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Comparing development paths of resource based industries:

Chile and Norway

- The role of knowledge institutions-

An introduction to PhD research project

Work in progress

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Introduction

This paper is an introduction to my PhD research project in which I present research questions, preliminary hypotheses and some initial work. My project is connected to one of the research groups within the larger Sinergia project called *Acteurs de la fabrique des savoirs et construction de nouveaux champs disciplinaires*: "Creating and using "useful knowledge" in small, industrialising European economies". The aim of the PhD research project is to analyse and compare the role of knowledge institutions in transmitting and diffusing "useful knowledge"[1] for economic purposes in the mining sectors in Chile and Norway A detailed comparative case study of mining education and its role in building competence and technological change processes in the two mining industries will constitute a part of the comparison. The period of investigation is around the last decades of the nineteenth century and the first part of the twentieth century, the period before and during which the two countries diverged (see graph 1).

Technological change and innovation underpin modern economic growth and are important in structural changes in an economy, due to their influence on production processes, efficiency and productivity. Because of the intimate link between technological change and growth it is relevant to investigate the sources of innovation and how new technologies are created, transferred and spread when analysing economic growth. Differences in technological advance seem decisive when seeking to explain variations in growth performance, and also the standard of living among the world's countries.

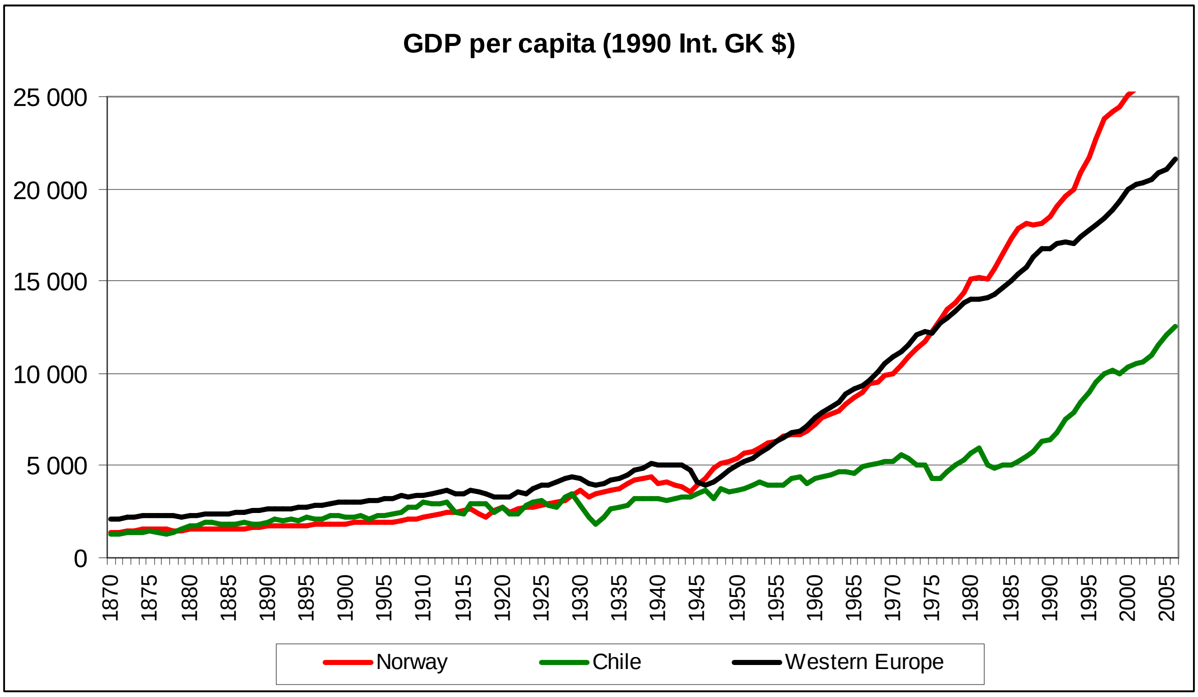
There are many non-knowledge determinants of growth, such as resources, finance capital, and market conditions. These factors should not be underestimated, but in this project it is the expansion and distribution of useful knowledge that is examined. Useful knowledge refers to the knowledge supporting technology, meaning any knowledge that goes into production, such as how to make and operate machinery and how to make technological improvements to create economic value. The transfer and diffusion of useful knowledge can be understood as the expansion of capabilities or skills to create, adapt, use, operate, manage and modify technologies and that has the potential to increase productivity. It is argued that useful knowledge needs to be analysed in an institutional setting and that knowledge institutions were crucial in the transfer and spread of useful knowledge. Knowledge institutions which encouraged and supported circulation of useful knowledge will therefore be used as the basis for analysis and comparison.

