International Raw Materials Observatory

Fostering international raw materials cooperation

Analysis of Research and Innovation

Operational report: summary

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Abstract

This report contains the operational analysis of research and innovation for the five reference countries of INTRAW (the U.S., Canada, South Africa, Australia and Japan). It describes and compares the different innovation systems, comprising – among others - the main role players, institutions and policies that drive research and innovation in the raw materials sector.

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The full report is available at http://intraw.eu/publications

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1. Extended summary

The aim of this report is to describe and evaluate the INTRAW reference regions, namely Australia, South Africa, Canada, the United States (U.S.) and Japan with respect to their research & innovation (R&I) activities.

The report applies the concept of 'Innovation Systems' for its investigation. This concept stresses the fact that innovation is not only the result of new knowledge creation, but rather of knowledge being 'used' in a variety of ways and by different actors. It puts emphasis on the quality and depths of interactions and the efficiency of knowledge creation and knowledge diffusion among the relevant organizations. Among these actors one will find companies of various types and sizes that interact with their customers and suppliers in the raw materials supply chain, organisations for research and education (e.g. universities, research centres) and various kinds of intermediate organisations (funding agencies etc.). All of them act in an environment that is shaped by the national innovation policy and the regulations that affect research and innovation.

Research and innovation (R&I) activities have become a substantial pillar in the attempt to explain the competitiveness of firms, industries and economies. Historically, technological progress happened more or less in a random manner as it was regarded mainly as the result of geniuses such as Thomas Edison or James Watt, who invented ground-breaking new products that led to a substantial increase of productivity and output in manufacturing. Research was not always a predecessor to an invention (for instance, much of the progress in aerodynamics came after the Wright brothers successfully built

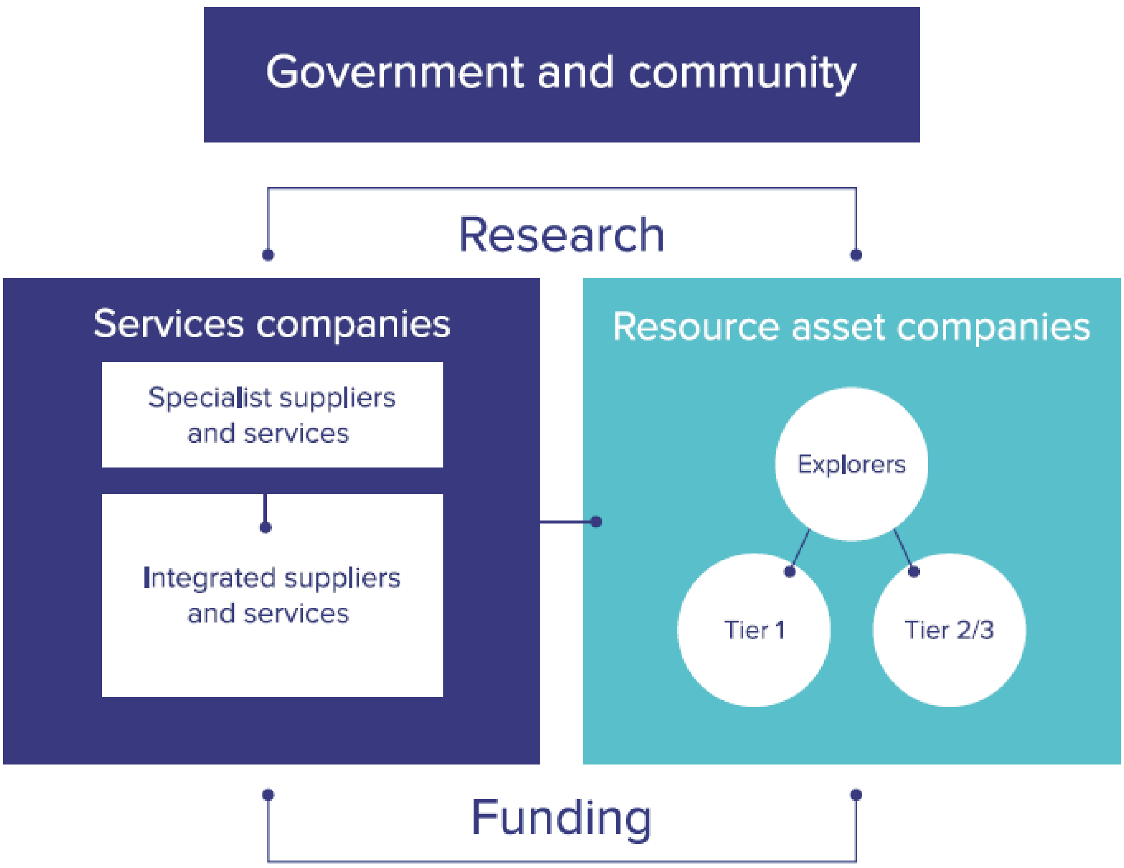

Figure 1: The Mining Innovation Eco-System (VCI, 2014).

their first 'flying machine'), but the accumulation of knowledge, especially in physics and chemistry, led to more systematic attempts to create new knowledge, new technologies and new products. In the first half of the 20th century, big research projects driven by the state, firms and science resulted in many more important innovations (explosives, rockets, computers), however, it was only until the 1950's and 1960's that corporate research and development (R&D) as we know it today, was established.

