

Knowledge-based metals & materials

by
Amir Sasson

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BI Norwegian Business School
Department of Strategy and Logistics

Amir Sasson
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Executive Summary

This study presents the Norwegian metal and material industry (defined as all metal and material related firms located in Norway, regardless of ownership) and evaluates the industry according to the underlying dimensions of a global knowledge hub - cluster attractiveness, education attractiveness, talent attractiveness, R&D and innovation attractiveness, ownership attractiveness, environmental attractiveness and cluster dynamics.

The Norwegian metal industry has maintained its share of the Norwegian GDP over the period 1999 to 2008. Due to the cyclical nature of the industry, the share of basic metals has varied over the period from 2.7% to 3.3% of GDP while the share of basic and fabricated metals varies from 4% to 5.3% of GDP. While the common perception in the economy is that industrial production is quickly disappearing, the metal industry has maintained its relative position in the economy.

On an international basis, significant consolidation of the metal industry has been observed in recent years, much of which has occurred through mergers and acquisitions. China has turned out to be the major player in many metal markets. The industry is facing higher costs due to increased competition that pushes firms to invest in finding superior new technologies, and growing pressure to implement more environmentally friendly solutions that may involve the creation of entirely new technologies. For these reasons, scale, which increases a firm's power and allows it to spread the costs of R&D which are not dependent on the tonnage produced, is the underlying mechanism behind these trends. This process could result in extreme market consolidation. We refer to this process as "*the giant competition hypothesis*": when national barriers to competition, establishment and trade are gradually reduced, and output is standardized, scale considerations will motivate actors to increase their respective sizes through horizontal mergers and acquisitions, and/or through the development of superior technologies.

Value creation in primary production is significantly above value creation in the rest of the Norwegian economy. Value creation in a non-crisis year for the entire primary production sector is around NOK 2m per employee. This is substantially above findings for other industries such as the oil supplying industry, maritime, and tourism. Secondary production and tertiary production firms have been growing linearly in terms of value creation from 2000 to 2009. Value creation in these sectors is moderate (around NOK 0.7m per employee).

The sectors are structurally dissimilar. Economies of scale and large fixed assets necessitate that primary production firms are large and immobile.

More than 90% of the sector revenues is controlled by very few and large firms. Secondary production and tertiary production firms are very similar in their structural distribution. Large firms control 35% and 60% respectively of total revenue in these sectors. A large number of firms are small- and medium-sized.

At first glance it seems that the Norwegian metal industry is complete. Firms are involved in all parts of the value chain. However they are operating in parallel, that is, they to a very small extent constitute a tight network of customer-supplier relations. Secondary production and tertiary production firms do not specialize in related technologies or have not evolved to be leading global suppliers through further value addition activities utilizing the metals produced by the primary production firms.

Production of metals including the subsequent value addition activities is not concentrated in any specific county or area. Primary production is mostly situated in the vicinity of a major power supply plant. To a large extent secondary production and tertiary production firms are not located in the vicinity of primary production units or other secondary production and tertiary production firms, but are located in the vicinity of their customers

The pool of graduates with relevant advanced knowledge of metal and materials is increasing in absolute and relative terms. This indicates the likely future availability of a larger pool of qualified R&D personnel in R&D institutions and of qualified workers who can accept employment in the metal industry. However, the same pool of graduates is highly sought after by other industries. It is research institutions related to metals and materials that attract talented graduates and to a much lower extent, the industry itself.

The labor composition of the metal industry differs substantially from that of the rest of the Norwegian private sector. Its composition is in line with the industry's focus on manufacturing as evident from the composition in other manufacturing industries (e.g., food, textiles, wood pulp and paper, and chemicals) and labor intensive industries (e.g., fishery). However, the trend in the composition of employment is one of stability. While the economy as a whole is advancing in terms of the general level of higher education, the composition of the human capital employed in the metal industry remains unchanged.

Norway has a productive academic community that continually publishes academic research on metal-related topics. The academic output in Norway related to the metals industry exceeds by far the national average, which reflects decades of experience with the industry in Norway and the resulting

knowledge-intensity in the country's academic specialization. On a global scale, Norway is not a central player in academic research relating to metals and materials in general, and its market share of this research remains stable over time. It may have developed niche competences as is evident in new aluminium and magnesium production processes and advanced material innovations.

To what extent can firms tap into the knowledge base residing within dedicated R&D institutions? The median level of R&D personnel is almost identical to the level in the rest of the economy and it remains constant between 2001 and 2008. The percentage of firms that have had product innovation in 2004 to 2008 is higher than the rest of the economy but the gap is decreasing rapidly. The levels of service innovations are insignificant. While innovative output has decreased, firms appear to generate the same turnover from innovative output in 2008 as in 2006. This allows for inferences about the relative quality of the innovations, which is inherent in the firm's ability to generate value from such innovations. However, as a whole the industry derives lower turnover from its innovations than other industries.

Local competitive linkages are weak. Metal firms meet the *toughest* competition for customers on the national and international levels. Local competitors are of comparatively little significance, with only 17% of firms meeting intense competition locally. Primary production firms in Norway operate in a globally competitive market but experience little local competition. Secondary production and tertiary production firms experience high levels of local competition but this is not the source of the toughest competition that they experience.

local suppliers are viewed as substantially less technologically leading than their foreign counterparts. This weakens the attractiveness of the metal cluster in Norway by challenging its completeness and competitiveness throughout the value chain. The metal industry is not a stand-alone industry but is linked to related industries such as oil and gas, construction, maritime and renewable energy. Primary production is isolated mainly maintaining relationships to its supplier of energy and capital. It plays a much more peripheral role in the network of Norwegian industries than secondary production and tertiary production.

Investments in competence development in the metal industry are similar to investments in the construction and tourism industries. Oil and gas, and health firms distinguish themselves from metal firms, as they have a lower share of firms that invest less than 1% and a higher share of firms that invest substantially (above 8%) in competence development. The metal industry as

a whole does not distinguish itself in terms of high investments in intra-firm competence development relative to other industries. Its distribution is similar to that seen in other labor-intensive industries and differs from investments made in more knowledge-intensive industries.

The Norwegian metal industry is at a crossroads. Norway has had a leading role in magnesium, which was lost to larger players. After a bumpy start for the silicon industry (e.g., Elkem) the industry evolved to solar energy wafers (REC). But like magnesium, the solar industry is about to abandon its position in the global market. Related R&D is now controlled by China National Bluestar. REC may be sold any day. That would mark the demise of the Norwegian position in this industry as well.

A number of academics and economists argue for its gradual shutdown. Others argue for maintaining the status quo. Based upon the development in the market presented in sections 2 and 3 and the data presented in the remaining sections of this report, we argue for a “*double or nothing*” strategy. Norway can either become a significant player in the metal production industry or become an insignificant player that will eventually be squeezed out of the markets as mentioned in the previous paragraph. Investment in knowledge that can partially solve environmental challenges, advance a new smelting technology or increase electricity efficiency will necessitate one of the following: either, investments and production capacity (also through replacement with a new technology) are doubled or for the benefits of all stakeholders, or it is best to announce policies that signal the industry’s gradual shutdown.

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1 Introduction

In this study, we assess the underlying properties of a global knowledge hub to examine the extent to which the Norwegian metal industry constitutes such a hub. We begin with a general discussion of the industry before we examine the underlying properties of global knowledge hubs: cluster attractiveness, educational attractiveness, talent attractiveness, R&D and innovation attractiveness, ownership attractiveness, environmental attractiveness and cluster dynamics. We conclude by providing clear recommendations for business and public policy. Our focus is primarily on the metal industry and we take a combined descriptive-analytical approach.

Magnesium: Round 2: SilMag DA was established in 2008, and is owned by Advanced Metallurgical Group (50%) and Norsk Hydro ASA (50%). Following the restart of Norsk Hydro's magnesium technology program, the firm's main aim is to establish Europe's only plant for the production of silica and magnesium. If successful, this will be the first new major production site established outside China in several years. News of this revival program, which is based on the development of new processes, was greeted warmly by customers, who have struggled with rising magnesium prices and limited availability outside of China in recent years.

The magnesium market is dominated by Chinese producers, which have a market share of approximately 80%. Israel and the US are also key players, but Chinese dominance greatly affects the global supply of magnesium. In 2009, SilMag built a pilot factory in order to verify its production process and product quality. The potential market for the planned silica production includes a variety of industries, while magnesium may be used in the aluminium and automobile industries. As the firm is currently in the establishment phase, R&D is centre stage. Revenue in 2009 was NOK 0, as production had not yet started. Operating profit for the same year was NOK - 59m, which reflects the investments made in the prototype plant, R&D and other assets.

The environmental impact of the new technology and the corresponding environmental costs may play a crucial role in determining the viability of the magnesium project. On the one hand, demand for more environmentally friendly production processes is increasing among environmental groups, governmental authorities, customers (mainly automobile producers) and end users. This may increase the likelihood of success for the new technology, which is environmentally superior. On the other hand, Norwegian firms are at a disadvantage to Chinese and other non-European producers as a result of the strict EU environmental legislation that subjects firms to additional levies and costs.

The future of the magnesium industry in Norway is still somewhat uncertain. After a decade of investments in R&D, including the construction of SilMag's pilot plant, it is still not clear whether this industry can thrive. If the technological developments cannot be successfully commercialized or if the environmental costs outweigh the environmental benefits, the entire project is likely to be abandoned or, more likely, foreign producers will purchase access to the superior technology.

Based on interviews conducted at Herøya industry park, company presentations and www.heroya.industripark.no.

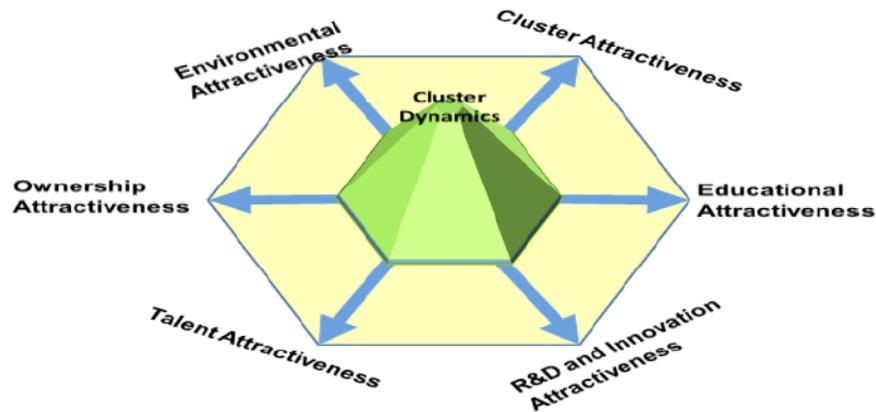
The SilMag case illustrates how a complex innovation in the production process may provide a solution to the current competitive challenges facing actors in the metal industry. The innovative solution combines technological developments with existing knowledge of metals and production. However, the lack of competitors and demanding customers in the vicinity of the firm is likely to constrain the firm's strategic options. This, in turn, weakens the likelihood of the formation of an industry that can build on the knowledge developed thus far to create additional value.

Global knowledge hubs

For Norway to be able to sustain its wealth in the future, an adjustment process must be initiated while oil reserves are still being exploited. Recently published innovation indexes (e.g., OECD 2010) raise concerns about the relative speed and comprehensiveness of the adjustment process in Norway. To address the shortfalls in the adjustment process, tough decisions are required on the national level. These decisions will affect Norwegian businesses and their representative organizations, as well as educational institutions and governmental agencies.

This study is based on three simple premises. For industries to be competitive and sustainable in a high-cost location like Norway, they have to compete globally, they have to be knowledge-based and they must be environmentally robust. Under such conditions, nations and regions face the challenge of attracting the best talent and the best firms. We argue that knowledge-based industrial development occurs in global knowledge hubs or superclusters characterized by a high concentration of innovative industrial actors interacting closely with advanced research institutions, venture capital firms and competent owners. Hence, firms, local authorities and national governments face the challenge of creating conditions under which knowledge-based industrial development can occur.

Figure 1-1: The Global Knowledge Hub[®] model



The Global Knowledge Hub[®] model presented in figure 1-1 provides a framework for analyzing the attractiveness of localities. The surface of the hexagon represents the room for maneuvering available to public authorities and a decision set for firms. It conceptualizes attractiveness as six dimensional. Localities differ in their attractiveness in accordance with their abilities to attract advanced-education institutions and departments, highly talented employees, advanced academic specialists and research and development projects, competent and willing investors and owners, and the creation and implementation of environmental solutions. Furthermore, attractiveness is also affected by the presence of a diverse and sizeable cluster of related firms.¹

The effects of these dimensions on economic performance are moderated by the degree of cluster dynamics, which refers to the extent to which related firms structure their internal and external relationships. The objectives are to identify existing and emerging global knowledge hubs, and to recommend policy initiatives designed to enable the further development and competitiveness of such hubs.

The next chapter presents a brief overview of the development of the industry. We then examine the underlying attractiveness properties that affect the success and failure of industrial initiatives within the Norwegian metal industry. In the concluding chapter, we discuss implications for firm strategy and public policy.

¹ In this study, we ignore the cultural dimension of attractiveness.

2 Metal markets

In the late 1800s, significant changes began to occur in the Norwegian economy. These changes led to economic growth and greatly improved standards of living.² Of critical importance was the construction of new roads, railways and canals, which helped to improve the transportation system. The first advanced industrial sites for the mass production of Norwegian raw materials were also built during this period. The textile industry was among the first to benefit from these developments, although it was closely followed by other industries, including the metal industry.

In addition to industrial developments, an essential element in the growth of the metal industry was the development of hydropower. Parts of metal production processes demand massive amounts of energy, which makes access to a cheap, plentiful supply of electricity a decisive factor in the industry's success. Norway's unique combination of high precipitation levels and natural mountain reservoirs provided both ideal conditions and natural advantages in the development of hydropower. Norsk Hydro reports that as early as 1906, the Bredal Committee had identified the potential national competitive advantage available to Norway if it could effectively harness the power from its natural water sources (Olsen 1955: 87). The committee made recommendations for the building and extension of hydropower plants in selected areas to specifically target the metal and chemical industries. Soon after the establishment of the first hydropower plant in 1882, Norway was producing the cheapest hydropower electricity in the world and was the focal point of global interest in this field. The metal industry began to establish itself in the years that followed and Hydro started investigating the possibilities for hydropower-based production of magnesium in 1935.

As a result of the German occupation of Norway during WW2, the magnesium production business did not develop as Hydro had planned. However, after the war the focus shifted towards rebuilding Norway and its affected industries. Particular attention was paid to public-sector concerns

² This section is based upon the following: Olsen, A. K. (1955). *Norsk Hydro gjennom 50 år. Et eventyr fra realitetenes verden*. Oslo, Norway, Emil Moestue A/S, Godal, O. (1998). *Metallindustrien i Norge Økonomi, sysselsetting og utslipp av klimagasser*. Policy Note. Oslo, Norway, CICERO. 2, and Ministry of Trade and Industry (2011). "Fakta om norsk næringsliv." from <http://www.erih.net/industrial-history/norway.html>.

and state-owned, energy-intensive industries. Governmental subsidies were provided to maintain agriculture and to allow some of the agricultural workforce to be channeled into more productive industries. This approach seemed to bear fruit and industries developed quickly, with the metal and chemical industries showing the most impressive growth (www.regjeringen.no).

The hydropower used to fuel production processes within the metal industry is a clean energy source in that its use results in the release of an insignificant amount of harmful waste products or pollutants into the atmosphere. However, the metal industry's production processes are responsible for releasing significant amounts of pollutant gases. In Norway, environmental improvements over the past two decades have reduced gas emissions and lowered energy consumption per unit of metal produced. In addition, the development of greener technologies within the Norwegian metal industry has advanced through partnerships between national producers and research institutions. A measure of the success of such programs is that the metal industry lowered its gas emissions by 43% from 1990 to 2006 (Godal 1998).

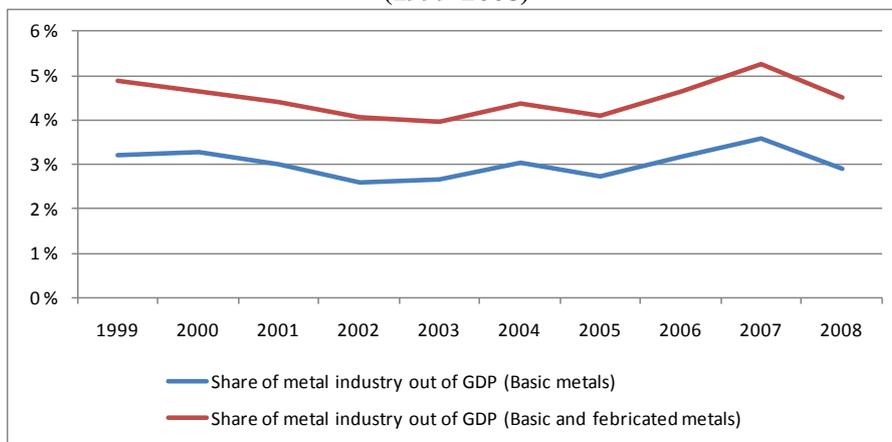
The Norwegian metal industry is restricted to distinct geographical locations, most of which are located along the coast. This is mainly due to the fact that, initially, electricity produced from hydropower could not be conducted over long distances without significant energy losses. Although the development of the transformer partially resolved this problem, most firms remain close to their natural resources. As a direct consequence of these geographical limitations, new industrial cities, like Notodden and Rjukan, developed around the power stations and metal factories.

The metal industry is not particularly labor-intensive but plants are of great importance for local employment and are often regarded as cornerstones of local communities. In 2007, the entire metal industry employed over 32,000 people while primary production of metal employed 7,500 people with the most marked effect on employment evident in the counties of Vestfold, Telemark, Vest-Agder, Rogaland, Sogn and Fjordane, Møre and Romsdal, Hordaland, and Nordland.

The Norwegian metal industry is comprised of firms producing basic metals as well as those involved in secondary and tertiary production processes. The

single largest branch in Norway is the aluminium segment, although the ferrous alloy segment has considerable scope and has been involved in innovations in the solar wafer industry. The industry also comprises steel, zinc and nickel production. Today, Norway is one of the world's largest producers of aluminium and has launched a promising program to develop magnesium production.

Figure 2-1: Value creation in the metal industry in percent of GDP (1999-2008)

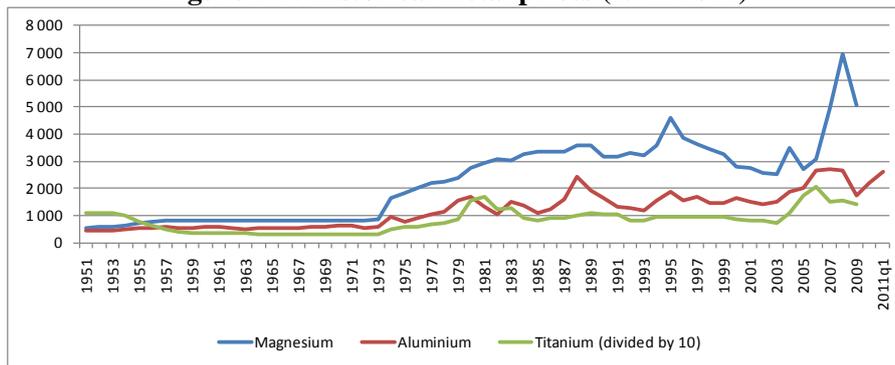


The Norwegian metal industry has maintained its share of the Norwegian GDP over the period 1999 to 2008 (Figure 2-1). Due to the cyclical nature of the industry, the share of basic metals has varied over the period from 2.7% to 3.3% of GDP while the share of basic and fabricated metals varies from 4% to 5.3% of GDP. While the common perception in the economy is that industrial production is quickly disappearing, the metal industry has maintained its relative position in the economy.

The industry exports a large share of its products. Hence, it is evaluated by its competitiveness in the global market for both primary and secondary metal production. Metal markets are cyclical (

Figure 2-2), and firm profitability is significantly influenced by fluctuating international prices. The Norwegian metal industry has experienced solid growth and value creation over the last ten years. However, value creation was 15% lower in 2006 than in 1990. Over the same period, employment declined by 34% (Godal 1998).

