. The periodical increase of export took place only in the years 2010 and 2013 and in the former case it was the result of an after-crisis rise in the demand for electricity while in the latter case it occurred due to the intensification of actions for moving the domestic overproduction to the foreign markets, including the reduction of selling price and offering highest quality resource to foreign recipients.

Table 1 - Export of Polish hard coal in years 2004-2013 [thousand tons]

Export	Year									
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
volume	19 897	19 525	16 883	11 883	8 097	8 163	10 121	6 056	6 642	10 488

Source: own work based on data of Ministry of Economy in regards *Information on the functioning of hard coal mining industry.*

In the examined period Poland exported mainly coal used for energy purposes which also constitutes a dominant part of domestic production. The share of coking coal in the total export fluctuated between 14% and 26%. Coal mined in Polish mining enterprises was first sent mainly to the recipients from the European Union, in particular to: Germany, Austria, Czech Republic, Great Britain and Slovakia. The main recipients outside the European Union were: Norway, Turkey, Morocco and Egypt. However, export to those countries was of definitely lower significance than export to the EU countries and in the examined period equaled between 1% and 9%.

As it was already mentioned, along with the decrease of the mining production, domestic sales and export, a systematic increase of coal being imported to Poland can be observed. The volume of this import in the years 2004-2013 is presented in table 2.

Table 2 - Import of hard coal into Poland in years 2004-2013 [thousand tons]

Import	Year									
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
volume	2 400	3 363	5 218	5 772	10 101	10 201	14 150	14 991	10 193	10 841

Source: own work based on data of Ministry of Economy in regards *Information on the functioning of hard coal mining industry.*

According to the data presented in table 2, since the year 2004 import of hard coal has been systematically increasing. The highest growth in import occurred in the years 2008 and 2010-2011 (Olkuski, 2013). In the years 2012-2013 the volume of import stabilized on the level of approximately 10 million tons. However, despite the decrease of the volume of import of hard coal its level still remains high, taking into consideration the fact that in the same period Polish mining enterprises had problems with selling raw materials and were achieving record levels of inventory, higher than anything achieved in the history of their operations.

In the years 2004-2013 Poland imported both power coal as well as coking coal. Until the year 2009 the share of coking coal in the total import was systematically increasing, achieving in the years 2007 and 2009 the value of around 50%. After the year 2009 the structure of import clearly changes. The share of coking coal decreased, in the period 2010-2013 it amounted between 15% and 24%. It is the result of a rapid increase in import of power coal that was observed in that period.

Power coal imported to Poland mostly comes from Russia and it is delivered by rail. In the last decade the share of Russian hard coal in the total import exceeded 60%. A significant part of imported coal also comes from the Czech Republic, however it should be noted that mostly it is coking coal, even though in the last four years the volume of power coal from the Czech Republic increased too. Coal is also delivered to Poland by sea. This is mainly power coal imported from the USA. In the last three years the volume of coal import from that country has been systematically rising which mainly stems from the decrease of the prices of this resource as a result of the revolution in the area of shale gas mining in the USA as well as the lowering of transportation tariffs and increasing the handling capacity of Polish sea ports. It is forecasted that in the future the volume of import of American power coal may continue to rise due to the favorable relation of price to quality ratio and the progressing development of Polish sea ports. Additionally, hard coal is also delivered to Poland from: Ukraine, Kazakhstan, Columbia, Australia and China (Stala-Szlugaj & Klim, 2012).

The main source of competitiveness of Polish hard coal is the abundance and sufficiency of the resources. It is estimated that the operative resources of Polish hard coal mines guarantee that the deliveries of this resource will be provided in the perspective up to the year 2050. There is also a possibility of further exploration of deposits in the Upper-Silesian Coal Basin, making it possible to start new investments in the existing or emerging mines. Until now the utilization of hard coal as a key resource in power industry was the main source of competitiveness for Polish hard coal mining industry.

The share of hard coal in the energy balance of Poland is decreasing in time in favor of the increase of using natural gas (Janusz, 2010; Kalisk, Szurlej & Grudziński, 2012) and renewable energy sources, particularly energy from biomass, wind and water. Nevertheless, the aforementioned changes occur quite slowly and require additional investments or modernization in the infrastructure of Polish power industry, which, up to this point has been functioning based on technological solutions adapted to the use of hard coal (Jonek-Kowalska, 2011). Because of this the utilization of hard coal in the power industry could remain one of the basic sources of competitiveness for Polish hard coal mining industry. However, the intensified flow of imported coal observed in the years 2010-2013 and the increase of inventory along with the problems with sales faced by Polish mining enterprises, allow stating that more and more often professional power industry in Poland purchases imported hard coal instead of the domestic resource. The main cause for such a state of things is a lack of price competitiveness of Polish coal (Lorenz, 2010) as well as the systematic decrease of the quality competitiveness.

In Polish hard coal mining industry for years the increase of the unit production cost has been observed (Turek, 2013a; Turek, 2013b; Kustra & Sierpińska, 2013; Kustra 2013), stemming from the progressive concentration of excavation, decreasing its volume and deterioration of geological and mining conditions, accompanying the deepening of the excavation as well as the constant pressure from trade unions focused on the increase of salaries, which is not reflected in the increase of mining efficiency and effectiveness.

An uncontrolled increase of production costs in the conditions of highly variable, and therefore highly unpredictable, market prices causes Polish coal to be more expensive than the coal imported from Russia and/or the United States. The decreasing price of hard coal is also worth noting, which, together with the increasing mining costs, only deepens the loss of competitiveness of Polish resource (Michalak, 2014; Nawrocki & Jonek-Kowalska, 2016).

For this reason, the professional power industry chooses cheaper imported coal with similar or even better quality parameters. In the year 2013 the average calorific value of imported power coal equaled 23 777 kJ/kg and the calorific value of domestic coal equaled only 22 165 kJ/kg. The level of sulfur for imported coal amounted 0.52% while of domestic coal 0.83%. The ash content of imported coal equaled 11.9% and of Polish coal – 18.3%. In the conditions of increasing emission restrictions the coal quality parameters become more and more significant, which is why Polish hard coal is losing the quality advantage too (Turek, 2011).

Based on the presented arguments it may be stated that without the improvement of the price (Turek & Jonek-Kowalska 2012) and quality competitiveness Polish hard coal will not be competitive in comparison to imported coal. In such conditions, with the existing free handling capacities of Polish ports, one can expect the increase of hard coal import to Poland by sea (Olkuski, 2010).