In the past 50 years, there has been a growing interest in the economics of innovation and technical change. It is now widely accepted that research, science and technology are vital to ensure national competitiveness. Governments across the globe are searching for ways to encourage investments in science and technology as they are expected to have a positive impact on a country's economy. The relation, especially between Resource asset companies and service companies in the context of the Mining Innovation Eco-System is shown in ***Figure 1***. Within this context, a survey published in 2014 confirmed, that there is a preference for in-house or closed innovation in the mining industry (VCI, 2014). Comparable to other industries, the company size is a factor influencing innovation behaviour: bigger mining companies have a more structured approach than smaller companies.

For the analysis of Research and Innovation, the following activities having a major importance for research and innovation activities have been considered:

1. **Exploration and evaluation:** The action of locating a deposit and proving it is technically and financially feasible to mine.
2. **Mine planning and design**
3. **Extraction:**
    - Mine Development: The action of setting up a mine production system (e.g. open pit or tunneling, transportation system, power supply, drainage, ventilation, communications…)
    - Mining: The action of producing ore (including, for instance, breaking, loading & hauling, conveying, crushing, stockpiling)
4. **Processing / Smelting and refining:** The action of converting the primary product into a bulk tonnage intermediate product (e.g. usually a mineral concentrate, then via smelting and refining into a metal or metal alloy), and of converting the intermediate product into a product suitable for purchase by sub-sequent industries (worked shapes and forms).
5. **Closure / Rehabilitation:** The action of restoring the post-mined landscape to the intended land use.

Each reference country's research and innovation performance is described and measured in qualitative and quantitative terms in a separate chapter of the report. Eventually, all the countries are compared against each other. It is worth mentioning that there is no such thing as an ideal innovation system. It is helpful, though, to compare them and to initiate reflection why some systems work better (or worse) than others (Edquist, 2001).

The main findings can be summarised as follows:

- R&I in mining is a complex subject, because there are drivers that push R&I in mining, while others are barriers to R&I and stakeholder interests often diverge. From a government perspective, for instance, increased R&I could drive higher levels of automation, which would increase productivity and raise the competitiveness of the mining industry in times of low mineral prices. Increased levels of automation, however, could also reduce the required manpower to run a mine, leading to more unemployment. Given the characteristics of mining (long cycle times, high investments), developing or adopting something 'new' is very expensive and risky for mining companies, which is why mining can be considered a rather conservative business in terms of R&I.
- R&I in mining takes place, but it happens in a complex interplay of different organisations (miners, suppliers, service providers, research organisations, government bodies) and it has proved difficult to identify

clear patterns of R&I. Recent studies suggest, for instance, that bigger mining companies have a more structured approach to research & development than smaller miners. They have the resources to pool innovation efforts, to build innovation centers and to make use of the results on a global scale.

- From the perspective of the INTRAW reference regions, there are significant differences in the innovation systems, which firstly depend on the countries' individual challenges related to mining. Japan stands out as the country with virtually no domestic metals production. Yet it has found a unique and successful strategy, which is strongly driven by the government, to secure access to mineral resources and to maintain a highly productive knowledge base that drives R&I. Conversely, we find that that there are countries with significant mineral endowments - and even very similar starting points in history, i.e. U.S. and Canada - that have developed different approaches to support R&I in mining.
- Globally speaking, we see that countries that have a strong manufacturing industry try to limit the impact of potential supply shortages (esp. Japan, U.S.). These countries have defined policies on how to avoid shortages (e.g. through funding international mineral exploration) and they have defined R&D policies that are supposed to reduce dependencies on materials (especially Rare Earths) in the long-run (e.g. through recycling, substitution of critical materials).
- Australia's situation is somewhat similar to Canada's, as both countries seek to maintain investment in the mining industry, while promoting sustainable development practices in mining. Both are vast countries, in which the federal states (or provinces/territories) play a strong role. They often operate mines in remote locations and have developed a capable mining equipment, technology and service sector. Both countries need to prepare for a number of challenges (lowering production costs, lack of skilled workers, decreasing ore grade, to name a few), which force them to re-think the current mining policies and, among others, to reinforce research and innovation.
- The United States is a country with significant minerals endowments and a strong processing industry, however, the relative share of the mining industry is smaller than in Canada, Australia and South Africa. With the exception of the DOE's policies to secure the provision of critical and strategic materials, the U.S. pursues a less explicit raw materials strategy. The major agencies involved in minerals and materials (DOI, DOE, DOD) sponsor R&D projects, but there are no comprehensive research & innovation programs especially designed for the mining sectors. Much of the R&I in minerals is driven by industry.
- South Africa represents a resource-abundant country, but has a very different historical background impacting R&I. Its main objective is to reduce unemployment, inequality and poverty through developing the minerals value chain, especially by having more minerals processed before they are exported. During its long history of mining, the country has developed a competitive level of know-how and a remarkable industry of suppliers of mining equipment and services. Innovation-wise, though, the country has seemingly come to a standstill. There is little industry engagement with research and a significant decline of personnel and (publicly funded) mining research programs.