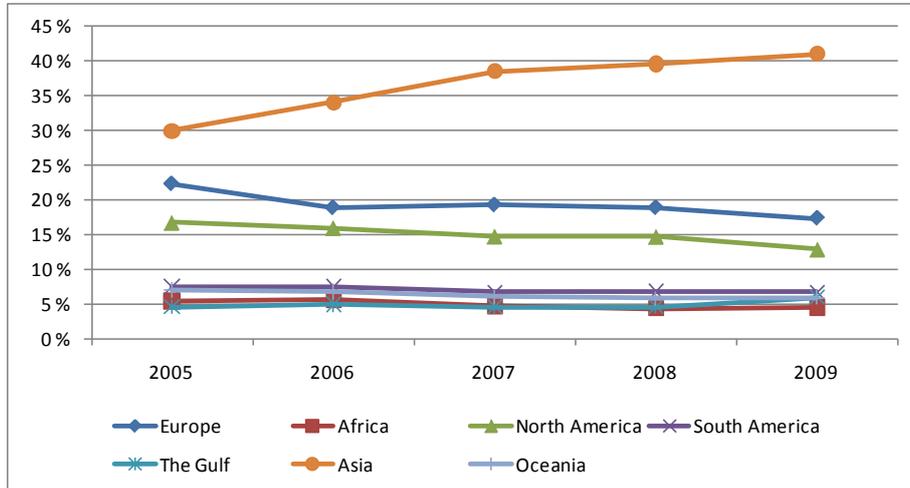
Figure 2-2: Historical metal prices (1941-2011)



Source: U.S. Geological Survey (2010)

On an international basis, significant consolidation of the metal industry has been observed in recent years, much of which has occurred through mergers and acquisitions. China has turned out to be one of the major aluminium and magnesium producers, and the country has both the size and scale to produce at relatively low costs. Its booming economy has also increased global demand for metals reflected in increased metal prices. Foreign ownership has been relatively high in the Norwegian metal industry for many some time now (see Section 7). Recently, however, Norwegian metal producers have begun establishing themselves abroad in order to take advantage of lower costs. Countries with low electricity costs and easy access to supplies of electricity are particularly attractive in this respect.

Figure 2-3: Global market share of aluminium production by region (2005-2009)

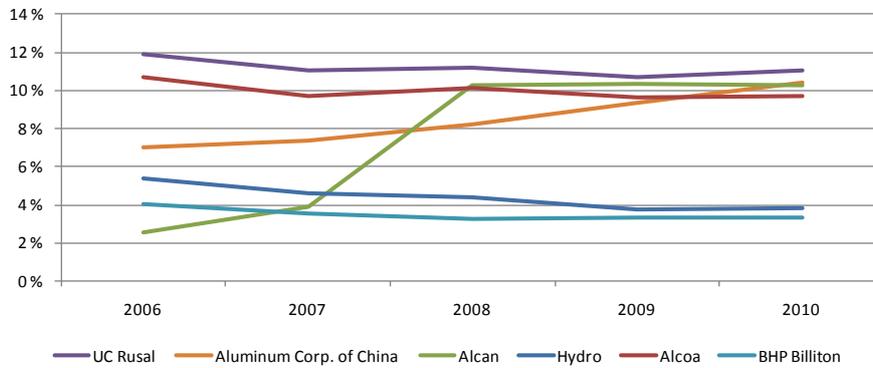


Source: International Aluminium Institute (2011)

Figure 2-3 presents the global production of aluminium by region. Asian firms, most of which are Chinese, have rapidly increased their global market share. In an industry where huge sunk costs make exits the option of last resort, a 10% increase in global market share over a span of five years is substantial. At the same time, the shares held by smelters in Europe and North America are slowly declining. Other regions have maintained their market share of between 5% and 7%. Similar trends are evident for other metals, such as magnesium and precious metals.

The cross-border consolidation process is evident in the aluminium industry. In late 2007, Rio Tinto merged with Alcan to create the second-largest aluminium production firm with a global market share of 10%. At the same time, RUSAL, a Russian aluminium firm, merged with SUAL and the alumina assets of Glencore to create UC RUSAL, the world's largest producer of aluminium. This marked the end of a long process of consolidation in the Russian aluminium industry. Currently, UC RUSAL has operations in 19 countries including Russia, Sweden, Italy, the Ukraine, Nigeria, Guinea, Armenia, Australia and Guyana. Figure 2-4 provides the development of global market share of the six leading firms in the production of primary aluminium.

Figure 2-4: Global market shares of selected companies (2006-2010)



Sources: BI and firm annual reports

In order to compete on a global scale, Norwegian metal firms have invested heavily in R&D. The main focus of this R&D has been on the development of innovative production processes and new products. As a percentage of total turnover, R&D expenditure for the metal industry has consistently been above the industrial average in the rest of the Norwegian economy.

The Norwegian metal industry may face tough times ahead but it is trying to remain innovative in terms of the development of new products and production processes. One example of this focus is found in Norwegian silicon production for the solar-panel industry, which is handled by Elkem and REC. Furthermore, Hydro is working to secure its future in the industry through the development of a new production technology for aluminium and the revival of its magnesium production program. Policy decisions regarding the production and supply of electricity may prove to be decisive with regard to the future success or failure of the Norwegian metal industry.

3 Cluster attractiveness

This chapter discusses the degree to which the cluster of Norwegian metal firms is attractive. In particular, we assess the extent to which the cluster contains all relevant activities (its completeness), the existence of a critical mass of firms in all parts of the industry’s activity system, its value-creation properties and its geographical distribution.

3.1 Structural properties

The Norwegian metal industry is a pure value-chain industry. Norwegian firms are involved in all stages of the value chain, including the mining and quarrying of natural raw materials, the processing and separation of extracted or purchased raw materials, the forming of such outputs, and final sales to customers, most of which are other businesses. The various parts of the value chain show few interdependencies (for more detailed information, see Section 9). In this section, we provide a brief overview of the main players in each sector (Figure 3-1) and the economical characteristics of each sector.

Figure 3-1: Classification of the industry

Sector	Definition	Examples
Primary production	Firms engaged in the extraction of one or several types of metals, or in the initial processing and separation of metals, such as aluminium from mixed raw materials.	Hydro Aluminium AS Norsk Hydro Produksjon AS
Secondary production	Firms specialized in transforming the outputs supplied by the primary sector into finished products. Products are supplied to a wide range of sectors, such as defense, maritime and construction.	Hydro Aluminium Rolled Products AS Kongsberg Defence & Aerospace AS
Tertiary production	Firms that interact with other businesses and end-customers through wholesale, retail and service activities.	Bredero Shaw Norway AS Celsa Steel Service AS

Primary production

The primary production sector is populated by large firms that either extract raw materials, or handle the initial processing and separation of metals, such as aluminium, from mixed raw materials. With the exception of Hydro, the

major players are very large foreign firms that operate as subsidiaries in Norway. These firms own and run the mostly geographically isolated production units.

Secondary production

Firms involved in secondary production focus on transforming standardized metals into products that have various levels of readiness. The main customers are businesses that utilize semi-finished and finished products in bundles with other products (e.g., housing) or services.

Tertiary production

Firms engaged in tertiary production interact with other businesses and end-customers through wholesale, retail and service activities. A large number of firms in this sector are primarily involved in supplying the construction industry, including the ship and oil platform construction sectors.

REC and Elkem: The REC case provides a good illustration of how material technology development in Norway can lead to a globally successful business idea. However, major challenges have arisen and questions are being raised as to whether the solar wafer industry has a future in Norway. Production abroad or foreign acquisitions may mark the end of the Norwegian solar journey.

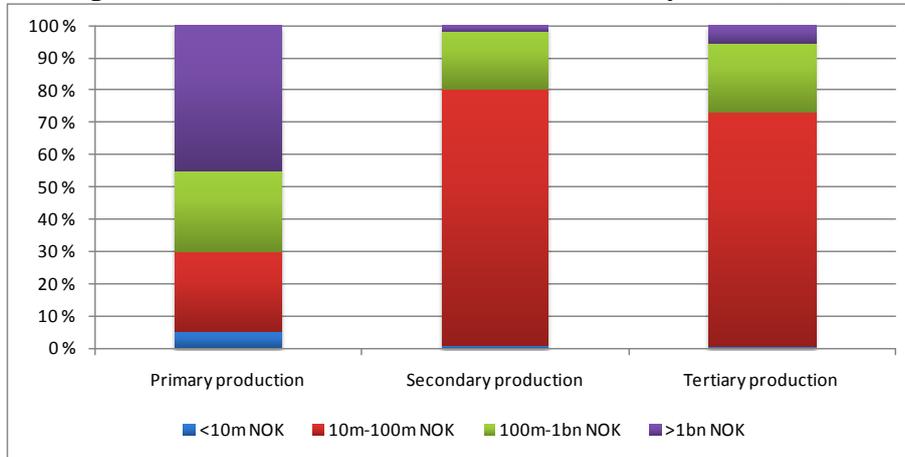
Alf Bjørseth, a chemical engineer and technical director at Elkem in the early 1990s, saw the potential offered by Norway's world-leading position in the production of ferrosilicon. He identified the fact that this material could be processed into silicon wafers for use in solar panels. He was the driving force behind the establishment of REC in 1996, which has grown rapidly since. Today, it is one of the leading players in the solar energy industry with activities covering the entire solar value chain. His competence within the materials field and sharp business mind led to continuous innovation and process development at REC over the years. One of the key success factors at REC has been accredited to the fact that they control every stage of the value chain and, in particular, have their own supply of high quality raw materials. Although solar wafers vary in quality, competition occurs mainly on the basis of cost. Therefore, if REC cannot cut its costs dramatically, it may need to lay off a large number of staff members and close production plants. Furthermore, wafer production is much more expensive at REC's Norwegian plants than at its Singapore plant, leading analysts to speculate that all production may move to Asia in the long run.

REC's share price has fallen dramatically recently as a result of external factors and despite the firm's good results. Analysts are concerned that over-capacity in the market will push prices down further. In addition, the threat of brutal subsidy cuts in the Italian solar industry, which is the second-largest market in the world, has negatively affected the industry on a global scale.

Chinese competitors operate on such a large scale that they are able to produce at a much lower cost per wafer. The acquisition of Elkem by China National Bluestar illustrates that Chinese firms are ready and willing to buy advanced technologies that offer many years of R&D-based growth potential. It also illustrates that foreign investors purchase a technology in order to export it rather than to invest in further technological development. The road forward, therefore, is still uncertain for REC.

Based on multiple articles in Dagens Næringsliv on REC, <http://www.recgroup.com> and in internal REC communications.

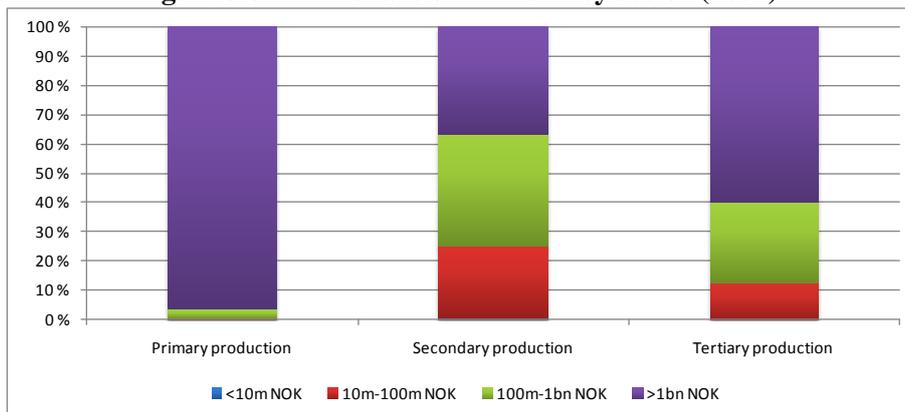
Figure 3-2: Firm share of the number of firms by sector (2009)



Sources: Brønnøysund Register Centre and BI

Figure 3-2 shows the percentage of firms in each sector and the composition of sector revenue in terms of reported turnover in NOK. 45% of primary production firms have turnover of more than NOK 1bn, compared to only 2% and 5% of secondary and tertiary production firms, respectively. Primary production's strong economy of scale benefits result in a small number of large firms. Secondary production and tertiary production exhibit extremely similar structural characteristics, with 80% and 73% of firms, respectively, having turnover of up to NOK 100m. In these sectors, efforts to customize products and services for business customers or end-users lessen the constraints on firm size arising from economies of scale. This indicates that the vast majority of firms in these sectors are of medium size. In Section 9, we examine the extent to which these sector exhibits cluster linkages-based properties.

Figure 3-3: Firm share of firm size by sector (2009)



Sources: Brønnøysund Register Centre and BI

Figure 3-3 shows the composition of the total turnover for each sector. 45% of primary production firms are within the top turnover bracket (above NOK 1bn). These firms create 97% of the total turnover in this sector, which indicates that these firms represent the economic foundation of this sector. Although only 2% of firms in secondary production have a turnover of over NOK 1bn, they contribute 37% of the sector's total turnover. The pattern is even clearer for tertiary production firms, where 5% of high turnover firms contribute 60% of the sector's total turnover.

The establishment of new businesses in the industry is very low. In 2007, 18 new firms were registered in the industry. However, 12 of these are a result of corporate restructuring and not new businesses. The remaining 6 firms contribute to merely 0.18% of total revenue in the metal industry two years after their registration.

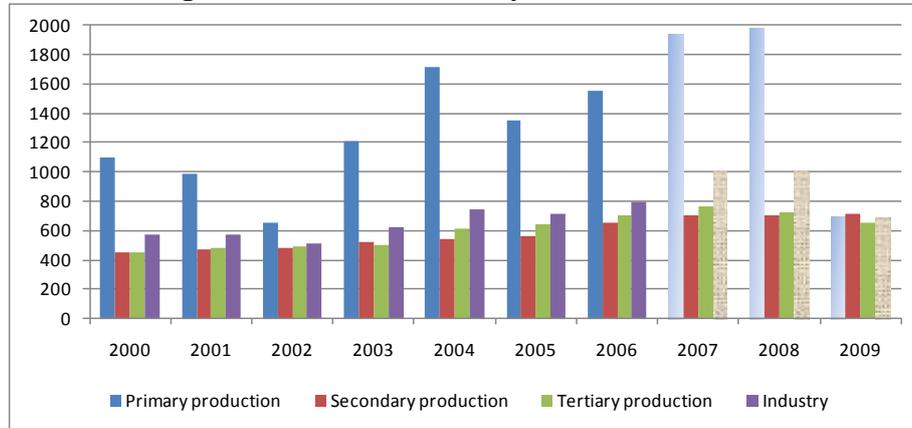
These characteristics reflect the general structure of the industry – there are only a few large players but their contributions to total turnover are significant. While there are few niche firms in primary production, smaller firms that specialize in producing a narrow range of products or services coexist in the secondary and tertiary production sectors together with medium-size niche firms and large firms. Finally, the rate of new establishments is rather low.

3.2 Value creation

We examine value creation per employee in Figure 3-4. The *value creation* of a given firm is defined as the economic resources it creates for distribution among its employees (salaries), capital owners (capital yield net of taxes) and the government (taxes on labor and capital).³ On average, a value creation per employee in the industry was NOK 1m in both 2007 and 2008. This figure plunged by NOK 0.68m in 2009, primarily due to lower global demand for metals as a result of the financial crisis and the corresponding decline in metal prices (for example, the price of aluminium fell from NOK 13,800 per ton at end of Q1 2008 to NOK 7,800 per ton by the end of Q1 2009). For comparison, in 2008, value creation per employee in the maritime industry was NOK 1.4m, while it was NOK 1.2m in the oil supply industry (the oil industry excluding operators, such as Statoil) and NOK 0.6m in the health sector. In the tourism industry, it was NOK 0.4m.

³ A firm's value creation may be approximated as: earnings before interest and taxes (EBIT) + depreciation + amortization + personnel costs.

Figure 3-4: Value creation by sector (2000-2009)

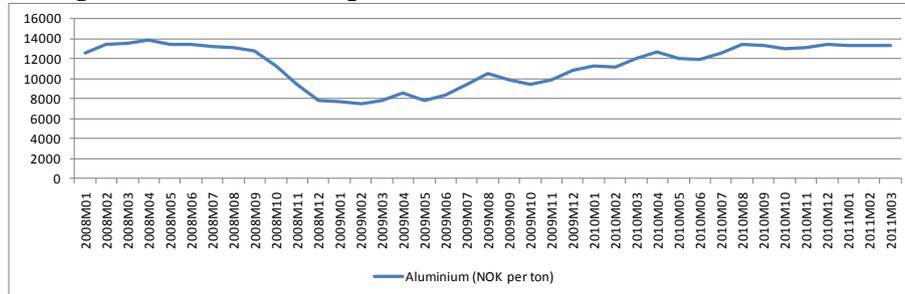


Sources: Brønnøysund Register Centre and BI

The various sectors in the metal industry exhibit different economic properties. Value creation in the primary production sector is very high relative to value creation in the other sectors of the metal industry and other industries. The figures for primary production include all primary production firms as of 2007, but the figures for primary production and industry averages before 2007 exclude Hydro. This is caused by the difficulty of unraveling value creation arising from Hydro's metal operations from value creation arising from its oil and gas operations.

Value creation in primary production in non-crisis years is two to three times higher than value creation in secondary and tertiary production. In crisis years or years in which metal prices are very low, value creation in primary production is similar to value creation in the other sectors. A similar pattern emerges for the years that include Hydro (2007-2009). On average, value creation was NOK 1.95m in 2007 and 2008. As a result of the financial crisis, which led to much lower annual results for primary production firms, value creation dropped to NOK 0.7m in 2009. All else equal, we expect value creation per employee to return to its 2008 level in 2010. For example, figures for the entire Hydro organization indicate that value creation increased by 35% from 2009 to 2010. The plunge in metal prices, especially for aluminium, was short lived. The price of aluminium stayed low at NOK 8,000 per ton from December 2008 to June 2009 but it had stabilized at about NOK 13,500 per ton by August 2010 (see Figure 3-5).

Figure 3-5: Aluminium prices and the financial crisis (2008-2011)



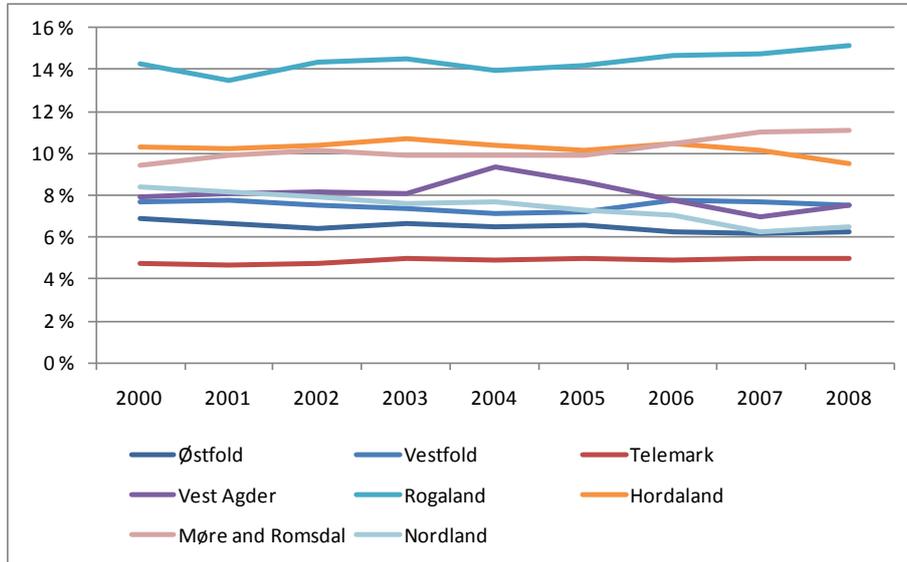
Source: Statistics Norway

Value creation in secondary production and tertiary production, with the exception of the financial crisis year, 2009, has shown steady growth over the period 2000-2009, during which the average annual growth in value creation was 6% for secondary production and 5% for tertiary production. However, the financial crisis dampened further growth in these sectors. The secondary production sector is showing mild growth of 0.7%, while the tertiary production experienced negative growth of 10% between 2008 and 2009. Value creation in these sectors is moderate. Value creation was NOK 0.71m for secondary production and NOK 0.65m for tertiary production in 2009.

3.3 Geographical distribution

One problem associated with the use of company employment data is that employees are counted as belonging to the county in which the company is headquartered. By using employment data from Statistics Norway, we may assign employees to either the county in which they work (place of work) or the county in which they live (place of residence) regardless of where companies are headquartered. In addition to data on total employment, the employment register provides data on employee competences. In this respect, we focus on the distribution of total employment by county and the distribution of employment of university-educated employees by county in accordance with their place of work.