THE PROJECTION OF COAL EXPORT AND IMPORT UP TO THE YEAR 2030 – RESULTS OF EXPERT SURVEY

In the aforementioned survey the experts' task was to formulate the prediction concerning the share of coal export in total Polish hard coal mining production and to indicate the potential directions of coal import to the countries of the European Union and others. In table 3 and 4 the distribution of experts' answers is presented respectively to the question about the share of power and coking coal export in total production in a perspective up to the year 2030.

Table 3 - Distribution of experts' answers to the question about the share of power coal export in total production in a perspective up to the year 2030 [%]

Answer variant	Year			
	2015	2020	2025	2030
less than 6%	7%	10%	17%	34%
from 6% to 10%	41%	55%	52%	34%
from 11% to 15%	34%	14%	7%	7%
from 16% to 20%	3%	10%	14%	14%
more than 20%	14%	10%	10%	10%

Source: own work based on the results of survey research.

Table 4 - Distribution of experts' answers to the question about the share of coking coal export in total production in a perspective up to the year 2030 [%]

Answer variant	Year			
	2015	2020	2025	2030
less than 6%	3%	7%	7%	7%
from 6% to 10%	3%	10%	10%	14%
from 11% to 15%	45%	41%	45%	41%
from 16% to 20%	38%	24%	17%	17%
more than 20%	10%	17%	21%	21%

Source: own work based on the results of survey research.

Accordingly, the largest group of experts who took part in the survey predicts that the share of power hard coal export in total production up to the year 2030 amounts from 6% to 10%. In case of coking coal the respondents assume a higher level of export share in total production – from 11% to 15%. In both cases the export share predicted by the experts in total production is lower than the average from the past ten years, which for power coal equaled 12.5% and for coking coal 16.1%.

Based on the survey predictions the projections of power and coking coal export were developed in a perspective up to the year 2030, presented in table 5. Two variants were used when developing the forecast:
1. variant 1 – 10% share for power coal, 15% share for coking coal,
2. variant 2 – weighted average of experts indications.

Table 5 - Projections of power and coking coal export up to the year 2030 [in thousand tons]

Specification	Year			
	2015	2020	2025	2030
Power coal – variant 1	5 868	5 771	5 570	5 260
Power coal – variant 2	6 465	5 861	5 503	4 788
Coking coal – variant 1	1 815	1 766	1 822	1 864
Coking coal – variant 2	1 815	1 766	1 822	1 864

Source: own work.

The projections made for the particular variants are very similar due to a low range of weighted average and to variant 1 being defined as upper bound of the range indicated by the respondents, both for power and coking coal (table 6 and 7). In case of power coal the experts forecast a permanent decreasing trend, compliant with the trends currently observed, but less rapid than in the years 2005-2030. In result, power coal export in 2030 goes down by over 66% in variant 1 and almost 70% in variant 2 in comparison with the year 2005. In relation with the year 2014 it is a reduction of over 10% and almost 26% respectively.

In case of coking coal the experts estimate a slight export increase in comparison with the year 2014, amounting to about 2.7% in both variants, however, in relation with the year 2005, export is reduced by over 26%.

Table 6 **-** Real and projected share of power coal export in total production up to the year 2030 [%]

Variant	Year					
	2005	2010	2015P	2020P	2025P	2030P
variant 1 – share of 10%	19.00%	14.00%	10.00%	10.00%	10.00%	10.00%
variant 2 – weighted average	19.00%	14.00%	11.02%	10.16%	9.88%	9.10%

Source: own work. P – projection.

Table 7 - Real and projected share of coking coal export in total production up to the year 2030 [%]

Variant	Year					
	2005	2010	2015P	2020P	2025P	2030P
variant 1 - 15%	18.00%	15.00%	15.00%	15.00%	15.00%	15.00%
variant 2 - weighted average	18.00%	15.00%	15.05%	14.07%	13.91%	13.74%

Source: own work. P – projection.

According to the experts the largest hard coal recipient in the European Union in 2015 are Germany (21% of experts thinks so), Czech Republic (17%), Austria (11%) and Great Britain (10%). These counties also remain the main recipients of Polish coal in the year 2030.

Beside the countries of European Union, Poland is supposed to send hard coal to Bosnia and Hercegovina (opinion of 14% of experts), Norway (10%), Turkey (7%), Morocco (7%), Egypt (7%) and Ukraine (7%). Therefore, it may be stated that the respondents, despite a decreasing amount of export, assume that the main trends of foreign sales markets are going to continue for the Polish resource.

As it was mentioned before, in the years 2008-2013 import of hard coal increased in Poland, what intensified the problem with sales in Polish mining enterprises. Imported coal is cheaper than the Polish resource and the rising unit production cost in Polish hard coal mines does not conduce the improvement of price competitiveness. The results of expert projections are presented below in terms of changes in import volume in a perspective up to 2030 along with a determination of coal inflow directions to Poland. And so, in table 8 the answers structure is included to the question concerning the direction of hard coal import changes in the next five years of the projection [Concordance coefficient W=0.22 with significance level p=0.144, value of verifying statistics χ^2=54.1 and critical value $\chi_{0.05;30}^2$ equals 7.815].

Table 8 - The answers structure to the question concerning the direction of hard coal import changes in a perspective up to the year 2030 [%]

Direction of changes	Year			
	2015	2020	2025	2030
Increase	36%	54%	54%	50%
Decrease	28%	28%	28%	28%
No changes	36%	18%	18%	22%

Source: own work based on the results of survey research.

According to the data included in table 8, a great share of experts predict the increase of coal import to Poland. In the period of 2020-2030 most of them indicate such direction of changes. On the basis of experts' forecast the projection of hard coal import to Poland was developed, what is presented in table 9. Taking the fact into account that the respondents provided the volume of changes predicted on their own, one variant of projection was made, including only the weighted average of experts' answers.

Table 9 - The projection of hard coal import to Poland up to the year 2030 [in thousand tons]

Specification	Year			
	2015	2020	2025	2030
Total hard coal	14 192	14 248	14 626	15 080

Source: own work.

According to data presented in table 9, import in the years of projection increases relatively slowly, however, in 2030 it is higher by almost three and a half than in the year 2005. It means that the experts do not perceive a reverse of unfavorable balance of foreign trade for Poland, in which hard coal import exceeds export, moreover, they assume that this balance is going to increase in time.

In the experts' opinion, the main suppliers of hard coal to Poland in future are going to be our neighboring countries, that is Russia, Ukraine and Czech Republic. Coal is also going to come from Australia and USA. Kazakhstan and Colombia appear among the potential suppliers too, however, with a much lower number of indications.