A basis for the findings are the different aspects analysed within the research and innovation country analysis. These are described in more detail in ***Table 1***.

The quantitative metrics available for the mining innovation system for each country are then compared to each other. Due to differences in data avai-

Table 1: Structure of the R&I Country Analysis.

CHAPTER	SUB-AREAS / EXPLANATION	LEAD QUESTIONS (EXAMPLES)
The big picture of innovation in raw materials and mining		• Which role does mining play in the country? (e.g. in terms of GDP contribution), Is the country a net exporter or importer of mining products? • Which role do mining products play in the country? • Drivers for R&I in mining/raw materials
The mining innovation system	**Raw materials strategy and priorities** National innovation policies directly influence the framework conditions of an innovation system.	• Is there an explicit raw materials strategy that is pursued by the country? • If so, what are the key R&I-related policies? Is there an implementation plan for the policies? • Which official policy documents exist?
	Key actors and organizations[1] Organizations contribute to technological progress, as developer, adopters, or indirectly, as regulators, financers etc. Firms represent the main unit of analysis in sectoral systems of innovation. They have cooperative and competitive relationships.	• Who are the main actors in the mining landscape (Governmental bodies, Industry, Support Organisations ...)? • How they behave within the context of market? • Which actors in the system are the most influential?
	Knowledge base for research and innovation A sectoral knowledge base describes how knowledge is shared by the industrial actors of the sectoral system through communication / exchange / cooperation with other players in the industry. A rich and multi-source knowledge base has an impact on the rate and direction of technological change.	• Which are the main knowledge domains relevant for the country • How is knowledge acquired from outside the company (through R&D services, cooperation with universities ...)? • What are the main patterns of collaboration?
	Key technologies Mining is a business that depends on the use of technology. Technological progress is a prerequisite to produce minerals at reasonable costs.	• What are main technologies that are being developed / have been developed in the respective country? • What is the pace of technological change in the country? • Who files patents and for which product category?

Metrics for mining innovation system	In addition to the qualitative data, some quantitative measures are used to illustrate the R&I intensity of each region. As sources of data we use the Global Innovation Index as well as other data, if it is more specific on mining (e.g. business expenditure on R&D [BERD] by mining companies). Note that the GII is a measure of a country's overall innovation performance. The performance of mining innovation may differ from the innovation intensity in other industries.	• Global Innovation Index • Innovation and Technology Readiness indicators

1 It is worthwhile noting that qualified professional research staff are mobile and will migrate to international centres of research excellence wherever they are. The location of such centres of excellence changes with time - new ones are opened, others are closed down (such as U.S. Bureau of Mines). Although there is a formal structure in some countries, the relative importance of different institutions changes with time.

lability, different information sources were considered to provide a maximum of potential sources for benchmarking and the identification of best practices. This includes information on innovation oriented personnel as well as standard measures such as BERD or the number of patent applications.

To show the results from the qualitative performance benchmark between the participating countries, the evaluation is done by measuring maturity levels (low, medium, high), which will be adapted to each of the categories described as being important for the mining innovation system. It is based on the information collected in existing publications and complemented by the expertise of the INTRAW consortium. Within this maturity model, the following areas have been considered, each in a specific benchmarking category (see also ***Table 1***):

- **Raw material strategy and priorities:** Does a strategy on research and innovation for mining exist, is it formulated based on relevant stakeholder requirements and able to be put into practice based on clear priorities to guide research and innovation activities?
- **Key actors and organizations:** Are the mining value chain as well as the different phases of research and innovation represented by actors and organizations? Are these actors and organizations collaborating to carry out research and innovation activities in a value-adding manner for the industry?
- **Knowledge base:** Is the personnel to carry out research and innovation activities available in academia and industry?
- **Key technologies:** Is there a basis and targeted research and innovation activities existing in key technology fields able to support the regional mining industry?

For each of these categories, specific maturity levels were defined. This allows generating a general evaluation of the maturity level of each country in the categories whereas it only provides a very rough indication for comparing one country with another.

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