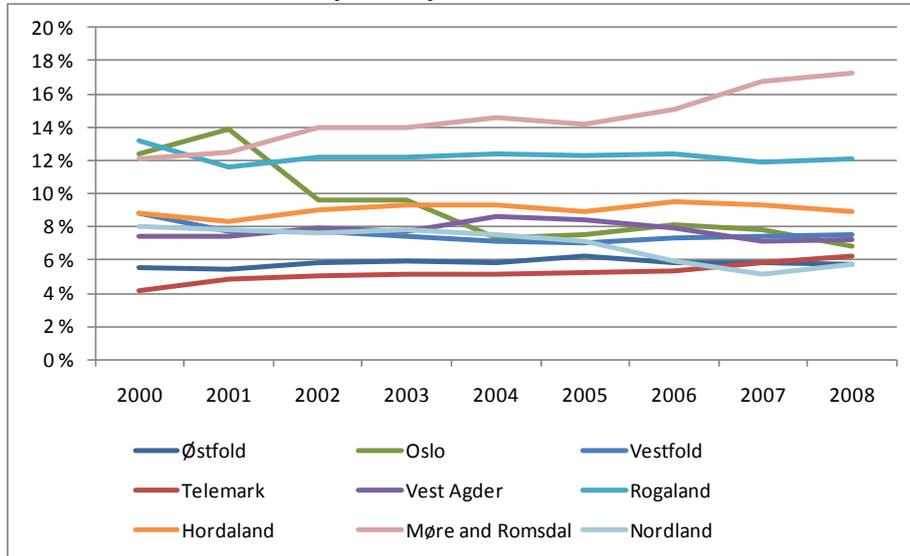
Figure 3-6: Geographical distribution of employment by county (2000-2008)



Source: Statistics Norway and BI

The major employment trend in the metal industry is stability. Figure 3-6 illustrates the market share of employment in the metal industry for all counties with a share of at least 5%. The large fixed-asset investments required in the primary production sector, as well as the smaller but relatively substantial fixed-asset investments necessary in secondary production, result in an industry that is immobile. For example, quarries and primary production facilities that were built more than 50 years ago are still in operation. The only apparent change is a slight increase in the centrality of Rogaland, which is related to an increase in employment in secondary and tertiary production. The figure also establishes that there is no geographical center for the industry. Firms are distributed over eight different counties and no single county has a market share of more than 15%.

Figure 3-7: Geographical distribution of higher education employment by county (2000-2008)

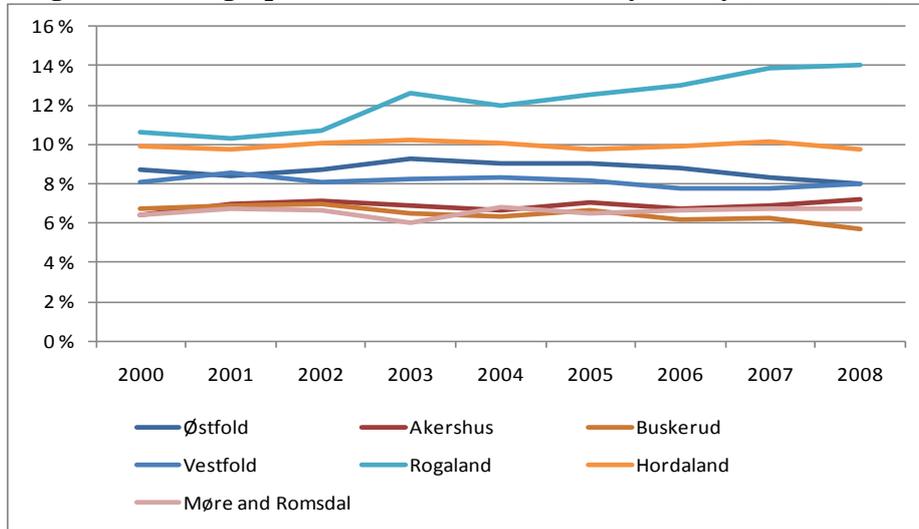


Source: Statistics Norway and BI

With regards to the distribution of employees with a university education, we observe that most counties do not change their relative importance over the period 2000 to 2008 (Figure 3-7). Oslo-based firms show falling employment in their headquarters. The most substantial change is evident in secondary production in Møre and Romsdal, where the number of firms rose by 30% from 2000 to 2008. The figure provides further evidence of the lack of a location-based knowledge center for the industry.

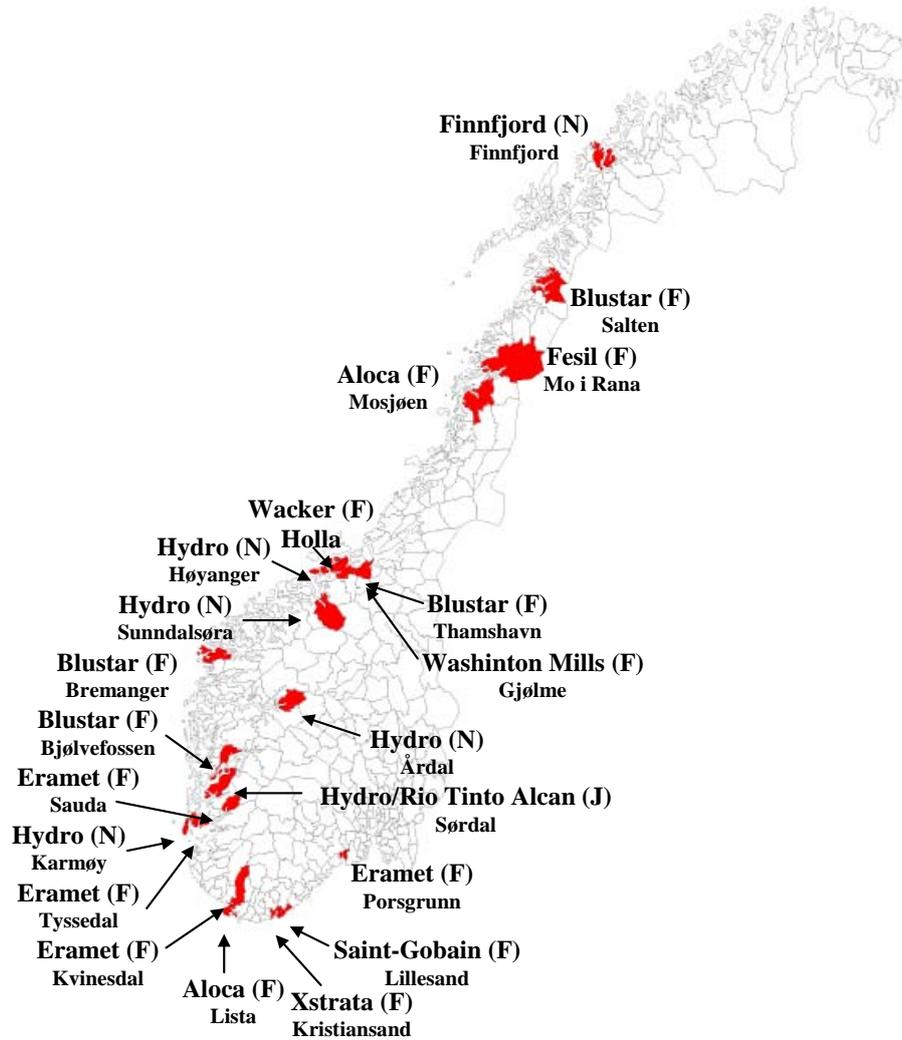
Figure 3-8, which depicts the distribution of firms by county, provides even more support for this finding. There are few changes in the composition of the industry over time and there is no clear center of activities for the industry.

Figure 3-8: Geographical distribution of firms by county (2000-2008)



Source: Statistics Norway and BI

Figure 3-9: Geographical distribution of major actors



Sources: Brønnøysund Register Centre and BI

Figure 3-9 depicts the geographical distribution of the major actors within the Norwegian metal and material industry. The distribution of activities reveals not only that it is conducted in districts but also that it is fragmented. The letters in the parentheses indicate the current ownership of the actors. The letter ‘F’ stands for Foreign and ‘N’ for Norwegian or widely held with a controlling share held by a Norwegian resident or the Norwegian state. All actors but for Hydro and Finnjord are foreign owned. We will return to this point in section 7.

3.4 Cluster attractiveness: conclusions

The Norwegian metal history has been successfully operating over an extending period of time. Its value creation is high but cyclical. However, it is vulnerable to global metal prices and, as indicated by the closure of the Hydro magnesium factory in 2002 and the substantially lower result for primary metal firms during 2009, has a low tolerance level.

Value creation in primary production is significantly above value creation in the rest of the Norwegian economy. Value creation in a non-crisis year for the entire primary production sector is around NOK 2m per employee. This is substantially above findings for other industries such as the oil supplying industry, maritime, and tourism. Secondary production and tertiary production firms have been growing linearly in terms of value creation from 2000 to 2009. Value creation in these sectors is moderate (around NOK 0.7m per employee).

The sectors are structurally dissimilar. Economies of scale and large fixed assets necessitate that primary production firms are large and immobile. More than 90% of the sector revenues is controlled by very few and large firms. Secondary production and tertiary production firms are very similar in their structural distribution. Large firms control 35% and 60% respectively of total revenue in these sectors. A large number of firms are small- and medium-sized.

At first glance it seems that the Norwegian metal industry is complete. Firms are involved in all parts of the value chain. However, as will be discussed in section 9, they are operating in parallel, that is, they to a very small extent constitute a tight network of customer-supplier relations. Secondary production and tertiary production firms do not specialize in related technologies or have evolved to be leading global suppliers through further value addition activities utilizing the metals produced by the primary production firms (see further section 9).

Production of metals including the subsequent value addition activities is not concentrated in any specific county or area. Primary production is mostly situated in the vicinity of a major power supply plant. To a large extent secondary production and tertiary production firms are not located in the vicinity of primary production units or other secondary production and tertiary production firms, but are located in the vicinity of their customers.

4 Education attractiveness

The ability of an industry to successfully compete in its relevant market is increasingly dependent on investments in human capital. Clusters are specialists in transforming generic education into productive use. While educational programs in various disciplines are found around the globe, there are generally only a few clusters for each discipline and these are located in just a few countries. The distribution of commercial activities based upon the knowledge of a specific discipline is spiky. This is even more apparent when knowledge from a number of disciplines is required. In other words, such commercial activity is not uniformly distributed across countries or regions.

Clusters can only excel in productively channeling knowledge if the human capital existing in educational institutions has the necessary basic knowledge and if that knowledge is increasing. Investments in human capital are first made by educational institutions outside the scope of control of industrial actors. Such investments enable the creation of industries. If they are lacking, industrial activities tend to disappear (for example, the knowledge required for constructing hydropower stations no longer resides within the human capital of the younger generation of Norwegians as a result of political factors, educational factors and a substantial reduction in the activity level). All else equal, if an industry is to be attractive over an extended period of time, it must be able to attract the best human capital into educational programs that provide the prerequisite knowledge upon which firms can build. Therefore, in this chapter we focus on the investments made by educational institutions.

Human resources generally receive advanced, subject-specific education through public education systems. As the OECD comments, "...almost every aspect of R&D and innovation requires the input of skilled people" (OECD 2010: 41). On a country level, Norway has performed worse than the vast majority of OECD countries with regards to education. The proportion of graduates with science and engineering degrees increased slightly from 1998 to 2007. Norway educated approximately 7.5% of its graduates in engineering and an equivalent percentage in science, which places the country in sixth-last place among the OECD countries (OECD 2010). There are even greater grounds for concern when the shares of degrees awarded to women are examined. With only 28% of science and engineering degrees awarded to women, Norway exhibits lower levels of gender equality than other OECD countries, including the traditionally male-dominated societies of Italy (38%) and Spain (37%), and lower levels than in other Scandinavian countries (Finland 29%, Sweden 34%, Denmark 34%). Therefore, it is

pertinent to examine the extent to which Norway educates future generations in subjects pertaining to the metals industry.

An attractive education program should lead to increasing interest in the program in absolute and relative terms. Absolute terms concern the availability of qualified personnel in the future, while relative terms concern the relative attractiveness of the subject to the general student population. All else equal, lower figures in relative terms will lead to the relevant industry representing a lower share of GDP in the future because a growing number of graduates will find employment in firms engaged in other activities.

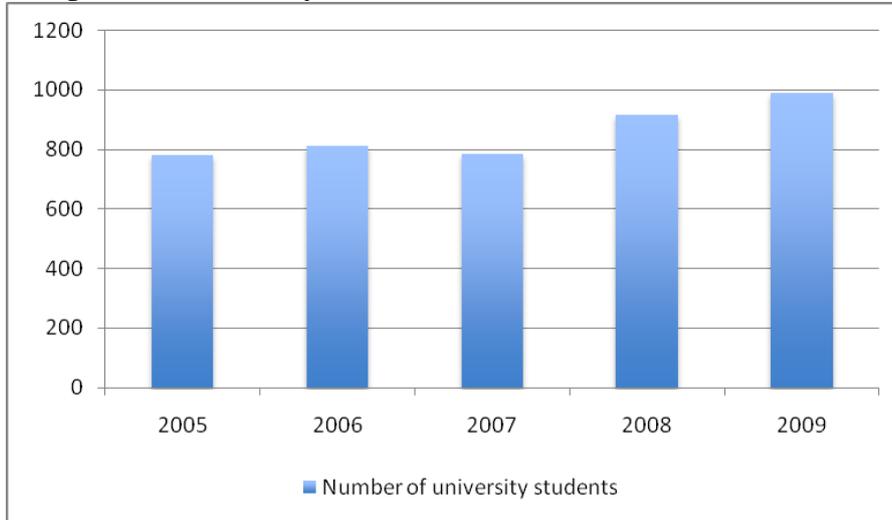
In this study, ‘education attractiveness’ is operationalized in the following manner:

- Level and growth of university students studying in metal-related fields,
- Share of university students studying in metal-related fields, and
- Level and growth of students studying in metal-related fields by educational level.

In this analysis, a distinction is made between the Master and PhD levels, so that university students are specifically categorized as Master or PhD students in metal-related subject areas. Master students include those taking the Norwegian engineering degree that can be obtained after five years of university studies (Sivilingeniør). Related subjects are narrowly defined to include materials science and metallurgy. To account for the lack of data on PhD students before 2002 and the impact of the Step I implementation of the Amendments to the University Acts in 2002⁴, which followed the Bologna process on higher education, the analysis is conducted using annual figures for the period from 2005 to 2009.

⁴ The amendments in pursuance of the EU harmonization of educational programs for Bachelors, Masters and PhDs.

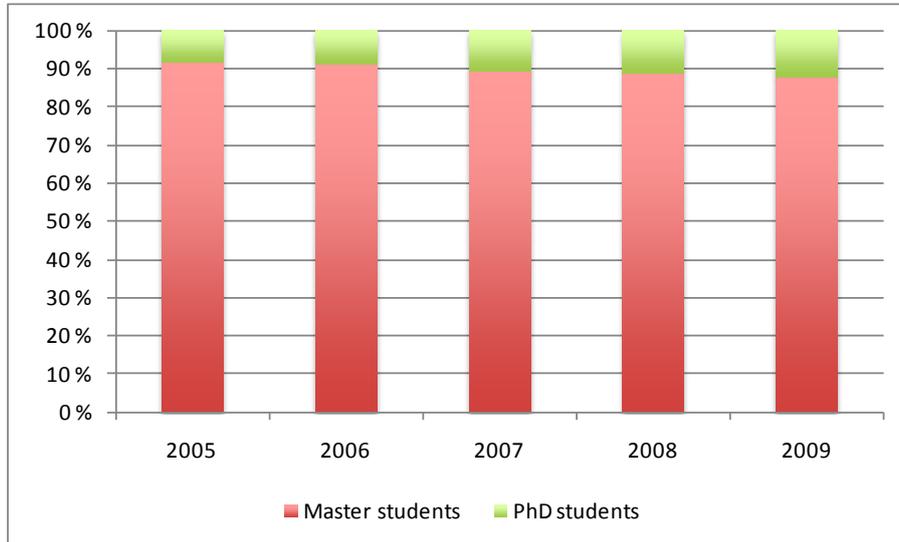
Figure 4-1: University students in metal-related fields (2005-2008)



Sources: NSD and BI

As Figure 4-1 illustrates, the number of graduate students enrolled in metal-related subjects has been increasing over time. The average annual growth rate of graduate students in metal-related subjects amounts to 4.8%, indicating that these subjects have attracted more students over time and, as a result, that the education sector is producing a growing number of qualified workers. When compared to national growth rates for graduate students (1.8% p.a. on average over the same period), growth in educational subject areas related to the metal industry is high. All else equal, this indicates that the knowledge platform from which the industry can draw is increasing.

Figure 4-2: University students in metal-related fields by study level (2005-2009)



Sources: NSD and BI

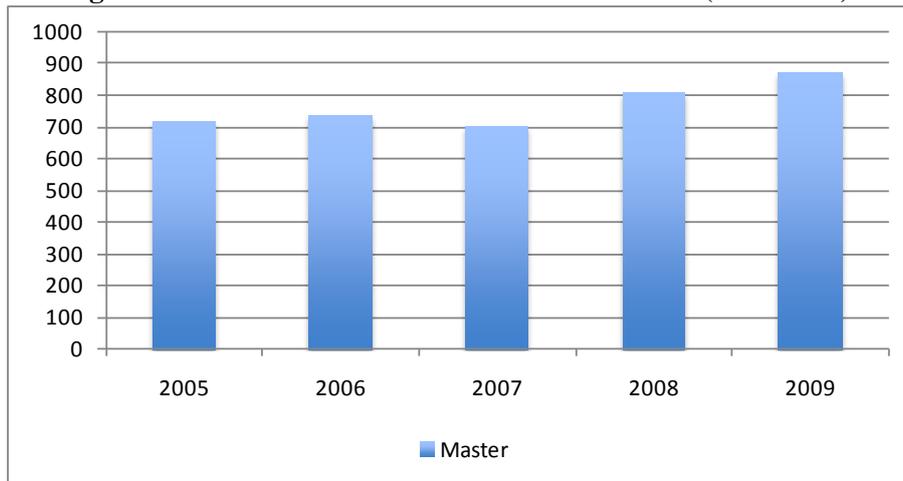
Figure 4-2 illustrates how the different levels of higher education are distributed over time. The share of Master students has decreased by approximately 4% from 91.8% to 88.1%, which can be attributed to a significantly lower, albeit positive, growth in the number of students on this level compared to the number of students undertaking a PhD. The share of PhD students as a proportion of all students enrolled in metal-related subjects has increased by 4%, which indicates that this educational level is supplying a higher proportion of talent to both the metal industry and academia, which may further accelerate academic productivity in the long run.

4.1 The attractiveness of metal-related education

Currently, no distinct Bachelor programs related to the metal industry are offered in Norway. Nonetheless, an increasing number of students are entering Bachelor programs in chemistry, which serves as an important foundation for more specialized graduate programs related to the metal industry. In the period of analysis, the number of Bachelor students enrolled in chemistry increased from 338 in 2005 to 621 in 2009, which represents an average annual growth rate of 18.7%. Moreover, the Norwegian 'Sivilingeniør' education in Material Science can be viewed as including an undergraduate education equivalent to the Bachelor level, as the program encompasses five years of study that culminate in a Master's degree.

Enrollment in the materials science ‘*Sivilingeniør*’ study subjects has grown at an average annual rate of 8.3%. Even more interestingly, growth in 2008 (11.3%) and 2009 (15.5%) in this subject was significantly higher than the averages for other subjects, indicating that this subject has become increasingly attractive in recent years.

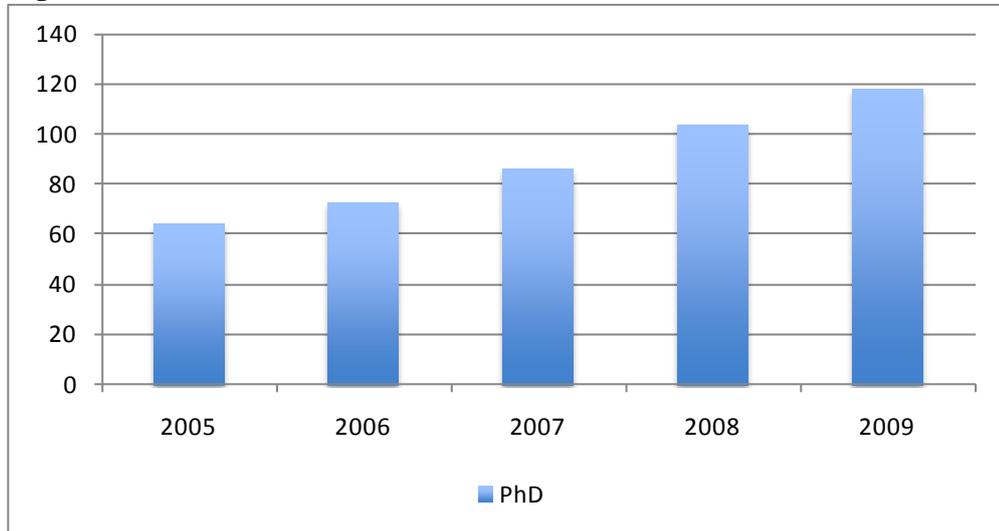
Figure 4-3: Master students in metal-related fields (2005-2009)



Sources: NSD and BI

As shown in Figure 4-3 the number of students in metal-related study subjects has increased at an annual average rate of 3.6%. Although the numbers indicate lower growth in students on this educational level than on the PhD level, this growth still follows a positive trend. By comparison, the level of Master students in the Norwegian educational system was stable over the reference period.