Consequently, the experts surveyed assume that the inflow directions of coal imported to Poland are not going to change in relation with the trends currently observed. In this time only the volume of import changes from the particular countries in connection with the level increase of total import in a perspective up to the year 2030, predicted by the respondents.

Beside the forecast concerning the volume of coal import and export, the experts interviewed were also asked to indicate the conditions affecting the hard coal balance (export-import) in Poland. The conditions encompassed five groups of factors:

1. **industry factors:** hard coal production cost in Polish mines, hard coal prices on the European market, hard coal prices on the global market, natural gas prices, crude oil prices, clean coal technologies in Poland, coal-based power industry in Poland, nuclear power industry in Poland, shale gas extraction in Poland, hard coal supply in Europe, hard coal demand in Europe, renewable energy sources in Europe covering the demand for energy, frequency and intensity of supply shocks on hard coal market (e.g. floods in Australia),
2. **economic factors:** economic growth measured by GDP (Gross Domestic Product), inflation, interest rate on investment loans,
3. **technological factors:** innovativeness of the economy, infrastructure of transport by sea, infrastructure of transport by rail,
4. **socio-demographic factors:** workforce availability, level of highly qualified managers, society's affluence,
5. **political factors:** legal regulations of the European Union concerning environment protection (CO_2 emission restrictions), energy security policy of the country promoting hard coal, promotion of renewable energy sources, supply of Russian gas to Europe.

Accordingly, among industry factors the experts considered coal unit production cost in Polish mines to be very important and having a negative impact on the balance (export-import). A similar effect, according to the respondents, on changes in this balance possess the prices of natural gas, as a direct competitor of hard coal, second energy carrier in terms of the share in power balance in Poland. The condition of clean coal technologies development is also unfavorable for the balance of foreign trade in Polish hard coal mining. The condition may be considered as not advanced enough in comparison with global research and implementations. In Poland many solutions from this area is in the experimental phase (e.g. underground hard coal gasification), what hinders the adjustment of the process of electricity production to the increasing requirements of the European Union regarding clean production and low emission of carbon dioxide to the atmosphere.

Industry factors that have a positive and negative influence on the hard coal balance (export-import) in Polish economy are thought by the experts to be hard coal prices on the global and European market, searching for the improvement of competitiveness of Polish hard coal mines in prices growth. In the current situation it may be the only chance for the quick improvement of production profitability. According to the experts, the situation of Polish mining industry could also be made better by the demand increase for hard coal in Europe. Nevertheless, the possibility of the occurrence of such increase is estimated as low and very low by the respondents. The experts also notice an increasing role of extraordinary occurrences in shaping the demand for coal, indicating the frequency and intensification of supply shocks on hard coal market as an important determinant of the balance (export-import), what takes place on the global markets and conduces at the same time export growth of the Polish resource.

Less important industry factors of hard coal balance (export-import) the experts consider to be crude oil prices as it does not play a major role in the Polish power balance. The respondents do not regard nuclear energy as a significant determinant of this balance either, its development is described as highly unlikely. Furthermore, in their opinion, hard coal balance (export-import) in Poland is not much affected by a gradual development of renewable energy sources in Europe.

Among economic conditions the experts surveyed rarely define the factors listed in the questionnaire as the determinants of very high or high influence on hard coal balance (export-import) in Poland. They do not agree on the predicted directions of changes of these factors, neither on the probability of their occurrence. The most important determinant of the balance of foreign trade in hard coal mining they thought to be the economic growth. The return on investment loans is indicated as a neutral factor by most experts and inflation as a determinant of an average significance for the examined balance.

General factors of technological character, similarly to economic factors, according to the respondents, have a lower impact on hard coal balance (export-import) in Poland than industry factors. The experts, in this group of determinants, most often estimated the power of impact of the particular factors on the balance of trade as low or average. Neither did they reach an agreement on the predicted directions of changes of these factors nor on the probability of their occurrence. An important technological factor is innovativeness of the economy and rail transport infrastructure. Sea transport infrastructure is also described as neutral for hard coal balance (export-import) in Poland.

Among the factors of socio-demographic character, the greatest significance for the interviewed experts has qualified managerial staff, and they indicate that it has a positive and vital influence on hard coal balance (export-import) in Poland. In the respondents' opinion, a considerable determinant of this balance is society's affluence. Availability of workforce in the current market conditions does not have a large influence on the analyzed subtraction. The distribution of experts' answers confirms the previously indicated role of managers in the process of the development and functioning of Polish hard coal mining.

In the last group of factors that encompasses political factors, for the experts surveyed the most important are EU restrictions concerning carbon dioxide emission that have a negative impact on hard coal balance (export-import) in Poland. It is worth emphasizing that most respondents expect the emission restrictions to be more severe and determine the probability of occurrence of these unfavorable conditions as very high and high. The experts confirm a significant role of energy security policy of the country that promotes hard coal in shaping the balance of foreign trade in Polish hard coal mining. Most of the respondents think that this factor has a positive influence on hard coal balance (export-import) but it is not an influence defined by the experts as strong or very strong. Two other political determinants in a form of promoting the renewable energy sources and supply of Russian gas to Europe – in the experts' view – do not affect the examined balance.

CONCLUSIONS

To sum up the experts' predictions concerning hard coal export and import in Poland in a perspective up to the year 2030, it should be stated that the experts surveyed foresee the continuation of the market tendencies currently observed in this area. They assume further increase of hard coal import to Poland and systematic decrease of export abroad. When they indicate the volume of the changes predicted they are rather cautious and usually choose low, not exceeding 10%, values of changes in the period of next five years in the projection in order to take the necessity of radical infrastructural and technical changes into account, which would be necessary in case of a greater scale of changes predicted on hard coal market and in power industry. The experts also agree on the direction of potential export, mainly indicating the previous recipients of Polish coal such as Germany, Czech Republic, Great Britain, Austria and Slovakia. A growing import of hard coal – in the respondents' opinion – is also going to come from the directions known, that is Russia, Czech Republic, Australia and USA.

Among the factors that affect hard coal balance (export-import) the strongest, the respondents most often indicate industry factors, mainly including hard coal unit production cost in Polish mines as well as coal and natural gas prices on global markets. Furthermore, great significance for the balance of foreign trade also have increasing restrictions concerning hard coal emission and insufficiently intensive development of clean coal technologies in Poland.

The experts predictions regarding changes in export and import are correspondent with the forecasts for the structure of Polish energy balance and hard coal production in Poland up to the year 2030. The respondents assume that the leading role of hard coal in Polish energy balance is going to maintain and at the same time the production is going to decrease in Polish hard coal mines. It requires supplying power industry with imported coal and makes it impossible to increase export to the values mentioned earlier. The experts also predict the rise in using energy coming from gas and renewable energy sources, including biomass above all.

The projections described are not in favor for Polish mining enterprises as production fall and continuation of coal inflow from import mean, in practice, that there is a necessity to close down some of the Polish hard coal mines if their production does not find recipients on the domestic market and foreign markets. Such predictions are not favorable for the maintenance of energy security in Poland because they assume that the power industry is going to be supplied by foreign distributors of hard coal. The main reason for such state of things – according to the respondents – is a lack of price advantage of Polish mining enterprises, fall of hard coal prices on the European market and insufficient development of clean coal technologies.

In the light of the above it may be stated that without a visible and quick improvement of price competitiveness of Polish mining enterprises their further development will be seriously threatened. Furthermore, the currently observed coal sales below the production cost on the Polish market is a short-term solution, leading to the extension of financial crisis to the whole industry. In result, such crisis may become a reason for the annihilation of the whole hard coal mining industry in Poland. It should also be added that a new and very serious threat for Polish mining enterprises is the EU limitation of state support for hard coal mining industry, aimed at full free-market operation of the industry and making it competitive or leading to its liquidation. In the current market conditions facing the rising market requirements will be a difficult challenge to handle for Polish mining industry.

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VOLATILITY AND RISK ANALYSIS OF LOW AND HIGH-GRADE IRON ORE SPOT PRICE SERIES

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VOLATILITY AND RISK ANALYSIS OF LOW AND HIGH-GRADE IRON ORE SPOT PRICE SERIES

ABSTRACT

This work is devoted to the modeling of volatility in different iron ore spot price series and to the comparison of market risk between low and high-grade iron ore products. The study is based on three price benchmark assessments for iron ore spot prices: Platts's Iron Ore Fines 58% Fe CFR China (IODEX 58), Iron Ore Fines 62% Fe CFR China (IODEX 62), and Iron Ore Fines 65% Fe CFR China (IODEX 65). The conditional volatilities of the three benchmark price assessments are estimated using different orders of Autoregressive Moving Average (ARMA) models combined with different orders of Generalized Autoregressive Conditional Heteroskedasticity (GARCH) processes, namely ARMA–GARCH models. In the volatility-modeling step the hypotheses of normal and Student's t distributions for innovations are tested. Once the best-fit model is chosen using Akaike's and Bayesian information criteria, the conditional variance and daily returns are simulated for a window of one month and used to compute risk measures such as Value-at-Risk (VaR) and Conditional-Value-at-Risk (CVaR). Considering a monthly pricing mechanism, we compare expected returns and risk measures for the three price series and conclude that a preference for certain grades of iron may be justified during a given period of time.

KEYWORDS

ARCH, GARCH, ARMA-GARCH, VaR, CVaR, Iron ore price volatility

INTRODUCTION

Before the mid-2000s, the seaborne iron ore market was characterized by a low volatility, given that contracts were made in an annual basis and prices were pre-agreed between big sellers and big steel producers. However, since the abrupt growth of steel production in China during the 2000s, the seaborne iron ore demand increased sharply. As a result, annual contracts faced a decline as sellers found better prices in the spot market. With the growth of the spot market, high volatility of spot prices has been observed and widely reported by the press, specially following the global financial crisis of 2008 (Ma, 2013). We can also mention the fall of iron ore prices observed since 2014 due to the growing uncertainty regarding Chinese economic numbers and the excess of iron ore supply in the seaborne market.

With the advent of the iron ore spot market and the increase in volatility, market participants must now deal with the increased risk. Our goal with this paper is to study the volatility and risk of the iron ore spot market. Here we estimate and compare the conditional variance, Value-at-Risk (VaR), Conditional Value-at-Risk (CVaR) and the expected monthly average returns of the three price assessments for the iron ore products 58% Fe, 62% Fe and 65% Fe. Then we discuss which price series has lower levels of volatility and risk, and the interplay between risk and return for the price series.

The expansion of iron ore spot market

Iron ore is a raw material mainly used for the production of steel. Iron ore products differ in chemical quality, most importantly in the grades of iron (Fe), silica (SiO_2), alumina (Al_2O_3), phosphorus (P), sulfur (S) and moisture (H_2O). Iron ore products also differ in particles size. Both chemical and physical compositions are taken into account in the IODEX standard specification.

Until 2009, the price of reference for iron ore was the price negotiated directly between big mining companies and big steel producers. This practice, known as the Year Global Benchmark (YGB), required long-term negotiation (up to six months) and prices would be held for the whole year (Liu, 2011). According to Wårell (2014), the YGB pricing system was a way to avoid the volatility of the iron ore prices and to keep the stability of the market.

However, since the 2000s the demand for iron ore products started to grow sharply, driven by the increase in industrialization and urbanization processes in China and other developing countries. As a consequence, new iron ore companies were created in different countries and the big miners installed new production capacity. In this context, new producers of iron ore emerged in China and, even with lower quality products and high costs of production, were able to sell at prices above the YGB, thus resulting in the emergence of the iron ore spot market (Franco, 2008).

In 2010, major iron ore mining companies Vale, Rio Tinto and BHP Billiton (Big Three) abandoned the YGB and adopted pricing systems based on IODEX. Primarily, in this system the price was determined by the three-month average spot prices IODEX (quarterly pricing mechanism). Since then, sellers adopt a mix of quarterly, monthly (one-month average spot prices) and spot (price set on the time of the transaction) price mechanisms, the majority of them based on IODEX. This change in the pricing mechanism is what motivates ours study of the new volatility and risk involved in this market.

IODEX, which is a price index assessed by Platts, a division of McGraw Hill Financial, gives daily price information about seaborne iron ore transactions in the spot market (Platts, 2015). The transactions are normalized considering quality of the product, time and port delivery, and then are published as iron ore indices, in a dry metric ton base (dmt). IODEX 62 was first published in Singapore in late 2008, and was globally recognized as the primary index of the iron ore spot price in 2010. In this work we use the indices Iron Ore Fines 62% Fe CFR China (IODEX 62); Iron Ore Fines 58% Fe CFR China (here called IODEX 58); Iron Ore Fines 65% Fe CFR China (here called IODEX 65).

LITERATURE REVIEW

The daily volatility is not directly observable because there is only one observation in a trading day, so we use econometric models to model the volatility. The most widely used models are the Autoregressive Conditional Heteroskedasticity models (ARCH), proposed by Engle (1982) and the Generalized ARCH (GARCH), proposed by Bollerslev (1986).