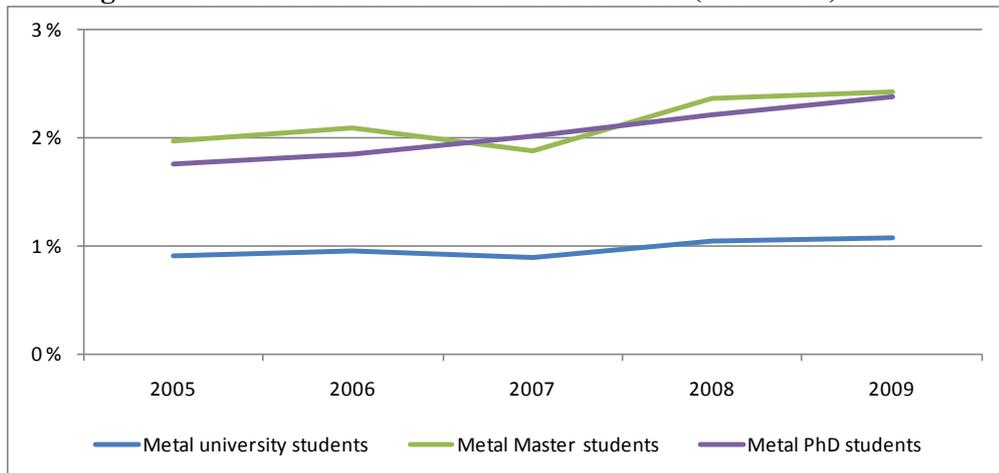
Figure 4-4: Number of PhD students in metal-related fields (2005-2009)



Sources: NSD and BI

Figure 4-4 shows that there has also been an increase in the number of PhD students in metal-related study subjects. Furthermore, the annual growth of 13.5% is significantly higher than the national average for the reference period. The majority of PhD students conduct their studies within Material Science, which also shows a positive growth trend.

Figure 4-5: Attractiveness of metal-related fields (2005-2009)



Sources: NSD and BI

Figure 4-5 provides an indication of the centrality of metal-related subjects compared to the national development of the total numbers of students on each level. If metal-related study fields are gaining popularity among the student population, one should observe an increase in the proportion of students taking metal-related subjects to the total number students. The top two lines in the figure provide support for the argument that the pool of graduates on the Master and PhD levels is increasing. Both educational programs are clearly gain market share in the advanced university educational market.

4.2 Educational attractiveness: conclusions

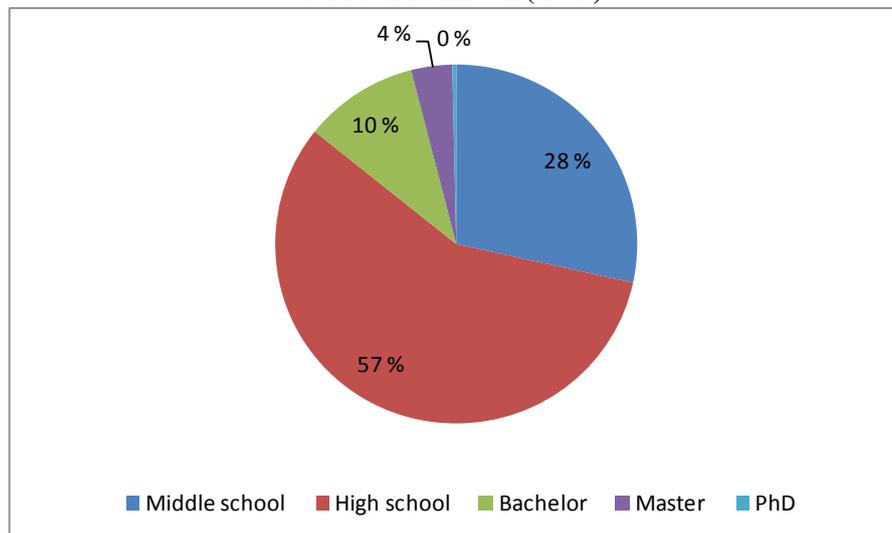
The pool of graduates with relevant advanced knowledge of metal and materials is increasing in absolute and relative terms. This indicates the likely future availability of a larger pool of qualified R&D personnel in R&D institutions and of qualified workers who can accept employment in the metal industry. However, the same pool of graduates is highly sought after by other industries. As is evident in the next two sections, it is research institutions related to metals and materials that attract talented graduates (see section 6) and to a much lower extent, the industry itself (see section 5).

5 Talent attractiveness

Educational institutions produce a kind of unique raw material: knowledge workers. Industries and firms compete in labor markets to attract the best and most talented knowledge workers. To the extent that an industry can attract talented individuals, it is better positioned than an industry that cannot. Hence, the output of educational institutions has to be attracted to specific industries. For an industry to be attractive over an extended period, it must be able to attract the best human capital and then invest in competence development on the firm level. This section focuses on the degree to which the metal industry has been successful in attracting and retaining highly developed human capital, while section 9 focuses on competence development programs initiated by the firms themselves.

In order to ensure the reliability of our findings, we conduct two analyses. The first is based on the employment composition of metal firms from 2000 to 2008. As such an analysis may exaggerate growth rates, we also conduct an analysis based on firm affiliations with the metal industry based upon their NACE codes (industry classification). The results of these analyses differ insignificantly and they support the same conclusions.

Figure 5-1: Distribution of the metal industry's labor force by educational level (2008)

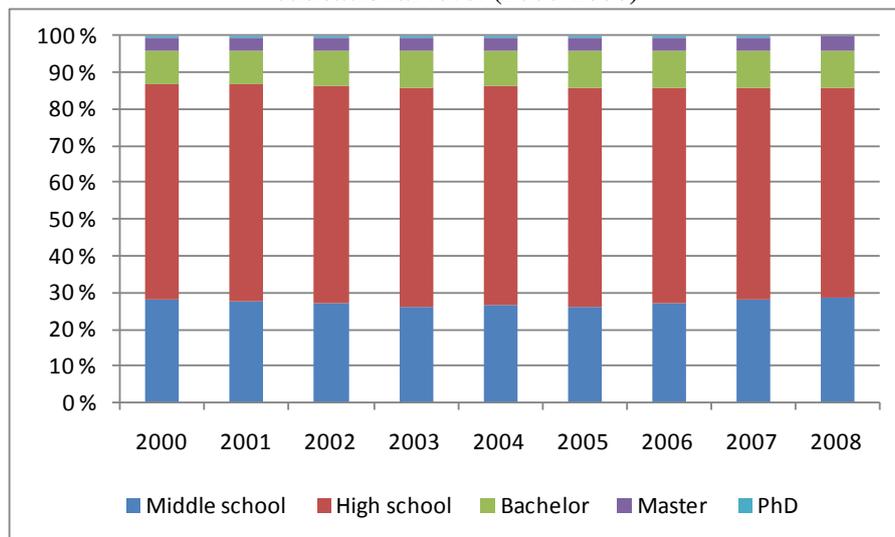


Sources: Statistics Norway and BI

Figure 5-1 displays the educational breakdown of the labor force employed in the Norwegian metal industry in 2008. The composition differs

significantly from the composition of the entire privately employed workforce in all industries in Norway. The most notable difference is evident in the percentage of university-educated employees. In the entire privately employed workforce, 30% of employees have completed a university education. The corresponding figure for the metal industry is 14%. Another major difference is found in the group of employees who have completed only middle school (28% in the metal industry and 16% for the entire privately employed workforce). Hence, on the aggregate, the metal industry does not attract advanced human capital relative to the available human capital in the workforce. The distribution of employment by education level in the metal industry is very similar to the distribution in other manufacturing industries (e.g., food, textiles, wood pulp and paper, and chemicals) and labor intensive industries (e.g., Fishery).

Figure 5-2: Distribution of employees in the metal industry by educational level (2000-2008)



Sources: Statistics Norway and BI

It is also useful to examine whether the composition of the metal industry workforce changed over time. Figure 5-2, which presents the distribution of employees over five educational levels over time, allows for inferences about the degree of professionalization in the industry. If we distinguish between the lower educational levels (middle and high school) and the higher educational levels (Bachelor, Master and PhD), we observe that the relative size of these groups has remained unchanged throughout the period 2000-2008. At the same time, the share of the workforce in the industry with a Bachelor-level education increased slightly from 9.4% in 2000 to 10.2% in

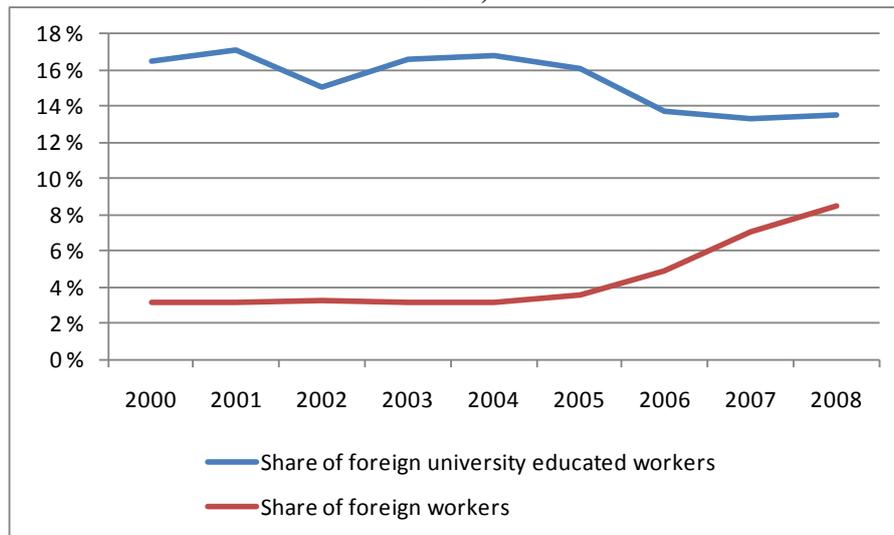
2008, and the share of employees holding a Master or PhD degree decreased somewhat (3.8% to 3.7% for Masters and 0.4% to 0.3% for PhDs).

5.1 Foreign employment

An attractive industry is a magnet for foreign talent. To what extent has the metal industry been successful in attracting advanced foreign human capital? Not only did the number of foreign workers within the metal sector increased by 164% over the nine-year period (Figure 5-3), but foreigners' relative share of total employment in the metal industry also increased by 5.3 percentage points from 3.2% to 8.5%.

An analysis of growth by origin type allows for further inferences with respect to shifts in the distribution over time. The growth rate for foreign employees is in sharp contrast to the decline in total employment in the metal industry during 2000-2008 (see Figure 5-3).

Figure 5-3: Foreign labor: participation and educational level (2000-2008)



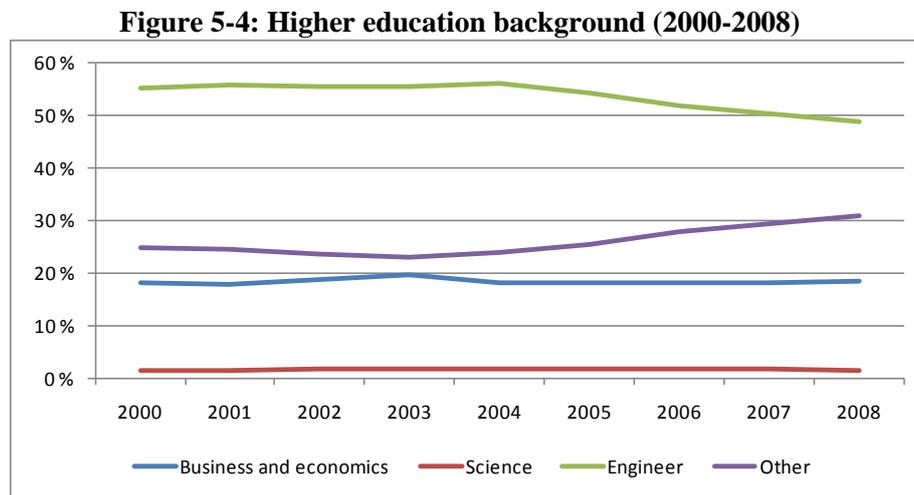
Sources: Statistics Norway and BI

The educational level of foreign workers on the aggregate is similar to the rest of the workforce within the metal industry. Only 13% of foreign employees in 2008 had a university degree, which is lower than the 16% observed in 2000 but in line with the industry composition of 14%. The foreign labor that the industry attracts is as advanced in terms of post-secondary education as the entire metal industry workforce. The largest difference between these two groups is found in the composition of

employees with middle school and high school education. While 28% and 57% of the metal workforce had completed middle school and high school, respectively, 50% of the foreign metal workforce had a middle school education and 37% had a high school education. Therefore, the education level of the metal industry’s foreign workforce is substantially below that of the national metal-related workforce.

5.2 Sources of formal education

The industry clearly relies on hands-on, experienced-based knowledge development (see section 9). In this section, we examine the extent to which the composition of the workforce with an advanced formal education changed from 2000 to 2008.



Sources: Statistics Norway and BI

Figure 5-4 covers the evolution in the composition of employees with advanced degrees by educational background. The percentages of scientists and employees with business and economics backgrounds out of the total employees with higher education are unchanged throughout the period. In contrast, the share of employees with an engineering background dropped from 55% in 2000 to 49% in 2008. At the same time, the share of employees with other social science backgrounds increased from 25% to 31%. This increase is explained by the professionalization of support activities, which used to be conducted by employees without a university education.

This may also explain the decline in the share of engineers to some extent. However, at the same time, the number of employees with a higher education fell from 3,140 to 2,957. In primary production, the decline in

engineers is moderate. From 2000 to 2008, the number of engineers decreased by 21 (3%). In secondary production and tertiary production, the number fell sharply by 268 (25%) indicating that advanced human capital directly relevant to the sources of creation of new products and processes is exiting the industry.

5.3 Talent attractiveness: conclusions

The labor composition of the metal industry differs substantially from that of the rest of the Norwegian private sector. Its composition is in line with the industry's focus on manufacturing as evident from the composition in other manufacturing industries (e.g., food, textiles, wood pulp and paper, and chemicals) and labor intensive industries (e.g., fishery). However, the trend in the composition of employment is one of stability. While the economy as a whole is advancing in terms of the general level of higher education, the composition of the human capital employed in the metal industry remains unchanged.

The share of foreign employees relative to total employment in the metal industry rose from 3% in 2000 to 8% in 2008. However, this increase has not contributed positively to the stock of human capital of the metal industry labor force. The average foreign worker is more likely to have completed a lower level of education than the average local worker.

The educational background of workers with a higher education is changing. Two trends are evident. First, support activities are being professionalized, which is in line with developments in the rest of the economy. Second, there is a clear decline in both the share and the number of engineers, especially with regard to secondary and tertiary production. This is likely to have negative effects on the likelihood of and sophistication of future innovations originating from these sectors.

6 R&D and innovation attractiveness

Research and innovation play central roles in economic progress and in shaping the trajectory of societal development. In this regard, a debate fueled by Norway's low percentage of gross expenditure on R&D (1.6%) relative to total Norwegian GDP has been underway for some time. On the one hand, some argue that Norway spends as much on R&D as New Zealand, another country rich in natural resources, and hence its R&D expenditure is in line with its industrial structure. On the other hand, some argue that Norway is failing to utilize its resource richness to invest in future innovation that would provide continued funding for the high standard of living and the relatively expensive social welfare system.

In this section, we provide evidence that the research community related to the metal industry is substantially more productive than those related to other Norwegian industries and that firms within the metal industry are more innovative. We also discuss the extent to which the metal industry is attractive for R&D-related investments, as well as its capacity to develop innovative outputs. In the conceptualization of R&D and innovation attractiveness, we examine R&D intensity, the structure of R&D investments, properties of institutional R&D, properties of firm R&D, financing innovation, innovative output, obstacles for innovation and the protection of investments in innovation.

6.1 Current Norwegian metal innovation system

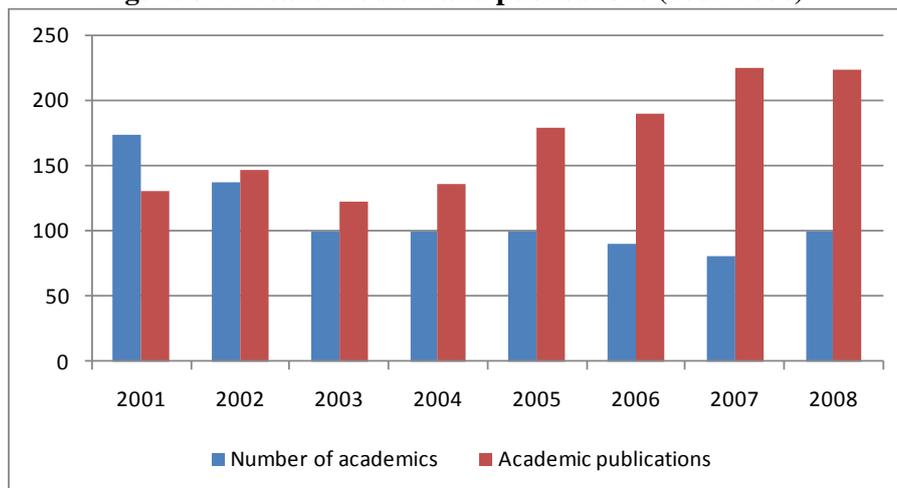
6.1.1 Academic R&D

How productive are the academic resources available in the metal industry? In order to investigate the productivity of industry-relevant resources, we examine the development of the number of publications, and the number of academics in related fields working within academic institutions and their productivity in terms of publication activity. OECD uses a similar measure – the number of scientific publications per million population – as a measure of R&D investment outputs. All else equal, the number of publications is a good proxy for the return on investment in the educational sector. Academic publications constitute a platform upon which commercialized innovation can occur. However, as scientific output is not a commercialized invention or innovation, we view it as an input to the two major objectives of economic progress and the shaping of society in the future, rather than as an output (commercialized activity).

Figure 6-1 illustrates the number of academic publications and the level of academic staff within the metal industry from 2001 to 2008. The analysis

follows a narrow definition of metal-related subject areas, which includes only materials science and metallurgy. While academic publications have increased on average by 6.1% per year, the number of academic staff has declined at an average annual rate of 6.5%. However, from 2007 to 2008, the number of academics in the field increased by 23.8%, which might indicate a possible positive trend shift.

Figure 6-1: Academic staff and publications (2001-2008)⁵

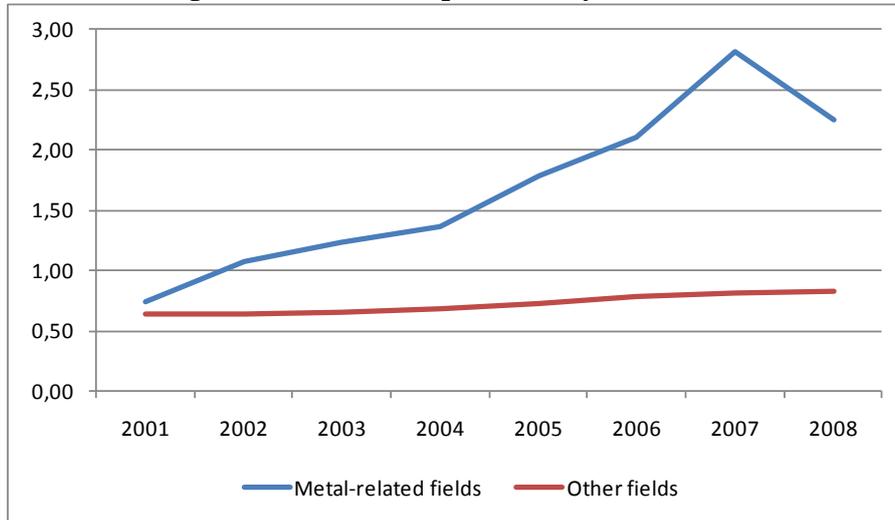


Sources: ISI web of science, NSD and BI

Figure 6-2 compares academic productivity levels in the metal industry with national levels. The rate of scientific publications per academic working within metal-related research areas rose from 0.9 in 2001 to 2.3 in 2008. The slight decrease from 2007 to 2008 can be attributed to the increase in the total number of academic staff in 2008. Compared to national levels, metal outperforms national productivity both in overall terms and in terms of growth. In other words, academics within metal-related fields appear to be considerably more productive when it comes to publishing their research outcomes than their colleagues in other research fields.