Volatility and risk in metals and oil markets have been widely studied. There are works modeling price volatility using models of the GARCH family for copper (Smith & Bracker, 2003), gold (Tully & Lucey, 2007), silver (Lee & Lin, 2011), and a lot more works on other metallic commodities. There are also several examples using the GARCH family in the oil market such as Agnolucci (2009) and Narayan and Narayan (2007). ARCH models and variations are also commonly used in the computation of VaR and CVaR risk measures (Wang, Chen, Jin & Zhou, 2010; Aloui & Mabrouk, 2010; Angelidis, Benos & Degiannakis, 2004).

In the iron ore market, volatility and risk analysis are relatively new subjects. Ma (2013) compared the volatility of IODEX 62 before and after the change on the pricing mechanism, for the spot pricing mechanism to the quarterly mechanism, to replace the role of annual pricing. For the two subsample periods considered (October 8, 2008-March 9, 2010 for spot mechanism, and March 10, 2010-September 21, 2012 for the quarterly mechanism), the results have shown that the quarterly pricing mechanism seems to alleviate the volatility of the spot price. Additionally, the author concluded that only negative shocks have a gradual effect on the volatility of iron ore prices after the adoption of the quarterly pricing mechanism.

THEORETICAL FOUNDATIONS

ARCH and GARCH models

Econometric models such as autoregressive moving average model (ARMA) or autoregressive integrated moving average model (ARIMA) are effective in modeling and forecasting the conditional mean of a series, assuming that the residues are white and that the noise variance is constant. However, this can be a very restrictive hypothesis for commodities prices, since they tend to alternate between periods of high and low volatility. On the other hand, heteroskedastic models allow the noise variance to be time-varying.

In financial series, periods of high and low volatility are not randomly distributed, existing some dependence between them. ARCH and GARCH models deal with processes of this type. Engle (1982) introduced the ARCH models in order to estimate the variance of the United Kingdom inflation. The heteroskedasticity implies that the variance is not stationary. The basic idea of an ARCH model is that the components of a time series are not correlated, but dependent, and this dependence can be expressed as a quadratic function of the past innovations. For a log-return time series r_t the model ARCH(q) can be described as:

$$r_t = \bar{r} + h_t z_t \tag{1}$$

$$z_t \sim P(0,1) \; or \; P_v(0,1,v) \tag{2}$$

$$h_t^2 = \alpha_0 + \sum_{j=1}^{q} \alpha_j z_{t-j}^2. \tag{3}$$

In the equations above, $\bar{r}$ is a constant term, h_t is the conditional standard deviation, z_t is a sequence of independent and identically distributed random variables (i.i.d.) with a parametric distribution such as P *or* P_v (respectively normal or Student's t with degrees of freedom v) of mean zero and unit variance. To ensure $h_t^2 > 0$, the parameters must satisfy $\alpha_0 > 0$ and $\alpha_j \geq 0$. The model is of order $q > 0$. The sum of α_j , $j>0$, must be less than 1 to ensure bounded variance.

Bollerslev (1986) introduced the GARCH model, which adds an ARMA model for the error variance i.e., the variance depends not only of the past innovations, but also of the past variance. Equation (4) gives the GARCH(p,q) model with r_t and z_t defined as ain Equation (1) and (2):

$$h_t^2 = \alpha_0 + \sum_{j=1}^{q} \alpha_j z_{t-j}^2 + \sum_{i=1}^{p} \delta_i \, h_{t-i}^2 \tag{4}$$

In order to have always $h_t^2 > 0$, the parameters must satisfy $\alpha_0 > 0$, $\alpha_j \geq 0$ and $\delta_i \geq 0$. The model is of order $q > 0$ and $p \geq 0$. To ensure bounded variance, the coefficients must satisfy Equation (5):

$$\sum_{j=1}^{q} \alpha_j + \sum_{i=1}^{p} \delta_i < 1. \tag{5}$$

To use models of the ARCH family, the return series must not be autocorrelated. Therefore, if the series is autocorrelated, it is necessary to apply linear models as ARMA(r,m) or ARIMA(r,m,i) on returns in order to void the autocorrelation and then work with the residual series as an ARCH family model. These are namely the ARMA-GARCH models. When is considered the Student's t distribution for the innovations, the models can be called ARCH-t and GARCH-t.

VaR and CVaR Risk Measures

One of the main objectives of risk management is to evaluate and improve the performance of financial organizations in light of the risks taken in their activity. Artzner, Delbaen, Eber and Heath (1999) defined four properties that a risk measure must have to be a coherent risk measure: translation invariance, subadditivity, positive homogeneity and monotonicity.

VaR is one of the most adopted risk measures in the market, even though it is not a coherent measure of risk. The VaR_β describes the highest economic loss that can occur in a horizon of time t previously established, with a level of confidence β. As in Pflug (2000), let Y be the losses and let F_Y be its distribution function, i.e. $F_Y(u) = P\ \{Y \leq u\}$. For a fixed level β, we define the VaR_β as the β-quantile, as in Equation (6):

$$\text{VaR}_\beta(Y) = F_Y^{-1}(\beta) = \min\{u: F_Y(u) \geq \beta\}. \tag{6}$$

Benefits of using VaR include that it is more meaningful than standard deviation, focusing on losses and not being affected by the opportunity of high profits. However, there are two drawbacks in using VaR that relate to its lack of subadditivity and convexity (Artzner et al., 1999). First, the VaR of a portfolio can be higher than the sum of the VaR of its individual components. Second, the problem of minimizing the VaR of a portfolio may have multiple local minimizers.

An alternative to VaR is the CVaR, also known as Mean Excess Loss or Expected Shortfall. In simple words, CVaR_β is the conditional expectation of the loss above VaR_β for the time horizon t and level of confidence β (Uryasev & Rockafeller, 1999). CVaR_β is computed as in Equation (7):

$$\text{CVaR}_\beta(Y) = E\big(Y \mid Y > VaR_\beta(Y)\big). \tag{7}$$

The CVaR_β may be computed as the solution of the convex optimization problem (Pflug, 2000), as in Equation (8):

$$\text{CVaR}_\beta(\text{Y}) = \inf_\tau \left(\tau + \frac{1}{1-\beta} E[\max(Y - \tau, 0)]\right). \tag{8}$$

CVaR overcomes the two drawbacks of VaR, and, additionally, complements information of VaR_β informing the loss that occurs with frequency $1 - \beta$, that is higher than the loss in VaR_β. Therefore, it is possible to say that CVaR_β takes into account the whole of the losses' distribution tail, something that VaR does not do.

EXPERIMENTAL METHODS AND RESULTS

Samples

The samples are the IODEX 58, IODEX 62 and IODEX 65 for the interval of October 27, 2009 (being October the month of introduction of the last released IODEX 58) until December 11, 2015, totalizing 1,535 samples for each IODEX. Figure 1 shows the three IODEX plotted.

Log-returns have superior statistical properties than price series (Christoffersen, 2011). In order to obtain a stationary series, we computed the log-returns for each IODEX as in Equation (9), where the log-return $r_{P,t}$ at time t is expressed as a function of the price series P:

$$r_{P,t} = \ln\big(P_{P,t}\big) - \ln\big(P_{P,t-1}\big). \tag{9}$$

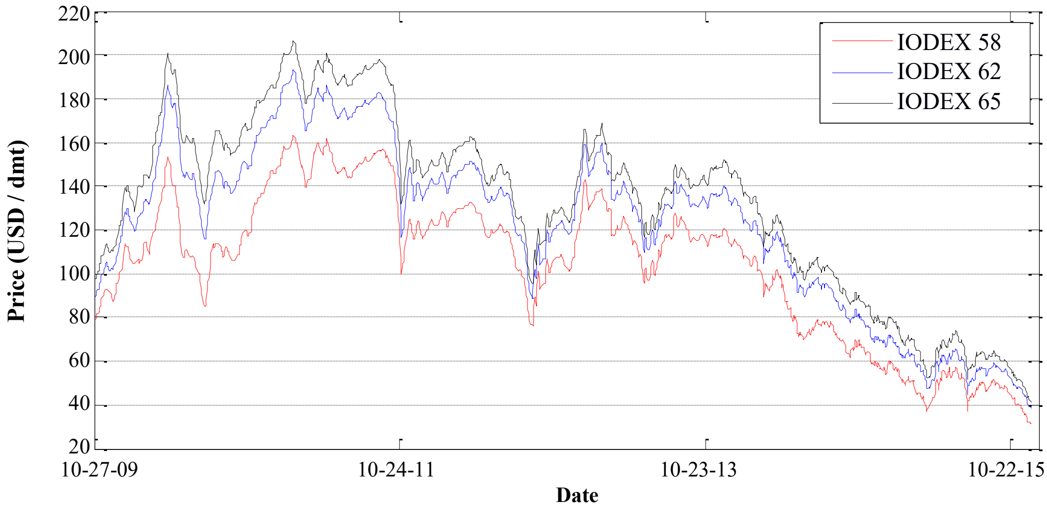

Figure 1 – Platts IODEX 58, 62 and 65 from October 27, 2009 until December 11, 2015

Table 1 shows some statistics for the prices series and returns r_P. High values of kurtosis and Jarque-Bera for the return series show that they are leptokurtic, that is, they are more peaked and have fatter tails than for the normal distribution. Based on the high absolute values of the Augmented Dickey-Fuller test (ADF test) for the return series, we can trust the stationarity of the return series, not seen for the IODEX series. We also tested the autocorrelation in the return series using the Ljung-Box Q-test. We found that the three return series are autocorrelated considering 95% confidence (null p-values).

Table 1 – Descriptive statistics for IODEX P and return series r_P

	IODEX 58	r_{58}	IODEX 62	r_{62}	IODEX 65	r_{65}
Mean (US$/dmt)	104.01	-0.0006	122.3826	-0.0005	132.5641	-0.0006
Median (US$/dmt)	110.25	0.0000	131.2500	0.0000	140.7500	0.0000
Standard Deviation (US$/dmt)	33.4827	0.0165	38.7576	0.0141	41.4341	0.0134
Skewness	-0.3933	0.1851	-0.3813	-0.0627	-0.3511	0.0385
Kurtosis	2.2	9.7	2.3	10.4	2.2	9.6
Jarque-Bera	79.4	2,889.4	72.6	3,485.4	67.8	2,790.3
Augmented Dickey-Fuller	-0.7	-28.3	-0.655	-27.5	-0.685	-27.3
Ljung-Box Q-test (lag 1)	-	151.3	-	176.0	-	182.3
Ljung-Box Q-test (lag 5)	-	198.0	-	258.4	-	198.0

Engle (1982) proposed the ARCH Lagrange Multipliers test (ARCH-LM), which verifies the presence of heteroskedasticity in the series. For the null hypothesis of no ARCH effects in the series, we found null p-values for the three IODEX series and for the three return series lagged by one day (1 sample), seven days (5 samples) and one month (22 samples). In words, the series have strong ARCH effects for any of the lag periods tested.

Modeling the conditional volatility

As in Tsay (2005), low-order GARCH models, say, GARCH(1,1), GARCH(2,1), and GARCH(1,2), are used in most applications. We fitted an ARMA model for the log-return series for each IODEX in order to eliminate the autocorrelation of the series, and then fitted GARCH models for the innovations. We fitted combinations of ARMA(r,m)-GARCH(p,q) for each IODEX varying r, m, p from order 0 to 2, and q from order 1 to 2. We split the time series into two parts, the first being the "fit window", composed by the first 1,200 samples, and the second the "validation window", with the last 353 samples. During the fit step, we tested either hypothesis of normal distribution and Student's t distribution for the innovations. We used maximum likelihood to fit the parameters and, in the case of Student's t innovations, we rounded the number of degrees of freedom to the nearest integer after optimization. In total, we fitted 324 models for the fit window, being 54 for each return series and distribution hypothesis for the innovations.

As suggested in Dziak, Coffman, Lanza and Li (2012), we considered both Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) to choose the order for the models. We computed both criteria to the fit window and to the validation window, and add the values for each criterion. For all the return series, both criteria elected the same model structure, which was the ARMA(1,1)-GARCH(1,1) model with Student's t innovations with degree of freedom three. Table 2 shows the coefficients of the model for each return series and Figure 2 shows the IODEX, the log-returns and the volatility h^2 for the IODEX 62.