⁵ Due to missing data, 2002, 2004 and 2006 are based on estimates. The decline between 2001 and 2003 can be attributed to a reclassification of academic staff.

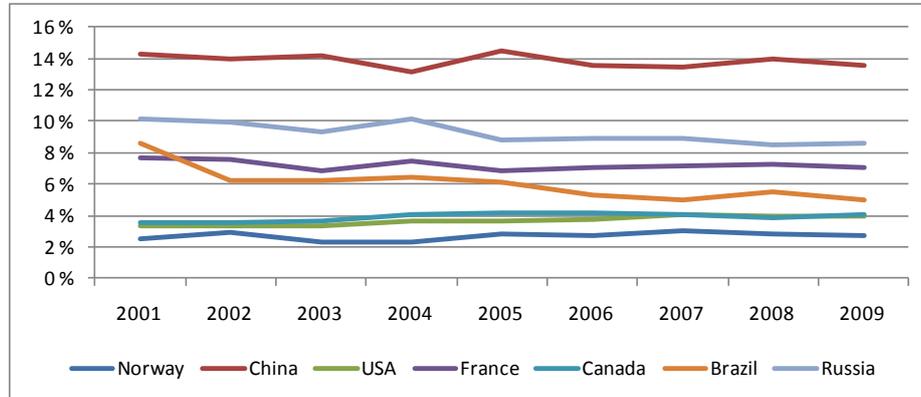
Figure 6-2: Academic productivity (2001-2008)



Sources: ISI web of science, NSD and BI

While academic researchers within metallurgy located in Norway are more productive than their colleagues in other academic departments, competition on the metals and materials markets is global. Figure 6-3 highlights the importance of metallurgy and material sciences to the core countries involved in the metal industry. The figure provides the share of publications in metallurgy and material sciences relative to the total number of scientific publications in each country. In Norway, the share of such publications varies between 2% to 3% from 2001 to 2008. This is relatively similar to the metal industry's share of Norwegian GDP (varies slightly around 3% from 1999 to 2008; see section 2). A relatively constant proportion of metal-related publications to the total number of national scientific publications is also evident in most other countries. While this share is 3% in Norway, it is 14% in China and 8% in Russia and France.

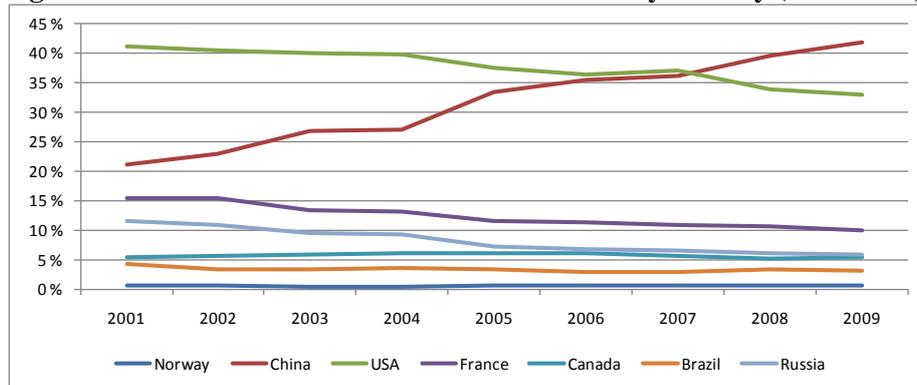
Figure 6-3: Academic specialization in metals and materials by country (2001-2009)



Sources: ISI Web of Science

A country's specific academic specialization is affected by its industrial structure. Given this bias, we examine the market share that each country holds in the market for publications on metals and material. We examine market share among the countries included in Figure 6-3 and find that Norway maintained its global market share of 1% throughout the period (Figure 6-4). However, China doubled its market share from 21% in 2001 to 40% in 2008. Furthermore, China's market share has surpassed the market share held by the US. The latter fell from 41% in 2001 to 34% in 2008.

Figure 6-4: Market share in metals and materials by country (2001-2009)



Sources: ISI Web of Science

In summary, the academic output in Norway related to the metals industry exceeds by far the national average, which reflects decades of experience with the industry in Norway and the resulting knowledge-intensity in the country's academic specialization. On a global scale, Norway is not a central

player in academic research relating to metals and materials in general, and its market share of this research remains stable over time. It may have developed niche competences as is evident in new aluminium production processes and advanced material innovation (see Ragasco AS). For this end, we focused on the Norwegian market share out of the total production of articles by academics residing in the list of countries referred to in Figure 6-4 in the narrow field of metallurgy. The results are very similar to those presented in Figure 6-4. Norway maintains a 1% market share from 2001 to 2009 (It actually decreases from 0.94% to 0.79%), while China gained market share (from 40% to 60%) and U.S. lost 14% (from 29% to 15%). One question arises: to what extent do firms operating within the metal industry utilize this advanced knowledge base?

Transforming technological ideas or production? As the fourth most common metal on Earth, titanium is relatively abundant. Titanium (and titanium alloys) has several unique properties that make it highly desirable. It is light and strong, and has the highest strength-to-weight ratio of any metal. The metal is also biocompatible, meaning that it will not be rejected by the human body, which enables its use in medical and surgical applications. In addition, it is well suited for use with composites, and is corrosion resistant in seawater and other corrosive environments.

However, primary production of pure titanium is a complicated procedure. The metal is produced in the form of titanium sponge through the multi-step Kroll process. This raw metal is then processed in numerous ways by various actors within the titanium sector.

Alf Bjørseth's company, Scatec AS, established Norsk Titanium AS in 2004. The company is managed from Oslo and currently consists of two subsidiaries: the fully owned Norsk Titanium Technology and Norsk Titanium Components. Norsk Titanium Technology conducts ongoing R&D with the aim of identifying and developing new production processes for the manufacture of titanium primary metal.

New, advanced production methods in the titanium value chain could offer significant environmental benefits. The undesirable chemical compounds currently used in the production process may be made redundant and energy consumption in the manufacturing processes could be dramatically reduced. In this regard, Norsk Titanium Technology's goal is to create the world's most efficient, environmentally friendly production of primary titanium metal in the forms of titanium sponge and titanium powder of high purity and high quality. Its main activity will be to secure raw material for Norsk Titanium Components, but the company will also be open to supplying other manufacturers. The firm cooperates with a number of actors, including SINTEF, NTNU and Kongsberg Automation, in order to gain access to specialized competences at each stage of the value chain.

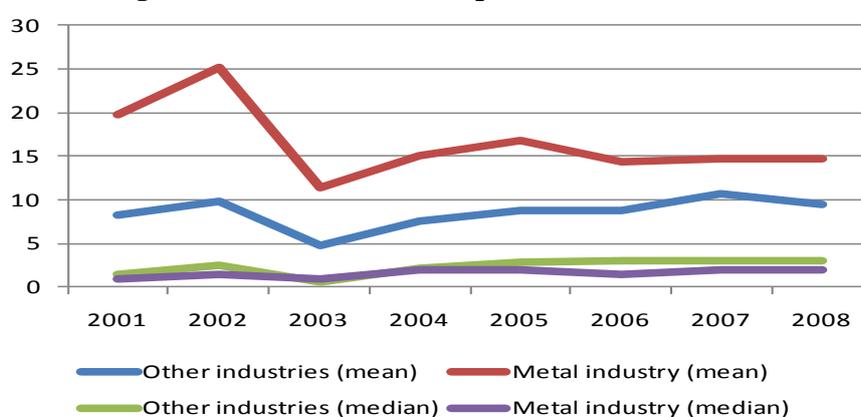
If the process is proven beneficial, will full-scale production commence in Norway? In addition, does Norway's competitive advantage lie in transforming technological ideas into viable production processes or in continuous production based on such technological advancements, or both?

Based on information from <http://www.norsktitanium.no/> and an interview with Scatec.

6.1.2 Firm R&D

To what extent can firms tap into the knowledge base residing within dedicated R&D institutions? Our attempt to answer this question begins with an analysis of firm investments in R&D personnel. One indicator of the capacity for innovation and execution of R&D projects is the total number of R&D personnel and researchers (OECD 2010: 44). Figure 6-5 provides an overview of the mean and median numbers of domestic personnel employed in firm R&D activities in the metal industry, and the mean and median levels for the rest of the Norwegian economy.

Figure 6-5: Number of R&D personnel (2001-2008)



Sources: Statistics Norway and BI

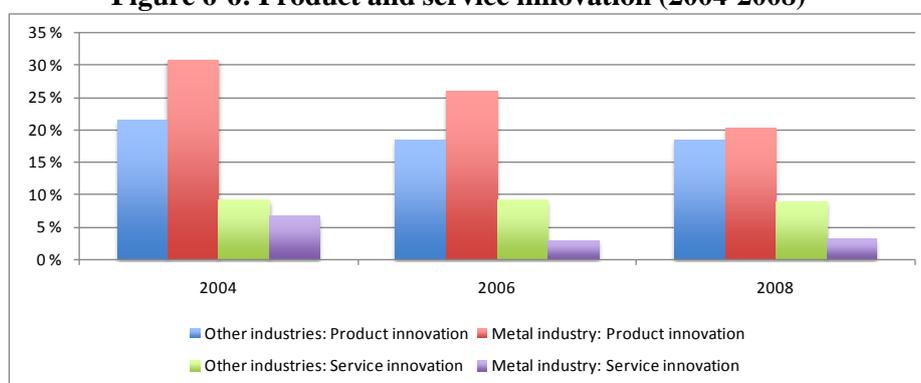
The metal industry appears to have a significantly higher average amount of employees active in firm R&D activities. The search for new resources and process efficiency is an inherent feature of the industry, which can be characterized by high demands on innovation and a constant search for innovative solutions. However, a decreasing trend in R&D-related personnel is apparent. The average level of R&D personnel per firm has declined and is regressing towards the mean levels of R&D personnel in the general economy. The median level of R&D personnel remains at lower, constant levels and is almost identical to the rest of the economy. The difference between median and mean indicates that the larger firms, which conduct the majority of R&D in the industry.

In light of the large investments related to operational efficiency in the industry, this decline may indicate that the underlying sources of efficiency gains are too complicated for in-house R&D. Alternatively, the decrease may be explained by the availability of more attractive opportunities for R&D personnel in other industries.

6.1.3 Current innovative capacity

An industry is attractive to the extent to which the firms operating in it can document a track record of innovative output. The nature of the relevant innovation – be it related to a product, a service or the organization as a whole – depends on industry-specific characteristics. The metal industry exhibits above-average product innovation levels. However, these innovation levels are regressing towards the mean product innovation levels in the Norwegian economy. Furthermore, the industry’s innovative capacity with respect to service innovation is declining, creating a widening gap to the service innovation capacity of other industries.

Figure 6-6: Product and service innovation (2004-2008)

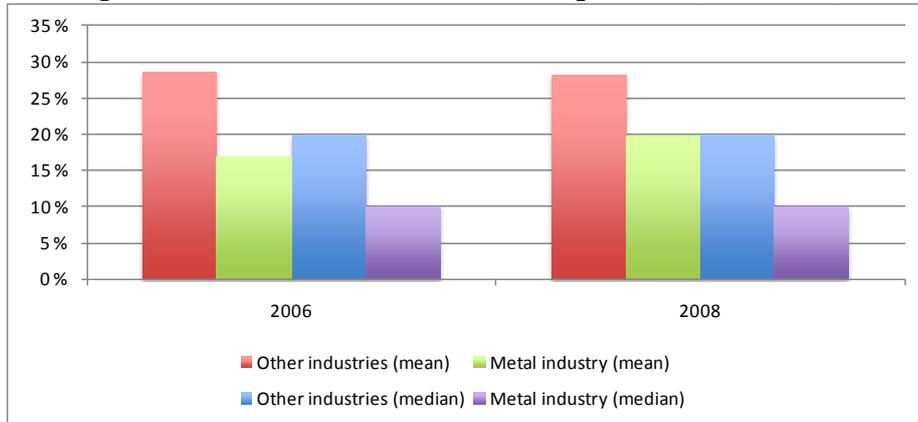


Sources: Statistics Norway and BI

Figure 6-6 presents the proportions of firms that introduced product or service innovations in the form of new or significantly improved goods in 2004, 2006 and 2008 (as a percentage of total answers). As the metals industry is less dependent on services than on products, innovation levels for services are lower. However, from 2006 to 2008, the amount of firms that introduced an innovative product fell from 26% to 20%. This means that only one out of five firms introduced a new product despite stable median levels of R&D personnel over the same period (Figure 6-5).

The apparent reduction in product innovation may indicate that innovation becomes more difficult over time as a result of the cost of innovation and the actual abilities of firms to introduce new products. The general industry trend could also be affected by the fact that margins are under pressure and that there are relatively few start-ups.

Figure 6-7: Turnover derived from new products (2006-2008)



Sources: Statistics Norway and BI

Figure 6-7 presents the percentage of turnover that originates from new or substantially improved products. As Figure 6-6 demonstrates, a comparison of the situation in 2006 and 2008 shows that the level of new product development and innovation has declined in the metals industry over time, which might be expected to directly influence turnover derived from new products. However, Figure 6-7 does not support this assumption. While innovative output has decreased, firms appear to generate the same turnover from innovative output in 2008 as in 2006. This allows for inferences about the relative quality of the innovations, which is inherent in the firm's ability to generate value from such innovations.

Magnesium is one of the lightest metals and has many structural applications. In recent years, the consumption of magnesium has grown significantly, particularly within the automobile industry. Norwegian magnesium production in Herøya started in 1951 at what was then one of Europe's largest magnesium plants, where it continued under Hydro's direction until the plant was closed in April 2002. The magnesium plant produced two products: magnesium alloys, which were primarily used for automotive components and electronic equipment, and pure magnesium, which was mainly used in aluminium alloys.

In 1935, Hydro began to explore the opportunities for a magnesium plant in Herøya, but was unable to get a license for the German-owned electrolytic production technology it required. The company therefore developed its own technology, which would allow it to produce magnesium from seawater. The initial idea was to become specialized in this new technology before moving on to develop a full metal production plant. At the time, magnesium was a prized alloy that was widely used in automotive and aircraft production. The metal was also utilized in the production of grenades, firebombs and optical instruments, as well as in the textile and printing industries.

In 1941, the company Nordisk Lettmetall was created, with shares owned by Hydro, I.G. Farben and Nordag. The latter represented the German Ministry of Aviation. After the war, Nordisk Lettmetall was taken over by the Norwegian state and Hydro, and renamed Herøya Elektrokjemiske Fabrikker AS. Reparation of the damage caused by the war took four years. Finally, in August 1951 Hydro's magnesium production at Herøya could then begin in earnest. By that time, the company had taken over the government's stake and was the sole owner of the firm. Hydro made its historical first delivery of magnesium in 1953. The years that followed brought major technological developments and plant expansions.

After more than 50 years of magnesium technology development in Norway, the company found it impossible to handle international competition, particularly from the Chinese. On October 25, 2001, Hydro's corporate assembly agreed to shut down magnesium production at the Herøya plant. Production was gradually reduced during the winter of 2001-2002, and on April 5, 2002, the plant closed. The plant in Herøya now stood empty, ready for a possible revival if market conditions or technological progress should prove to be favorable in the future.

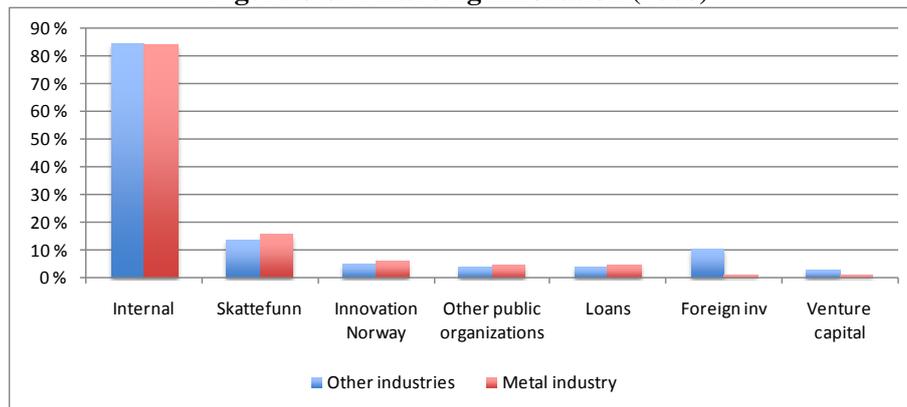
Based on information from the Hydro brochure 'Magnesiumproduksjonen på Herøya'.

An analysis of the gap between mean values and median values of turnover derived from new products in the metal industry shows that some firms appear to be able to generate significantly higher turnover from their innovations than others. This indicates a large difference not only in firms' capacity to innovate but also in their ability to commercialize their innovations. Product innovations have fewer effects on the total turnover of metal firms than in other industries. For the median firm in other industries, 20% of turnover can be attributed to new or substantially improved products. The corresponding figure for the median firm in the metal industry is a mere 10%.

6.1.4 Financing R&D

In order to understand the extent to which firms will be able to maintain and enhance the level of innovation in the future, we need to understand the principal factors that prevent them from innovating. Given the challenging nature of financing risky projects over extended periods, we focus on the financing of innovative activities.

Figure 6-8: Financing innovation (2008)



Sources: Statistics Norway and BI

Figure 6-8 shows the proportions of various financing sources for R&D relative to total R&D financing in 2008. The graph compares mean values for financing sources in the metal industry with mean values of all other industries combined. Other financing sources have also been analyzed but were found to be insignificant.

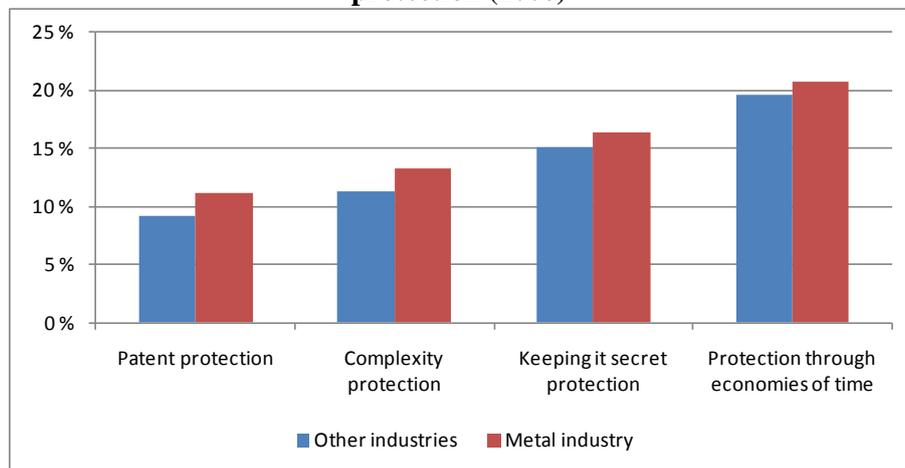
The metal industry follows the general trend of the economy in terms of financing R&D. The primary source of finance is internal capital, which contributes approximately 85% of the total financing in the industry. Investment in innovative projects in the metal industry appears to be unattractive to both foreign investors and venture capitalists. While the large

firms have access to equity markets and can finance R&D through equity and free cash flow, start-up firms do not have access to a vibrant venture capital community that is willing and able to invest in their projects. Skattefunn and Innovation Norway, which are important sources of R&D financing, provide above-average funding to the metal industry. Although these sources are helpful, they cannot offset the lack of investments by and the role played by venture capital firms.

6.1.5 Protecting investments in innovation

The initiation of innovative activity is also dependent on the extent to which the proceeds of investments in innovation can be shielded from imitation by competitors (Barney 1991; Peteraf 1993). Figure 6-9 shows the percentages of respondents that have chosen to protect their inventions and innovations according to the protection method used. The utilization of different methods of protection in the metal industry is similar to that seen in other industries. However, patenting is much more frequently used in the metal industry than in the rest of the economy. If the Norwegian metal industry were globally attractive, we would expect it to outperform the rest of the economy in terms of the frequency with which various protection method are utilized. As shown in Figure 6-9, this is true only for patenting, which is much less frequently utilized as a protection mechanism both by metal firms and other firms in the economy.

Figure 6-9: Protecting inventions and innovation by method of protection (2008)



Sources: Statistics Norway and BI

6.2 R&D and innovation attractiveness: conclusions

Norway has a productive academic community that continually publishes academic research on metal-related topics. The academic output in Norway related to the metals industry exceeds by far the national average, which reflects decades of experience with the industry in Norway and the resulting knowledge-intensity in the country's academic specialization. On a global scale, Norway is not a central player in academic research relating to metals and materials in general, and its market share of this research remains stable over time. It may have developed niche competences as is evident in new aluminium and magnesium production processes and advanced material innovations.