Table 2 – Coefficients for the ARMA(1,1)-GARCH(1,1)

	ARMA(1,1)			GARCH(1,1)		
	$\bar{r}$	r_1	m_1	α_0	α_1	δ_1
r_{58}	-1.5152×10^{-4}	5.4491×10^{-1}	-1.7030×10^{-1}	9.7940×10^{-6}	7.1175×10^{-1}	2.8825×10^{-1}
r_{62}	-1.8060×10^{-4}	6.3881×10^{-1}	-2.5831×10^{-1}	7.9082×10^{-6}	7.4237×10^{-1}	2.5763×10^{-1}
r_{65}	-1.3585×10^{-4}	6.1653×10^{-1}	-2.4203×10^{-1}	6.7558×10^{-6}	7.3571×10^{-1}	2.6429×10^{-1}

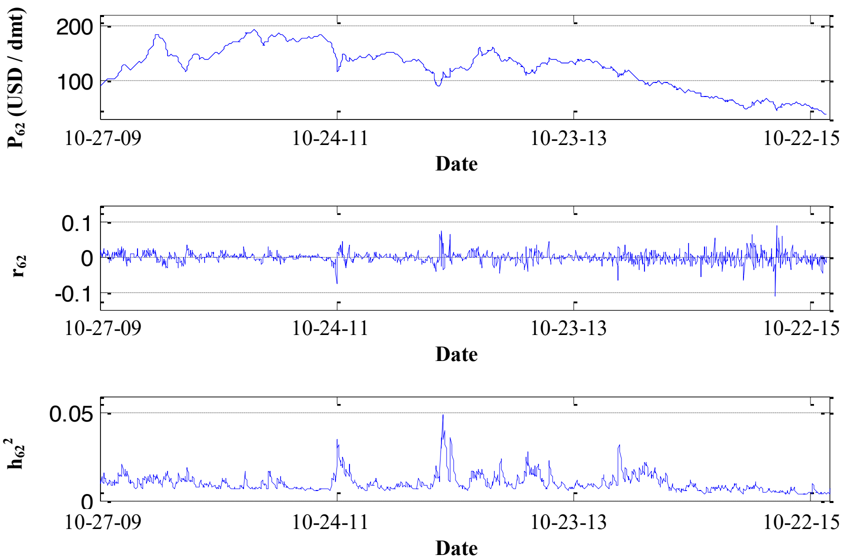

Figure 2 – IODEX 62 and corresponding log-returns and conditional variance in the fitting window

Computing VaR and CVaR

With the models for each IODEX at hand, we compute next the VaR and CVaR measures. We aim to evaluate the risk for the one-month pricing system and, thus, we simulated the returns r_P for a window of 22 days as the IODEX are released only on business days. We initialized the simulation with the information available on time t = 1,535. We sampled randomly N = 10,000 innovations and then computed the variance $h_{t,j}^2$ and return $r_{t,j}$ for the time t_1 = 1,536. We repeated the calculus until time t_f = 1,557 (22 days).

From the simulated returns r_P, we computed for each IODEX the aggregated loss for one month following Equation (10). In the equation, AL is the daily average of the aggregated loss for the simulated returns r_P in a period of one month.

$$AL_j = \frac{1}{22}\sum_{T=t_1}^{t_f}\left(1 - e^{\sum_{t=t_1}^{T} r_{t,j}}\right) \tag{10}$$

The motivation behind this definition of loss is in that contracts are often priced considering the time average across previous months. If we draw N Monte Carlo samples of AL_j, we can approximate the expression for the CVaR in Equation (7) by the following linear program in Equation (11):

$$\begin{cases} \text{CVaR}_\beta \cong \min\limits_{\tau,\omega_j}\left(\tau + \dfrac{1}{N(1-\beta)}\sum_{j=1}^{N}\omega_j\right) \\ \text{subject to } \ \omega_j \geq 0 \\ \omega_j \geq AL_j - \tau. \end{cases} \tag{11}$$

The solution gives us both the CVaR and the VaR, which corresponds to the minimizer τ. We solved the minimization problem varying the confidence level β from 0 to 90%, with increments of 10%, and for β = {95%, 97.5%, 99%}. Since the expression in Equation (11) is only approximated, we repeated the Monte Carlo procedure until the standard deviation for the CVaR$_\beta$ was below 1%. Figures 3 and 4 show, respectively, the VaR and CVaR for the different confidence levels.