To what extent can firms tap into the knowledge base residing within dedicated R&D institutions? The median level of R&D personnel is almost identical to the level in the rest of the economy and it remains constant between 2001 and 2008. The percentage of firms that have had product innovation in 2004 to 2008 is higher than the rest of the economy but the gap is decreasing rapidly. The levels of service innovations are insignificant. While innovative output has decreased, firms appear to generate the same turnover from innovative output in 2008 as in 2006. This allows for inferences about the relative quality of the innovations, which is inherent in the firm's ability to generate value from such innovations. However, as a whole the industry derives lower turnover from its innovations than other industries.

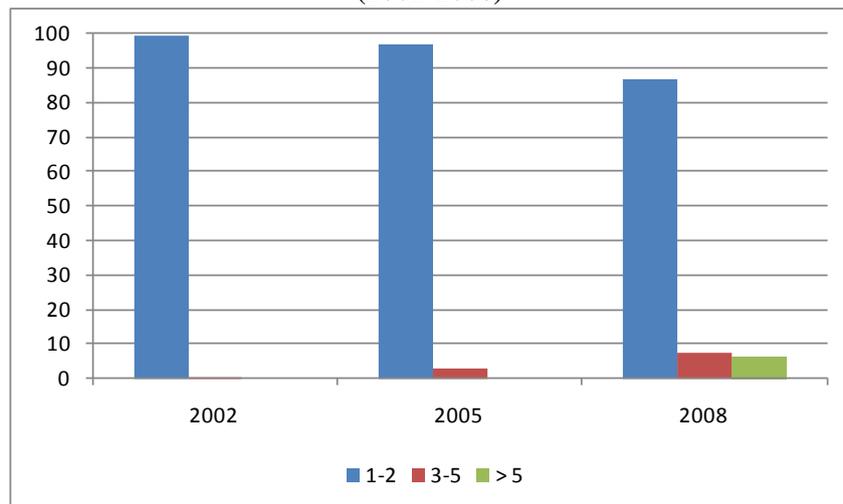
R&D is mostly financed by internal funds. The second-largest source of finance is Skattefunn, followed by Innovation Norway. A risk-capital milieu is lacking from the list of possible financing sources for R&D activities. This has a direct impact on the likelihood of the creation of start-ups. Firms within the metal industry do not utilize protection mechanisms for innovations more frequently than other firms in the economy. Although patenting is used more frequently in the metal industry than in the rest of the economy, it is the least utilized protection method by both the metal industry and other industries.

7 Ownership attractiveness

An industry's ownership attractiveness is the extent to which it manages to attract competent capital, either national or foreign, to finance its activities. Emerging industries, such as biotechnology applications within the health sector in Norway, typically suffer from a lack of competent owners who can competently evaluate new projects. In more mature industries, competent capital is crucial for the financing of innovative and novel projects, and for the injection of fresh capital into existing, growing firms. All else equal, a community of competent owners that enjoys the benefits of narrow searches for investment targets, easier selection and foresight into the operation of the industry should assist the growth and sustainability of an industry. In this section, we discuss the extent to which the Norwegian metal industry attracts competent capital.

We first examine the extent to which the industry is home to serial owners. Serial owners are those that own a number of firms within a specific industry. Figure 7-1 provides an overview of ownership attractiveness within the metal industry. In 2002, the industry has no serial owners specializing in investing in its various parts. A negligible percent of turnover (0.4) was controlled by a single entity, which held an ownership interest in three firms. By 2008, the percentage of ownership by serial owners had increased to 13%, where owners with five or more investments controlled 6% of the total turnover (excluding the ownership of the Norwegian state).

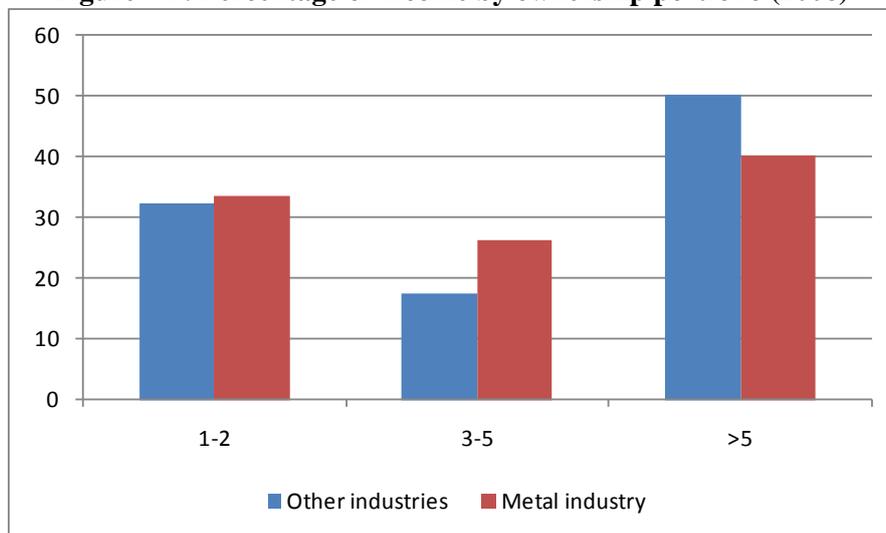
Figure 7-1: Percentage of income by metal industry ownership portfolio (2002-2008)



Sources: Brønnøysund Register Centre and BI

If serial owners who specialize in the industry are not present, it is possible that investors in the metal industry are serial investors of a different kind. Some serial investors may control a portfolio of investments in a range of industries, which may include metal firms. Figure 7-2 establishes that the metal industry has a higher percentage of owners with a medium-size ownership portfolio than the rest of the economy but a lower percentage of owners with a large ownership portfolio (40% in the metal industry and 50% in all other industries).

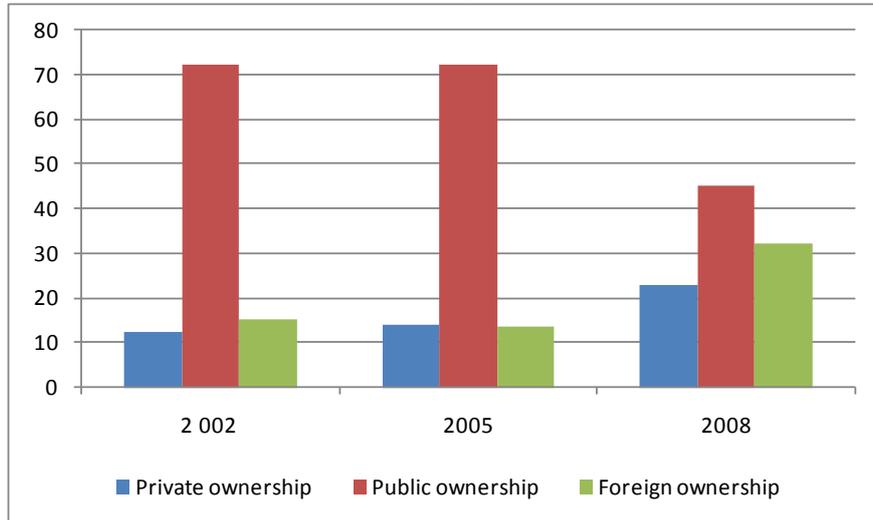
Figure 7-2: Percentage of income by ownership portfolio (2008)



Sources: Brønnøysund Register Centre and BI

We also examine the extent to which regional concentration is evident in terms of the localization of firms in the investors' ownership portfolios. However, we find no geographical concentration. The vast majority of counties had single owners (owning one or two firms). Only Rogaland exhibits some county-specific serial ownership.

Figure 7-3: Norwegian metal industry sales by ownership type (2002-2008)



Sources: Brønnøysund Register Centre and BI

Figure 7-3 shows that the major owner in the Norwegian metal industry in 2008 was the Norwegian state, which controlled 45% of all sales. Foreign owners controlled 32%, while private Norwegian owners controlled 23%. Over the last decade, a number of foreign and global actors within the metal and material industry have purchased production facilities based in Norway (e.g., Elkem, Alcoa). Currently, with the exception of Hydro, the vast majority of quarrying and basic metal production is foreign owned.

Titanium: The production of titanium is a complex process that results in varying qualities of finished material. One Norwegian firm that operates within this field is Norsk Titanium Components, which is owned by Norsk Titanium AS and is based in the Eiker Industrial Park in Hokksund. Its products have multiple applications in the aerospace, and oil and gas industries.

Norsk Titanium's advanced production techniques lower metal use by 90% to 95%, which lowers costs for customers and result in higher product quality. Spirit Aerosystems, for example, states that Norsk Titanium Component's products exceed their pureness and strength criteria, i.e., they are free from cracks and air bubbles. Innovations within the production process have also led to increased flexibility, less machining and a lower environmental impact. Investments in R&D make the process of secondary titanium production as cost-efficient as possible. In addition, the company has focused on producing the highest quality products possible in order to remain competitive.

Large quantities of titanium are produced in China and Russia, but are not subject to the strict environmental controls found in Norway. This implies extra costs for Norwegian producers that customers may not be willing to cover in the form of price premiums. Therefore, other global competitors have an advantage. However, the fact that Norsk Titanium Components has its own supply of raw material allows it to respond quickly and relatively cheaply to customer requests.

Despite the technological developments in this field, the future will show whether Norway can maintain its titanium industry. In the long run, the technology may be abandoned in Norway or a foreign investor may be found waiting with cash in hand.

Based on information from <http://www.norsktitanium.no/> and an interview with Scatec.

The trend in the global primary metal industry is consolidation along two related avenues. The first is vertical integration, whereby producing firms backward integrate in order to secure a supply of raw material. In this regard, Hydro recently (2010) acquired Vale's aluminium assets in order to "secure the supply of alumina to [its] operations and [create] a strong platform for further organic smelter growth. A long alumina equity position enhances Hydro's value as an attractive partner for new projects, and places [it] in a profitable alumina market where [it] can influence the trend toward more sustainable pricing mechanisms" (Hydro 2011: 49).

The second horizontal consolidation trend is based on market power and economies of scale logics. National companies are quickly turning into global players that purchase assets to supplement those they already possess in a growing number of foreign locations. For example, Hydro owns smelters in Slovakia, Germany, Australia, Canada, and Qatar, in addition to Norway. Alcoa owns smelters in Australia, Brazil, Canada, Iceland, Norway, and Spain, in addition to the US. A similar trend is evident in the horizontal consolidation within the precious metals market, where Chinese firms now own up to 90% of the world supply of some metals and advanced materials (e.g., Elkem's sale to China National Bluestar). This leads to a race for the purchase of available geographically isolated assets. It is hence of no surprise that the isolated assets in the Norwegian quarry industry (e.g., Mo i Rana) and metal and material productions (e.g., Elkem, Eramet) have already been purchased by foreign owners. This creates a new dynamics in such industries. They are merely a pawn in a large chess game controlled by mostly diversified metal and material conglomerates which tend to centralize future R&D technological investments or create a number of specialized R&D centers. The future viability of such assets rests on its cost structure and in some cases also on its attractiveness in terms of R&D. The likelihood of local spin-offs and continued investments in R&D in such isolated assets is reduced. This is supported by the lack of large new establishments over the last few years in the industry.

These trends are likely to continue in the near future. The industry is facing higher costs due to increased competition that pushes firms to invest in finding superior new technologies, and growing pressure to implement more environmentally friendly solutions that may involve the creation of entirely new technologies. For these reasons, scale, which increases a firm's power and allows it to spread the costs of R&D which are not dependent on the tonnage produced, is the underlying mechanism behind these trends. This process could result in extreme market consolidation. We refer to this process as "*the giant competition hypothesis*": when national barriers to competition, establishment and trade are gradually reduced, and output is standardized, scale considerations will motivate actors to increase their respective sizes through horizontal mergers and acquisitions, and/or through the development of superior technologies.

8 Environmental attractiveness

This chapter highlights two environmental factors – electricity usage (indirect emissions) and production related emissions (direct emissions) – and develops the global environmental advantage hypothesis. It covers major developments in the industry with respect to electricity usage and emissions.

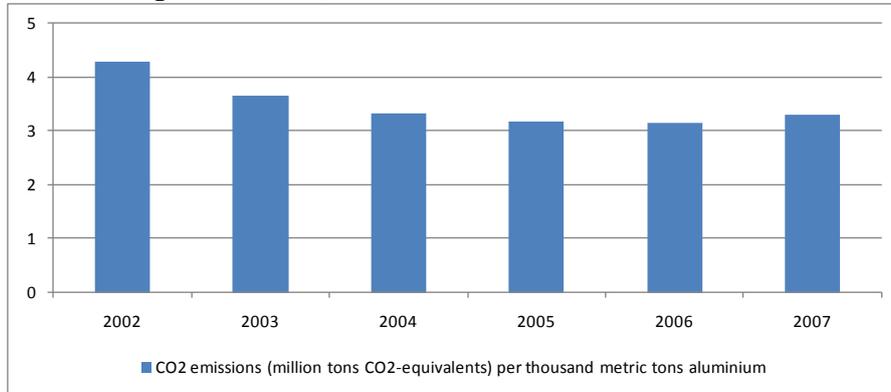
The ability to foresee and meet tomorrow's environmental requirements will be a major factor in the future success of the Norwegian metals industry. There is an ever-increasing demand for cleaner industrial processes, and both research institutions and major players see the need to focus on reducing harmful emissions and pollutants in order to meet global environmental challenges.

Four elements of the aluminium value chain currently represent the majority of emissions in European production of aluminium: the refining of aluminium oxide (31%); the production of pre-baked anodes (7%); primary aluminium production, including continuous casting (44%); and, secondary aluminium production (9%). The latter three activities take place in Norway. Furthermore, all major parts of the aluminium value chain, with the exception of mining and refining, are present in Norway, so that Norwegian firms are involved in primary, secondary and tertiary aluminium production.

Environmental attractiveness for the metal industry is assessed on the basis of annual CO₂ equivalent emissions and electricity usage. Both variables are standardized in thousands of metric tons of produced aluminium using consolidated primary aluminium production as reported by Hydro, the major player in the industry.⁶ CO₂ emissions in the metal industry originate mainly from electrolysis, perfluorocarbons (PFC) and stationary combustion. With more than 3.1 million tons of CO₂ emissions attributable to the production of aluminium in 2007, the metal industry is a leading contributor of process-related emissions in Norway (Monsen, Ratvik et al. 2009). However, improvements in the amount of energy required for the production of aluminium allows the industry to draw attention to its cleaner, more environmentally sustainable process.

⁶ Consolidated figures can be retrieved from the respective annual reports.

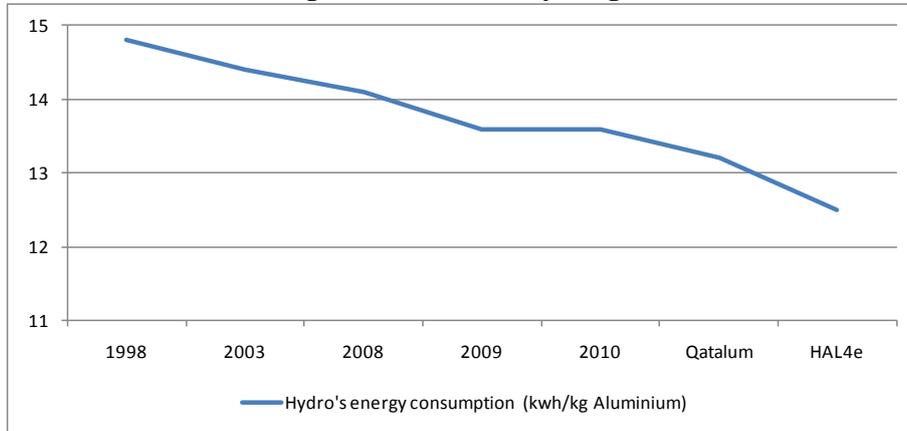
Figure 8-1: CO₂ emissions standardized (2002-2007)



Source: Statistics Norway

Figure 8-1 shows CO₂-equivalent emissions per thousand metric tons for aluminium produced in Norway. Despite the fact that data is not available for 2003 and 2004, a clear trend is observable. We derive the missing data by assuming a linear reduction in emissions between 2002 and 2005. Emissions of 4.3 million tons in 2002 were significantly reduced to 3.2 million tons in 2005, which indicates improved environmental performance in the Norwegian aluminium industry. Since 2005, emissions appear to have been stable, indicating that new environmental measures have not been properly introduced to further reduce emissions. However, given the huge potential that lies in making this industry more environmentally attractive, initiatives are underway with the goal of significantly reducing emissions by 2020 through a reduction in flare frequency (a reduction of 470,000 tons of CO₂ equivalent), the modernization of anode-burning stoves (a reduction of 24,300 tons CO₂ equivalent) and the replacement of traditional coal with more emission-friendly charcoal (a reduction of 66,000 tons CO₂ equivalent.). If the Norwegian metal industry manages to comply with this action plan, its emissions would decline further over the next 10 years, which would transform the industry into a global forerunner in terms of environmental friendliness.

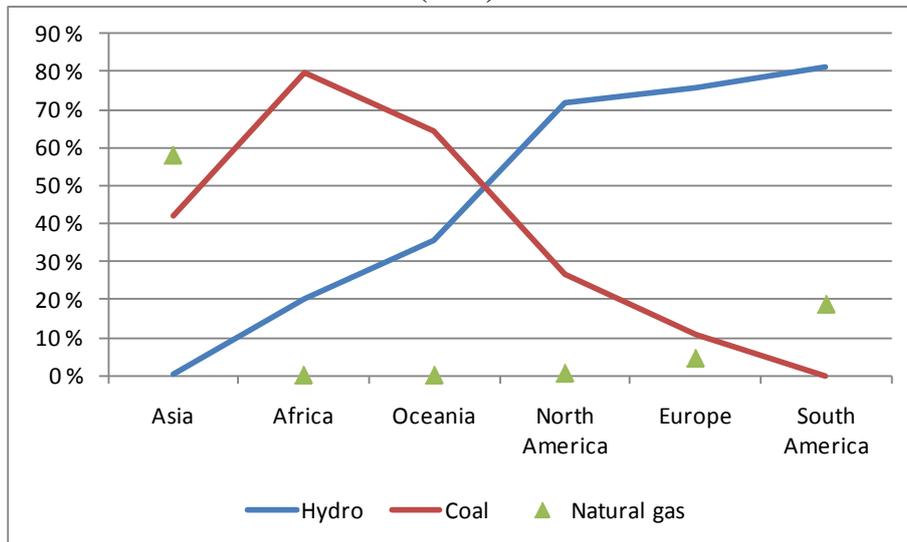
Figure 8-2: Electricity usage



Source: Hydro (2011)

Figure 8-2 shows Hydro's electricity usage, standardized by unit of produced aluminium. A similar trend is evident for the electricity usage associated with all metals produced in Norway. As the figure illustrates, the use of electricity in the aluminium production process is decreasing, and the construction of the new Qatalum plant and the innovation of the new HAL4e technology provide further reductions in electricity usage per unit of produced aluminium.

Figure 8-3: Reported electrical power used by source and continent (2010)



Source: International Aluminium Institute (2011)

What are the likely environmental consequences of a closure of Norwegian hydropower-based aluminium production units? Figure 8-3 reports the sources of electric power utilized for the aluminium production process by continent. The figure highlights the substitution effect – continents rich in hydropower utilize this almost emission-free source in the production of aluminium, while continents that lack this natural resource rely heavily on non-renewable resources (primarily coal and, to a lesser extent, natural gas). Given China's increasing global market share, a reduction in Norwegian production will most likely be offset by an increase in production based on electricity derived from coal or natural gas. Hence, such closures will result in the substitution of Norway's marginal emissions (indirect emissions) with notoriously high emissions. In this respect, Norwegian metal production makes a positive environmental contribution, given that the alternative, such as production in China, would lead to higher emissions.

Furthermore, in the western world in general and especially in Norway, government and environmental organizations have been very active in lobbying for strict emission requirements. Orders for treatment plants and strict controls result in a Norwegian industry that, in the global context, is far ahead in terms of environmentally friendly innovations. One example is Eramet's (Porsgrunn) reduction of mercury air emissions. Under pressure from Bellona, an environmental organization, and others, the company effectively stopped new releases (Jørstad 2008).

9 Cluster dynamics

The dimensions previously reviewed describe the conditions under which firms can excel. The extent to which firms can utilize those dimensions to their benefit depends on the extent to which they succeed in creating a dynamic environment. Previous literature (Reve and Jakobsen 2001) identifies four upgrading mechanisms through which clustered firms can experience increased innovation and productivity: innovation pressure arising from closeness to demanding customers, technologically leading suppliers and internal competition; critical mass (section 3); knowledge externalities, mainly in the form of labor mobility and strong business linkages; and transaction-cost reductions through the establishment of long-term relations. Dynamism is, therefore, a function of competitive and cooperative linkages, the degree of intra-industry labor mobility, which proxies for the extent of knowledge spillovers, and the degree of overlap between various industries. These linkages are examined in this section.