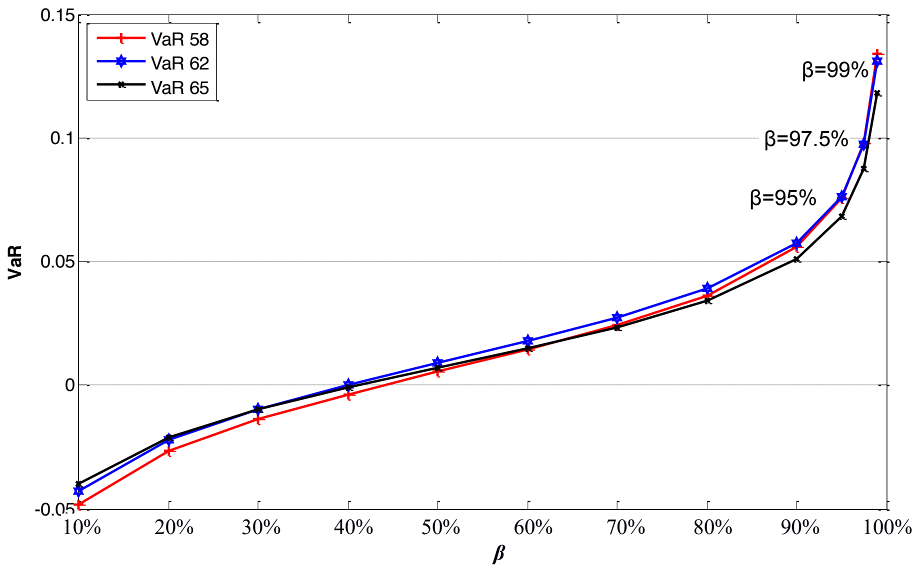

Figure 3 – VaR for the IODEX 58, 62 and 65

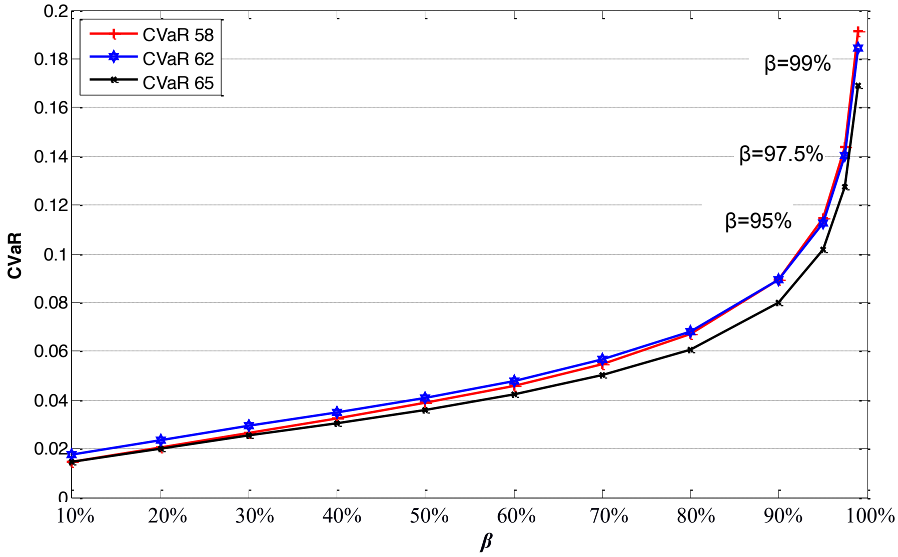

Figure 4 – CVaR for the IODEX 58, 62 and 65

Table 3 shows the values of VaR and CVaR computed. Considering the figures and the table, we can see that for $\beta < 60\%$ the IODEX 65 shows higher VaR than the IODEX 58. For $\beta > 60\%$, there is an inversion and the IODEX 65 presents the lowest values of VaR.

Focusing on CVaR, that is a coherent measure of risk, we can see that the IODEX 58 has the highest CVaR for $\beta > 90\%$. IODEX 65 has the lowest CVaR for $\beta > 20\%$. We can conclude that IODEX 65 is the one with the lowest risk when considering the monthly pricing mechanism.

Table 3 – VaR and CVaR for confidence level β

β	VaR 58	VaR 62	VaR 65	CVaR 58	CVaR 62	CVaR 65
10.0%	-4.82	-4.29	-3.98	1.45	1.76	1.47
30.0%	-1.38	-0.97	-1.00	2.66	2.93	2.54
50.0%	0.55	0.90	0.69	3.87	4.11	3.60
70.0%	2.43	2.73	2.34	5.48	5.65	5.00
90.0%	5.57	5.76	5.09	8.94	8.93	8.02
95.0%	7.55	7.64	6.81	11.46	11.28	10.20
99.0%	13.39	13.08	11.84	19.15	18.43	16.89

Computing expected returns

The CVaR for $\beta = 0$ is equal to the expected average loss or, more interestingly, to minus the expected return. However, this expected value is not finite in the case of Student's t distribution for the innovations. For this reason, we make use of the computed CVaR to define a trimmed expected average return, as in Equation (12):

$$E[r]_\beta = \frac{\beta \cdot \mathrm{CVaR}_{1-\beta} - (1-\beta) \cdot \mathrm{CVaR}_\beta}{1-2\beta}, \;\; \beta < 0.5. \qquad (12)$$

This trimmed average return corresponds to the expected average return discarding the lower and the higher β quantiles. Table 4 shows the trimmed average returns for $\beta = 10\%$ and Figure 5 shows these average returns versus the CVaR with confidence level 90% for the three IODEX. As we can see, the IODEX 58 has the lowest average negative return and the highest CVaR. Comparing with the IODEX 65, there is no dominance once the IODEX 65 has the lowest CVaR of the three series, but higher negative average return than the IODEX 58. IODEX 62 presents the highest negative average return and CVaR similar to the IODEX 58. We can conclude that the IODEX 62 is the one with the worst performance under our simulations.

Table 4 – Expected trimmed returns for $\beta = 10\%$

Price Series	R_β
IODEX 58	-0.51%
IODEX 62	-0.86%
IODEX 65	-0.65%

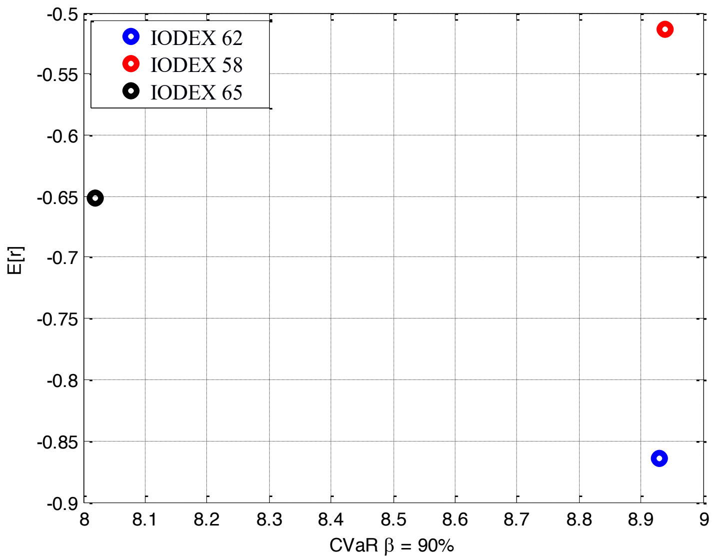

Figure 5 – $\text{CVaR}_{90\%}$ and the expected trimmed returns for the IODEX 58, 62 and 65

CONCLUSION

We tested different orders of ARMA-GARCH models for the conditional variance of the iron ore spot price series using cross-validation. Considering AIC and BIC information criteria, the best performing models for the iron ore spot prices was the simple ARMA(1,1)-GARCH(1,1) with Student's t innovations. The ARMA(1,1) was sufficient to remove the autocorrelation in the three return series. The hypothesis of Student's t distribution for the innovations is recognized to lead better average performance than the normal distribution as in Hansen and Lunde (2005) and Orhan and Köksal (2012).

Examining the CVaR for the price assessments Platts IODEX 58, IODEX 62 and IODEX 65, we concluded that the IODEX 65 is the one with the lowest risk, being IODEX 58 and IODEX 62 similar in terms of risk. The IODEX 62's CVaR is close to the IODEX 58's CVaR mainly with β between 70% and 95%. For example, the average loss that we can expect in one month for the IODEX 58 with 95% of confidence is 11.46% while for the IODEX 62 is 11.28%.

When we consider the compromise between expected average returns and risk, we notice the worst performance for the IODEX 62. Between IODEX 58 and IODEX 65, there is no dominance as the IODEX 65 provides less risk and the IODEX 58 provides better expected average return. One of the hypotheses for the worst performance for the IODEX 62 is that it suffers more with market speculation and futures spread once it is the most traded and future traded type of iron ore in the world, although futures are commonly traded considering the TSI index, not the IODEX.

Finally, we must emphasize that the validity of the present results may vary in the medium-term as model parameters change. Different results may also occur in the case of other pricing mechanisms and actual prices may also be affected by factors such as the chemical quality of products (e.g. lower Fe and higher SiO_2 than the specifications in each IODEX).

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