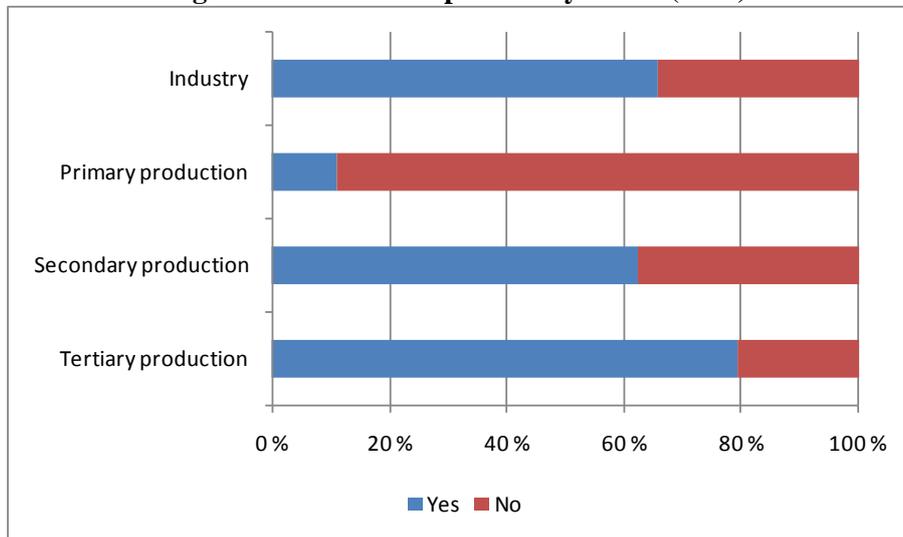
NCE Raufoss: Raufoss industrial park evolved from the ammunition industry in the Mjøsa region. Today, a wide range of products – from ammunition to car suspensions – is produced at Raufoss, with the car and defense industries dominating the region. Metals are not produced at Raufoss, but advanced metal processing is conducted there in order to produce end products demanded by the market. Raufoss aims to market and sell lightweight products, made from alternative and innovative materials, on a global basis. Some of the firms located at Raufoss include Hydro, ammunition producer Nammo and fishing equipment manufacturer Mustad. Raufoss has a strong international network and is represented on a global basis. Despite the high costs associated with operating in Norway, Raufoss has been successful. Increasingly, more foreign owners, such as Bentler, have chosen to invest in the cluster. Highly demanding customers are one of the driving forces behind Raufoss, and its development of new products and materials. The strategy employed by Raufoss members is to understand the needs and functions of customers in order to develop the best possible solutions for them, rather than focusing on a particular material or production process regardless of customer requirements. Close interaction with customers is common, and often involves discussions of new products and materials. This strategy drives innovation and forward thinking among Raufoss members.

One of the most important capabilities within Raufoss is the flexibility to pick up on current trends and to respond to changing requirements. Volatile commodity prices force Raufoss members to consider alternative materials for their products. Typically, members produce well-known products, such as car bumpers, that are made of different materials. The innovative mindset of Raufoss members leads to many prototypes being produced and tested in the region. There is an element of risk involved in such intense R&D but the firms choose to focus on the first-mover advantage they can gain by taking the first step. Working in close cooperation with customers and allowing for open communication minimizes this risk. NCE Raufoss and SINTEF are working together to establish a common research unit for all actors in the region in the future. This unit will be based around a common infrastructure. In addition, Raufoss is on the lookout for new competences to enter the region in order to encourage further innovation and development. Based on interviews and communication with NCE Raufoss.

9.1 Competitive linkages

The degree of local competition has been theorized to drive firms to excel (Porter 1990; Burt 1992). Competing firms that locate in the same vicinity have been repeatedly observed to have an incentive to remain ‘on top of things’ by continuously innovating and seeking new technologies and customers. 66% of firms in the Norwegian metal industry report having at least one direct competitor in the local region (Figure 9-1). This local competition may help to increase levels of innovation, as firms use competitive pressure to try to stay one step ahead. The importance of local competition varies greatly among the metal industry sectors.

Figure 9-1: Local competition by sector (2010)



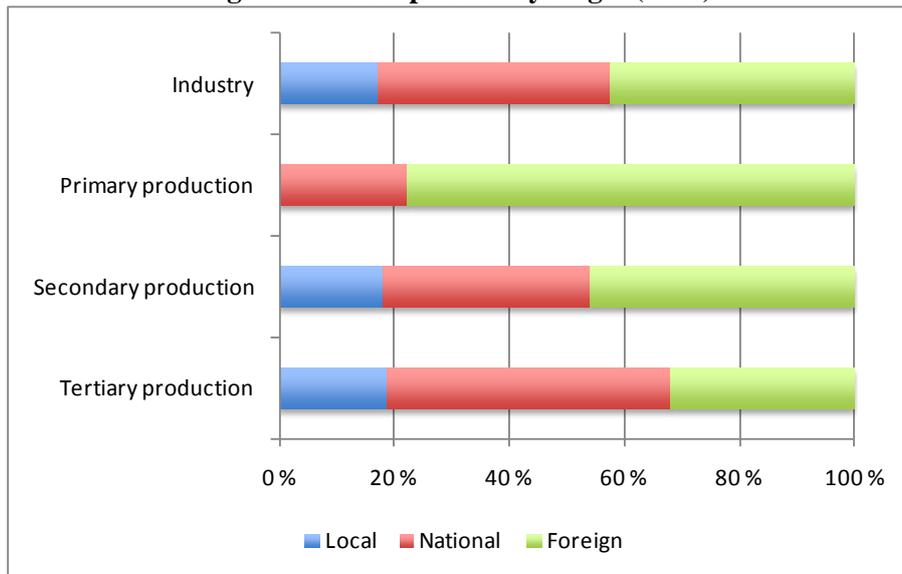
Sources: BI Survey

Figure 9-1 shows that primary production firms have the lowest levels of local competition (11%). The lack of local competition implies a lack of local competitive driving forces, which are required for the promotion of innovation and development. This, in turn, means that the vast majority of primary production firms in Norway operate as stand-alones in relative competitive isolation. Cluster theory implies that such isolation is likely to be detrimental for innovation and subsequent economic development.

Secondary and tertiary production firms have high levels of local competition. 63% and 79%, respectively report having at least one direct competitor in the local region. The toughest competition is however not from those competitors. The most significant competition originates from national or international, as shown in Figure 9-2. International competition for customers poses a very real threat for firms throughout the different sectors

of the Norwegian metal industry. As the sectors are involved in the processing and production of metal products, foreign countries with lower labor and production costs have a competitive advantage and are often able to offer similar products at much lower prices than Norwegian firms.

Figure 9-2: Competition by origin (2010)



Sources: BI: Survey

Figure 9-2 demonstrates that, on the industry level, metal firms meet the *toughest* competition for customers on the national and international levels. Local competitors are of comparatively little significance, with only 17% of firms meeting intense competition locally.

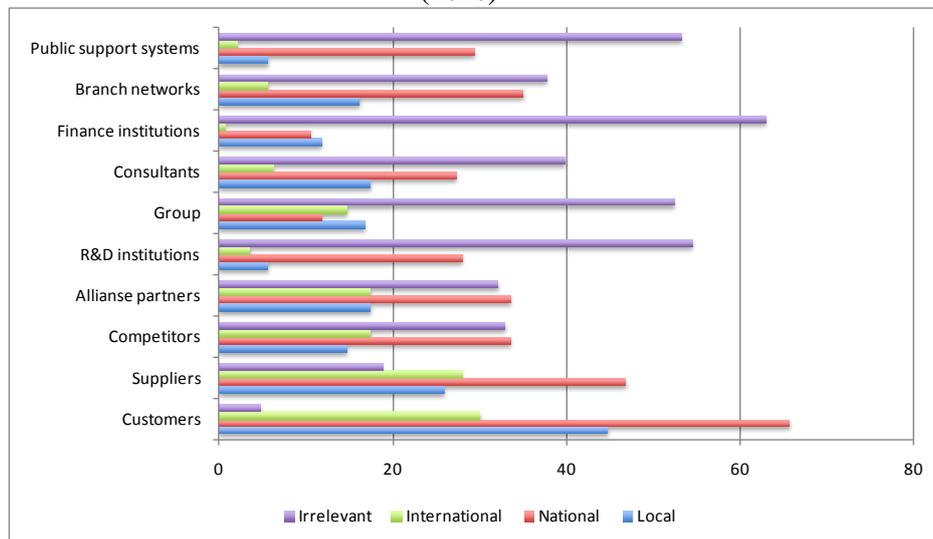
A more detailed examination of the sector level allows us to observe deviations from the general industry trends, particularly in the primary production sector. One striking result in the figure is that primary production firms experience the most competition almost entirely from international firms (78%). This may be because the output of such firms is, to a great extent, a standardized commodity that is sold on the global market. For these firms, local competition is non-existent, indicating that the primary production facilities in Norway are either operating in geographic isolation from others or are the only ones producing a particular product.

9.2 Collaborative linkages

Innovations seldom occur in isolation, and R&D is increasingly becoming interconnected and globalized. Innovative linkages across firm and country

boundaries allow for higher returns, which originate from the sharing of cross-boundary knowledge, the joining of complementary resources, and the transferring of effective governance mechanisms for work and innovation processes (Dyer and Singh 1998). Given the increasing globalization of economic activities, cross-border linkages are of increasing importance (OECD 2010). Norway as a whole underperforms in this regard. Only 5% of firms report involvement in international collaboration on innovation. In comparison, 17% of Finnish and 8% of Danish firms report such involvement.

Figure 9-3: Innovative linkages across firm and country boundaries (2010)



Source: BI: Survey

Collaborations in the metal industry may take many forms: vertical relationships between customers and suppliers, horizontal relationships between companies on the same level in the supply chain, or relationships between companies and governmental agencies, R&D institutions, finance institutions, etc. In general, relations with certain actors are more significant than others in the development of new ideas, processes or products. Relationships with customers, suppliers and personal networks, on all geographic levels, are of key importance.

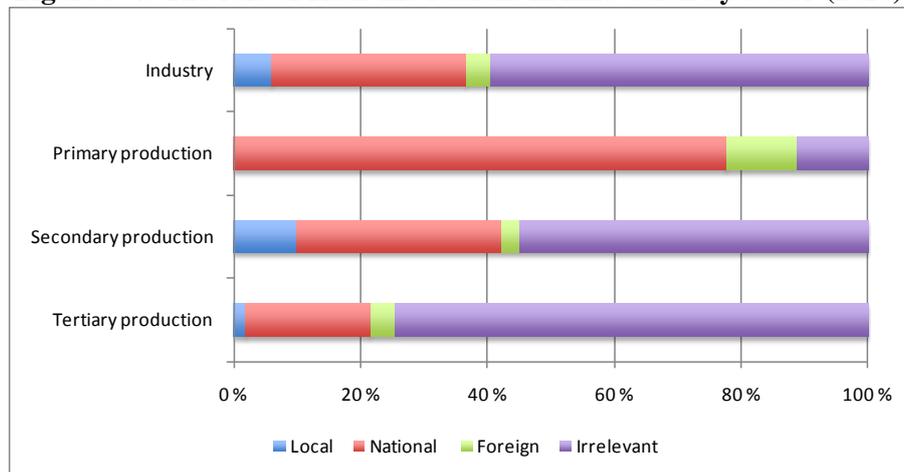
Surprisingly, 55% of respondents state that R&D institutions are irrelevant in their innovative product developments (Figure 9-3). This percentage is much higher than in the oil industry (38%) or the health industry (32%). Many of the recent developments in the metal industry are directly related to R&D institutions (e.g., magnesium innovations). Furthermore, given the decrease

in R&D personnel (section 6), the increase in the complexity of material composition and the emergence of innovations that facilitate higher productivity, this indicates that a large portion of the industry is exploiting previously developed knowledge rather than exploring new knowledge arenas.

9.2.1 Collaborations with R&D institutions and suppliers

In order to better understand these trends, we compare industry results with sector-specific results (Figure 9-4). We first examine the role of R&D institutions, which are rated as irrelevant by 60% of industry players, and the role of suppliers, which are central in cluster theory as agents of adaptation and innovation.

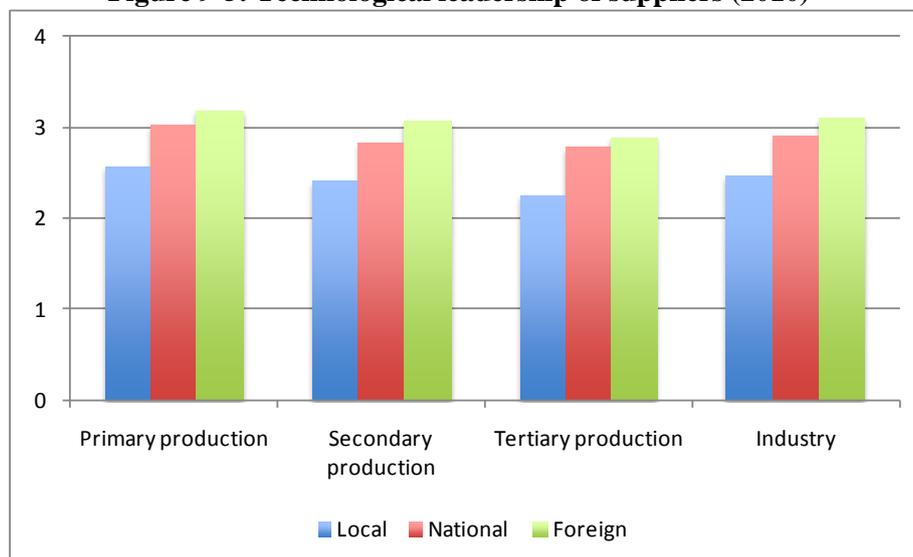
Figure 9-4: The role of R&D institutions in innovation by sector (2010)



Source: BI Survey

The role of R&D institutions varies across the metal sectors, with national R&D institutions being consistently of far greater significance than international R&D institutions. For primary production in particular, this highlights the importance of *national* R&D institutions in enabling Norwegian firms to innovate in the global marketplace. Both secondary and tertiary production firms rate R&D institutions as largely irrelevant for innovation. When discussing the role of R&D institutions, one may think in terms of researchers pelting out brilliant ideas that are then seized upon to create successful companies. However, one should also assess the importance of laboratories and test centers made available to the industry, such as those made available through SINTEF.

Figure 9-5: Technological leadership of suppliers (2010)



Source: BI Survey

Foreign suppliers were mentioned more frequently than local and national suppliers as a source of innovation. Metal firms in all sectors perceive their international suppliers as more technologically leading than their national suppliers (Figure 9-5). This clearly indicates a lack of competitiveness among local and national suppliers to all sectors, which renders firms even less able to innovate and outperform rivals. Furthermore, local suppliers are viewed as substantially less technologically leading than their foreign counterparts. This weakens the attractiveness of the metal cluster in Norway by challenging its completeness.

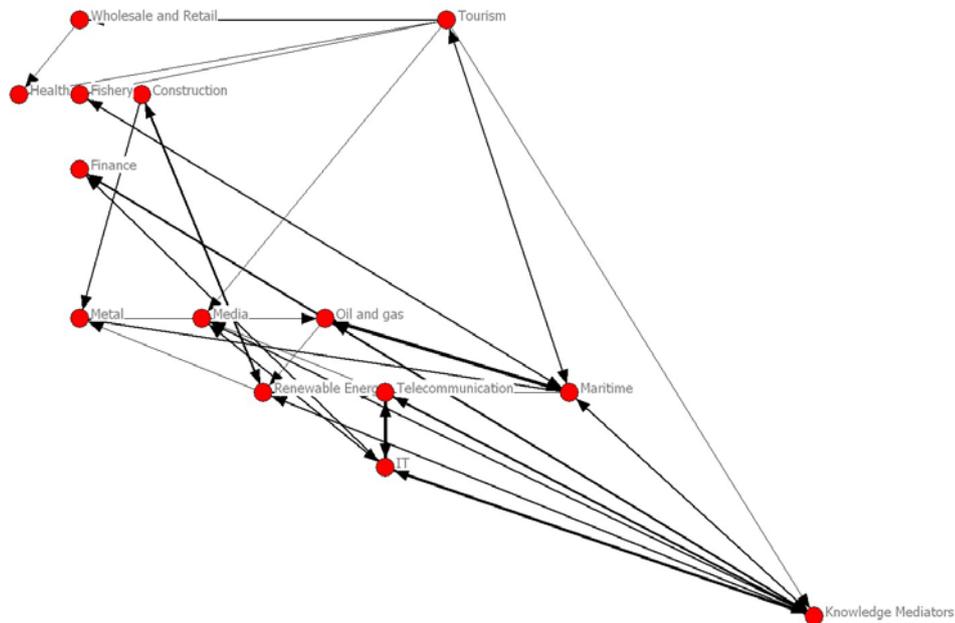
9.3 Labor dynamics

Another source of industry dynamics is the labor market. Spillover effects have been identified as one of the three major mechanisms by which cluster advantages materialize (Marshall 1920; Jaffe, Trajtenberg et al. 1993; Almeida and Kogut 1999). Spillover in labor markets happens through the transfer of employees across firm boundaries. Intra-industry labor mobility is a rare phenomenon in the metal industry. 99.8% of employees who worked in primary production in 2007 and continued to work in the metal industry in 2008 remained in primary production. The corresponding figure for employees in secondary and tertiary production is 99.6%. As only an insignificant number of employees who changed employment moved from one sector of the industry to another, the opportunity for knowledge transfer is limited. Furthermore, if we examine the flow of employees holding a university degree, such opportunities are virtually non-existent.

9.4 Overlapping networks

Clusters thrive in the presence of related clusters in the economy, from which the former can draw upon (Porter 1990; Porter 1998) for competent labor, demand for its products, specialized machinery and competent owners. Is the metal industry a stand-alone industry or does it have related clusters and, hence, complementary sources of competences and ideas to utilize in its operations?

Figure 9-6: Overlapping networks (2008)

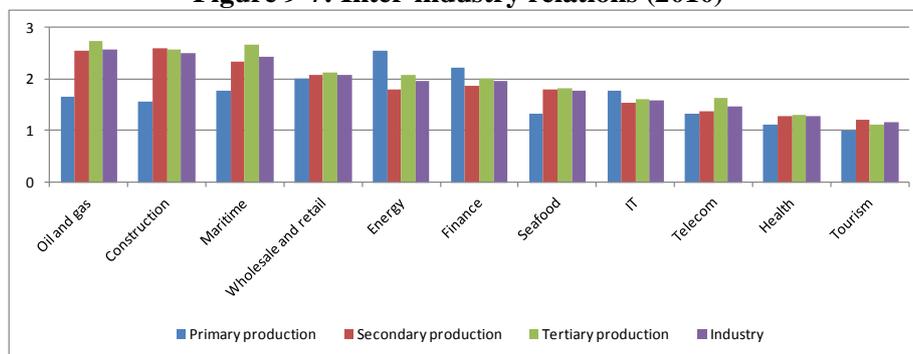


Source: Statistics Norway and BI

Figure 9-6 depicts the flow of personnel between industries in Norway during 2008, which is similar to the pattern for earlier years. The metal industry receives a disproportionate number of employees from the construction and renewable energy industries, and provides a disproportionate number of employees to the oil and gas, and maritime industries. These linkages are vital for the development of the maritime, and oil and gas industries, as well as in the emerging renewable energy industry. The link between construction and the metal industry reflects the importance of various metals, especially iron, in the construction industry.

A related issue is the inter-relationship between other manufacturing industries not already discussed. We examine the extent to which the metal industry has close labor-mobility-based relationships with other industries, such as the food, textiles, wood, paper and pulp, chemical, furniture, and machinery industries. The metal industry's labor-mobility-based relations with these industries are very weak with the exception of the machinery industry, which is a disproportionate (relative to its size) source of employees for the metal industry. The metal industry is not a disproportionate source of employees for any other manufacturing industry.

Figure 9-7: Inter-industry relations (2010)



Source: BI Survey

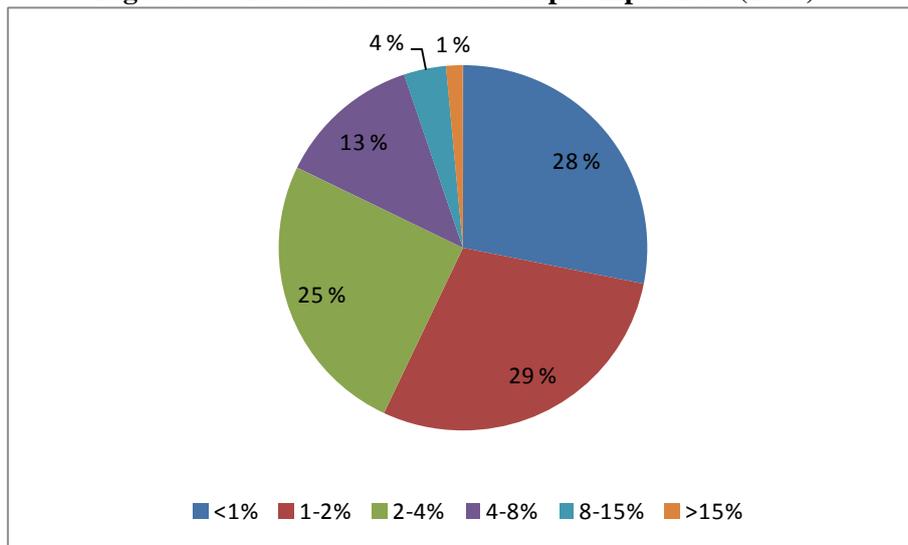
Survey respondents were asked to assess the strength of their overall relationships with other industries on a scale of one (weak) to four (strong). Figure 9-7 depicts the average responses for the entire metal industry and for each sector. The results are ordered in a descending order from left to right in accordance with the values for the entire industry. The results on the industry level corroborate the labor mobility findings reported in Figure 9-6: the strongest relationships are maintained with the oil and gas, construction, and maritime industries. The same applies to secondary and tertiary production. Given the vital importance of energy to the production of basic metals, the primary relationships of primary production firms are with the energy sector. Primary production firms also have close relationships with the financial sector due to the capital intensity of their activities. While secondary production and tertiary production have developed a number of important relationships with other central industries in Norway, primary production plays a much more peripheral role in the network of Norwegian industries. In the theoretical case of its disappearance, the impact on other Norwegian industries should not be significant.

9.5 Indirect linkages: competence development

Firms can supplement investments made by educational institutions, individual employment choices and the spillover from already acquired industrial knowledge by investing in employee competence development (Figure 9-8). We examine this factor because investments in employee competences are semi-public goods. There is no guarantee that employees will remain with a particular firm and, hence, the benefits of investments in competence may be captured by other firms.

In light of the low share of employees with a higher education and the industry-wide perception of the importance of learning-on-the-job, we would expect competence development to be central for firms in the metal industry. In order to examine this assumption, we analyze the distribution of the share of revenue that is used for competence development in the industry. We then examine the distribution of such investments by sector before we provide a comparative analysis of such investments in other industries.

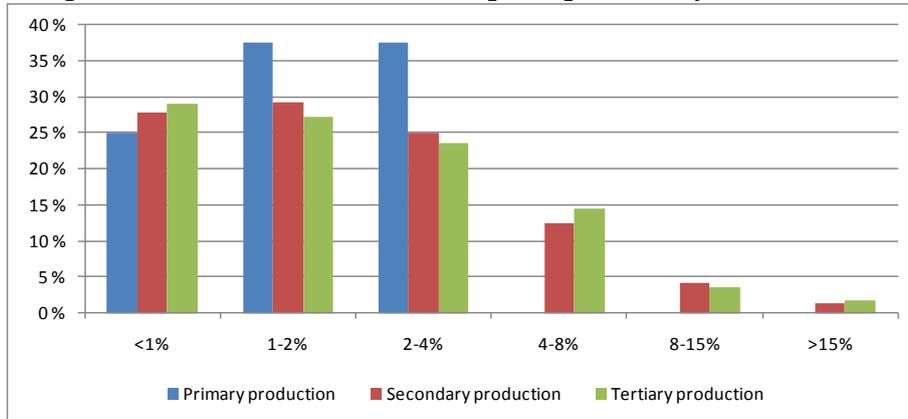
Figure 9-8: Revenues used to develop competences (2010)



Source: BI Survey

We find that 28% of metal firms invest less than 1% of their turnover in competence development, 29% invest between 1% and 2%, and 25% invest between 2% and 4% (see Figure 9-8). A marginal share of firms (1%) invests more than 15% of revenue in competence development. This indicates that few firms hold the view that high intra-firm competence development investments can add value to their firms.

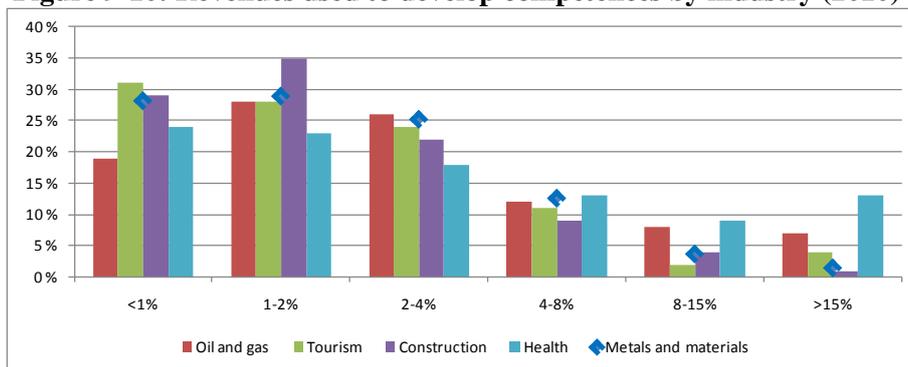
Figure 9-9: Revenues used to develop competences by sector (2010)



Source: BI Survey

Investments in competence development vary substantially by sector (Figure 9-9). Primary production firms are relatively large firms that rely on standardized production processes to produce high quantities of standardized outputs. Under such conditions, these firms are unlikely to invest a large share of their revenue in competence development. In real terms, the investments made by these firms are much larger than the investments made by firms in secondary or tertiary production. The latter firms are similar in terms of their investments in competence development. 5% to 6% of such firms invest more than 8% of their respective revenues in competence development, while an additional 13% to 15% invest between 4% and 8%. At the other end of the scale, we find that the share of secondary and tertiary production firms that invest less than 1% of their revenue in competence development is higher than the share of primary production firms.

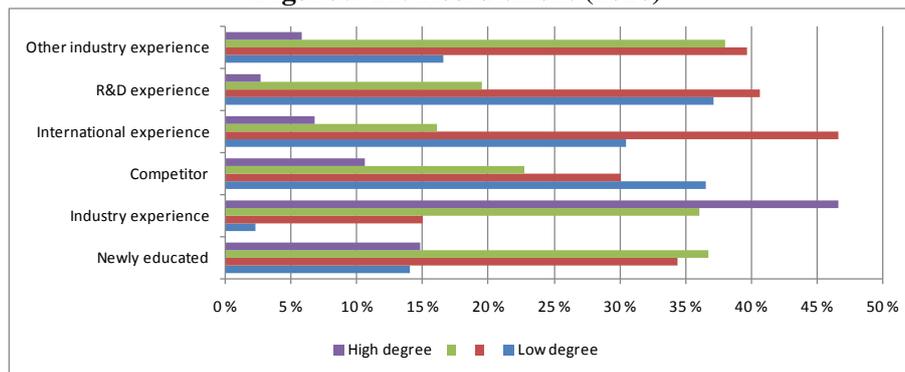
Figure 9-10: Revenues used to develop competences by industry (2010)



Source: BI Survey

Do metal industry firms invest as much in competence development as firms in other industries? Figure 9-10 provides details on investments in competence development as a percentage of revenue for the oil and gas, tourism, construction, and health industries. The blue diamonds provide the same percentages for the metals and materials industry. Investments in the metal industry are similar to investments in the construction and tourism industries. Oil and gas, and health firms distinguish themselves from metal firms, as they have a lower share of firms that invest less than 1% and a higher share of firms that invest substantially (above 8%) in competence development. The metal industry as a whole does not distinguish itself in terms of high investments in intra-firm competence development relative to other industries. Its distribution is similar to that seen in other labor-intensive industries and differs from investments made in more knowledge-intensive industries.

Figure 9-11: Recruitment (2010)



Source: BI Survey

An examination of those important factors affecting recruitment highlights a single source deemed as most important (Figure 9-11). The recruitment of employees with focal industry experience is regarded as contributing knowledge to a *high degree* by 47% of firms in the survey. 83% of firms indicate that recruitment of employees with focal industry experience is at least of *above-average* importance as a source of knowledge and competence. Only 14% of firms rate recruitment of new graduates as being of high importance. This is in line with the importance of new graduates for the oil and gas industry but is only half of the importance of new graduates for the health industry. R&D experience, international experience, and experience from other industries are generally not viewed as important for the metal industry, which prefers to recruit from its own ranks. Therefore, a relevant issue is whether the Norwegian metal industry is attractive for the newly educated and those with international or R&D experience.

9.6 Cluster dynamics: conclusions

Local competitive linkages are weak. Metal firms meet the *toughest* competition for customers on the national and international levels. Local competitors are of comparatively little significance, with only 17% of firms meeting intense competition locally. Primary production firms in Norway operate in a globally competitive market but experience little local competition. Secondary production and tertiary production firms experience high levels of local competition but this is not the source of the toughest competition that they experience.

Collaborative relations with customers and suppliers are viewed as the most central for innovation. Surprisingly, 55% of respondents state that R&D institutions are irrelevant in their innovative product developments (Figure 9-3). This percentage is much higher than in the oil industry (38%) or the health industry (32%). Many of the recent developments in the metal industry are directly related to R&D institutions (e.g., magnesium innovations). Furthermore, given the decrease in R&D personnel (section 6), the increase in the complexity of material composition and the emergence of innovations that facilitate higher productivity, this indicates that a large portion of the industry is exploiting previously developed knowledge rather than exploring new knowledge arenas.

Metal firms in all sectors perceive their international suppliers as more technologically leading than their national suppliers. This clearly indicates a lack of competitiveness among local and national suppliers to all sectors, which renders firms even less able to innovate and outperform rivals. Furthermore, local suppliers are viewed as substantially less technologically leading than their foreign counterparts. This weakens the attractiveness of the metal cluster in Norway by challenging its completeness and competitiveness throughout the value chain.

The metal industry is not a stand-alone industry but is linked to related industries such as oil and gas, construction, maritime and renewable energy. Primary production is isolated mainly maintaining relationships to its supplier of energy and capital. It plays a much more peripheral role in the network of Norwegian industries than secondary production and tertiary production.

Do metal industry firms invest as much in competence development as firms in other industries? We find that 28% of metal firms invest less than 1% of their turnover in competence development, 29% invest between 1% and 2%, and 25% invest between 2% and 4%. A marginal share of firms (1%) invests more than 15% of revenue in competence development. This indicates that

few firms hold the view that high intra-firm competence development investments can add value to their firms. Investments in the metal industry are similar to investments in the construction and tourism industries. Oil and gas, and health firms distinguish themselves from metal firms, as they have a lower share of firms that invest less than 1% and a higher share of firms that invest substantially (above 8%) in competence development. The metal industry as a whole does not distinguish itself in terms of high investments in intra-firm competence development relative to other industries. Its distribution is similar to that seen in other labor-intensive industries and differs from investments made in more knowledge-intensive industries.

10 Conclusion

In this concluding chapter, we provide recommendations for business strategy and public policy which are based on the findings summarized at the end of the previous sections. The Norwegian metals industry has enjoyed global success particularly through activities in aluminium and advanced material productions. But times are changing, and the wave of consolidation and environmental pressures in the industry raise concerns for the future. Can the Norwegian metals industry flourish as a world market leader, or will foreign investors provide an exit path leading to the eventual abandonment of metal production in Norway?

This report has focused on the current status and emerging trends within the seven dimensions of the Norwegian metals industry as a global knowledge hub: cluster attractiveness, educational attractiveness, talent attractiveness, R&D and innovation attractiveness, ownership attractiveness, environmental attractiveness and cluster dynamics. The Norwegian metal industry offers many opportunities for value creation on a global scale due to the inherent nature of its relevant markets. These opportunities have attracted the attention of scientists, investors and public authorities, and have resulted in the investment of considerable resources in the pursuit of advanced metals production technologies and the renewal of older techniques in order to compete with larger global players.

10.1 Public policy recommendations

Double or nothing. Norway has had a leading role in magnesium, which was lost to larger players. After a bumpy start for the pure silicon industry (e.g., Elkem) the industry evolved to solar energy wafers (REC). But like magnesium, the solar industry is about to abandon its position in the global market and silicon and solar energy R&D is now controlled by China National Bluestar. REC may be sold any day. That would mark the demise of the Norwegian position in the silicon based industries.

The Norwegian metal industry is at a crossroads. A number of academics and economists argue for its gradual shutdown. Others argue for maintaining the status quo. Based upon the development in the market presented in sections 2 and 3 and the data presented in the remaining sections of this report, we argue for a “*double or nothing*” strategy. Norway can either become a significant player in the metal production industry or become an insignificant player that will eventually be squeezed out of the markets as mentioned in the previous paragraph. Investment in knowledge that can partially solve environmental challenges, advance a new smelting

technology or increase electricity efficiency will necessitate one of the following: either, investments and production capacity (also through replacement with a new technology) are doubled or for the benefits of all stakeholders, it is best to announce policies that signal the industry's gradual shutdown.

Secondary production and tertiary production has never fully taken off. A leading downstream aluminium firm, Sapa is owned by Orkla and has no plants in Norway. Secondary and tertiary production firms are distributed without much agglomeration around the country preventing strong cluster mechanisms from operating and increasing the likelihood of those firms losing out to foreign competitors. Primary production firms are either isolated and foreign-owned (leading many to assume that we are seeing those firms last sprint), or part of a global metal player which, everything else equal, needs to double its size in the near future.

Create a synchronized strategic direction. Governmental cycles are short relative to the cycles evident in the metal industry. Investors, talented individuals and future students are likely to choose a different industry unless it is not made absolutely clear that metals both production and further value chain activities, are not put at a disadvantage vis-à-vis foreign competitors. This prioritization must be evident in the form of solving the uncertainty with regards to future environmental levies and future electricity supply. Currently, a comprehensive implementation strategy (that includes pupils, students, talented workers, existing firms, environmental organizations and investors) that addresses primarily talent attractiveness, R&D and innovation attractiveness, environmental attractiveness and cluster dynamics for the metal industry is lacking.

Act as a knowledgeable owner. The 'double or nothing' strategy may require Hydro and other players, especially in the secondary production and tertiary production, to double their respective sizes in order to remain competitive. The Vale acquisition by Hydro signifies the willingness to decrease, even for a short-period, the ownership stake of the Norwegian government. The state should be willing to consider either repeating the temporary reduction of ownership or purchasing new equity if market conditions necessitate the acquisition of aluminium production assets of much larger and diversified metal producers.

Long-term electricity prices and expansion. The above strategy of 'double or nothing' and the synchronized strategic direction call for a resolution of the uncertainty surrounding electricity supply (which is coupled with global reduction in CO₂ emission, as discussed in section 8). Electricity contracts are long terms contracts and hence decisions about pricing are inherently

dependent on uncertain models of supply and demand in the Nordic and Continental energy markets in the coming 20 to 40 years. Currently, advanced models predict very different energy prices in 2030 than today. An alternative solution is to commit further energy resources to energy intensive industries to both directly reduce global CO₂ emissions (a substantial environmental program taking into consideration that the exchange of 5Twh hydropower-based smelter with a coal-based one results in an increase of 4.3m tones of CO₂ emissions (Hydro, 2011)) and increase the stability of future revenue for energy producers. This should be coupled with direct investment in replacing old technology with new and, if demand for metals continues to increase, further expansion of activities.

Transforming the knowledge-base. In primary production, where the main production firms are the largest or very large employers in their respective local communities, we see that the population of workers is rather constant with regards to its age distribution. For example, the mean age has merely increased from 42.30 in 2000 to 43.06 in 2008. This indicates that the production units continue to attract local labor for their production. Otherwise we would have observed the aging of the primary production population. Productivity increases will further reduce the centrality of labor in the production processes and of the employing organizations in the local communities where they currently operate. The possible threat of halting production and the transfer of production capacity to other countries requires these communities to find alternatives. Herøya is an example that diversity and hard work can transform the closure of a smelter into an economical revival for the region. However, the sole focus on one type of activity without developing competences that can be applied in related industries and projects is likely to hamper such transformations in some of these rural communities.

Increasing the knowledge infrastructure. A community of advanced academics in the fields of metals and materials already resides in Norway. Their knowledge combined with industry knowledge has allowed for many of the evident innovations in the industry. This trend will continue in the future as the search for more energy efficient production processes, environmentally friendlier production processes, and new advanced materials (e.g., composite, or nano-based) will only intensify. This requires that specific and large investments such as those evident in PETROMAKS or FUGE will be allocated to develop the conditions under which Norway can become a significant player in the global metal industry. It should be noted that if the 'Nothing' part of the strategy is chosen (or by default if the 'Double' is not chosen), such knowledge investments are best terminated and resources channeled to activities that have a long-term horizon for value creation.

10.2 Strategic recommendations

Taking the above recommendations into account, we also briefly discuss firm strategies within the metal industry.

Consolidation. The industry is consolidating. Economies of scale assist in dividing mounting R&D costs (investments in new production processes, more efficient utilization of existing technologies and cleaner production processes) over production quantities. Cross-boarder horizontal mergers and acquisitions have been taken place in many metal markets, not merely aluminium. The trend is likely to continue in the future. Norwegian firms have not significantly participated in this horizontal trend (as buyers). This has made them more attractive as acquisition targets and accordingly in the last decade many have been acquired.

Expansion. As explained in section 10.1, a solution to the uncertainty surrounding electricity supply is the further expansion of metal production in Norway. Higher demands for metals in the future, the need to rejuvenate the aging aluminium production units in Norway and the replacement of the old technology with the emerging new technology may provide the conditions under which further production capacity expansion may be both prudent (e.g., magnesium) and an economically viable alternative.

Niche market strategies. Secondary and tertiary production has not taken off in Norway. With some exceptions, the firms in these sectors specialize on being sub-suppliers to other Norwegian industries. The economic returns and knowledge investments in competence and higher human capital are at or below average levels. Firms which are in the shadow of the larger metal producing firms and other more visible industrial actors have to find attractive niche markets. Such markets are mostly reached through their creation, not through the entry into already existing markets (*i.e., invest in blue oceans rather than crowded streets*). Establishment should either be in the vicinity of their own customers (e.g., maritime and offshore customers) or in the vicinity of existing firms that employ a similar strategy (e.g., NCE Raufoss). Activities focused solely on narrow and competitive fields are likely to hamper the success of local firms. At least in the foreseeable future, projects that focus on fields where there is no direct competition allow for slightly more flexibility and have a better chance of success.

11 References

Almeida, P. and B. Kogut (1999). "Localization of knowledge and the mobility of engineers in regional networks." Management Science **45**(7): 905-917.

Barney, J. (1991). "Firm resources and sustained competitive advantage." Journal of Management **17**(1): 99-120.

Burt, R. S. (1992). Structural holes. Cambridge: MA, Harvard University Press.

Dyer, J. H. and H. Singh (1998). "The relational view: cooperative strategy and sources of interorganizational competitive advantage." Academy of Management Review **23**(4): 660-680.

Godal, O. (1998). Metallindustrien i Norge Økonomi, sysselsetting og utslipp av klimagasser. Policy Note. Oslo, Norway, CICERO,. **2**.

Hydro (2011). Annual Report-2010.

International Aluminium Institute (2011). "Statistics." from <http://world-aluminium.org/Statistics>.

Jaffe, A. B., M. Trajtenberg, et al. (1993). "Geographic localization of knowledge spillovers as evidenced by patent citations." Quarterly Journal of Economics **63**(3): 577-598.

Jørstad, S. (2008). Nores metallindustri, også i fremtiden. Trondheim, Norway, NTNU.

Marshall, A. (1920). Principles of economics. London, Macmillan.

Monsen, B., A. P. Ratvik, et al. (2009). Tiltak og virkemidler for reduksjon av klimagasser i norsk prosessindustri. Trondheim, Norway, SINTEF. **A11606**.

OECD (2010). OECD Science, Technology and Industry Outlook 2010. Paris, OECD.

Olsen, A. K. (1955). Norsk Hydro gjennom 50 år. Et eventyr fra realitetenes verden. Oslo, Norway, Emil Moestue A/S.

Peteraf, M. (1993). "The cornerstone of competitive advantage. A resource-based view." Strategic management journal **41**(3): 179-192.

Porter, M. E. (1990). The competitive advantage of nations. New York, Free Press.

Porter, M. E. (1998). "Clusters and the new economics of competition." Harvard Business Review **76**(6): 77-90.

Reve, T. and E. W. Jakobsen (2001). Et verdiskapende Norge. Oslo, Universitetforlaget.