Why is comparing Chile and Norway relevant? While Chile and Norway are different in many respects, they also, perhaps surprisingly, have shared significant commonalities. The two countries in the periphery have faced similar communications and infrastructure challenges and have had similar characteristics in terms of economic activities. In geographical terms they are both long, narrow countries, with major mountain areas and long coastlines with fiords and coastal islands. An important point in relation to this research is that both countries can be characterised as "resource based economies". Historically speaking they have developed many of the same natural resource sectors, such as fish, hydroelectric capacity, different metals and mining industries, timber and timber-related industries etc. and they have based a large amount of their output, income and trade earnings on the exploitation of natural resources (and this is still the case). Both have had a large service sector, which is

[1] See next section for explanation

often a characteristic of resource based economies. What is known as manufacturing or high-tech industries have in both countries only involved a small part of the economy.[2]

The two countries had quite similar long term growth patterns until the 1930s, as seen in graph 1. The strong set-back of Chile's economy during the 1930s crisis, however, changed the balance between the two economies. From that time Norway started to move ahead of Chile. It is important, however, to emphasise that Chile has had considerable growth in the last two decades and has grown to be one of the most developed countries in Latin America.[3] Nevertheless, the overall question in this context is what were the reasons for the divergence between the two countries?



1. Graph. Source: Angus Maddison, Historical Statistics of the World Economy: 1-2006 AD.

The end of the Denmark-Norway union in 1814 opened up to a new political situation where democratic and liberal ideas achieved breakthrough. The parliament was composed by representatives from a broad set of classes. An important point in the Norwegian Constitution of 1814 was that the role of the state was to remove the obstacles for free competition. The state withdrew from production of goods, with some exceptions. Between 1839 and 1874 the Norwegian parliament established new laws with the aim of establishing equal access to business and industry, as opposed to the old regime's differential treatment, and the system of privileges were abolished. Equality before the law and protection of property were introduced.[4] Norway was a poor country in Europe in the eighteenth and nineteenth century compared to other Western European countries and was based in a large degree on agriculture.[5] During the nineteenth century, however, there was a change in production, use of

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[2] Bergh (ed.), *Norge fra u-land til i-land: vekst og utviklingslinjer 1830-1980*, 1983, p. 237; Braun, (ed.), *Economía chilena 1810-1995 Estadísticas históricas*, 2000, pp. 31-33 and 220-222; Smith, "Innovation and growth in resource-based economies", in *Competing from Australia*, 2007, p. 53; World Data Bank: World Development Indicators (WDI) & Global Development Finance (GDF).

[3] Blomstöm, "Chilean Economic Development, 1880-1990" in Blomström (ed.), *Diverging Paths Comparing a Century of Scandinavian and Latin American Economic Development*, 1991.

[4] Hodne (ed.), *Norsk Økonomi i det 19. Århundre*, 2000, pp. 137-141

[5] Bergh, *Norge fra u-land til i-land: vekst og utviklingslinjer 1830-1980*, 1983.

technology, organisation etc. in almost every sector. More processed products were produced such as textiles, soap, metal products, matches, cans, food products and also bigger constructions such as buildings and ships etc. Mechanical workshops played an important role in supplying other sectors with machines from the mid-nineteenth century. Even so, the manufacture sector's share of GDP has been set to 17, 8 per cent in 1860 and 30, 1 per cent in 1930. The natural resource sectors and services formed the largest share.[6] There was also a higher degree of processing in old sectors; in the fish sector fish oil and flour increased from the 1850s, in the timber sector cellulose and paper production were introduced in the late nineteenth century and the mining sector grew and became more diversified with emerging metallurgical and electrochemical industries from the early twentieth century.[7] By the mid-twentieth century the country's GDP grew to over West European average.[8] Productivity and income in Norway are today among the highest in the world, even without the extra contribution of the nation's oil and gas sector.[9] After World War II Norway developed and maintained a welfare state which sought to cover health, education and social protection for the whole population.[10] The country has in the last years been ranked first in the world in the UNDP's World Development Index.[11]

Chile was also towards 1850, in essence, an economy based on agriculture. The majority of the population worked in big low productive haciendas[12] as permanent or seasonal tenant farmers. The haciendas represented a feudal system which controlled the majority of the land and resources.[13] Chile, in contrast to Norway, had a major concentration of wealth in the higher classes. The executive had strong power, the society was highly hierarchical and the political power was concentrated in a small elite of landowners and merchants.[14] Even so, it is argued that Chile has, as Norway, long democratic traditions. There is a general consensus among historians that Chile consolidated slowly democratic institutions within a political system of a high degree of stability during the nineteenth and twentieth centuries. During the nineteenth century Chile became influenced by foreign ideas, such as European, and especially French; liberal ideas, encouraging education, free press and secular laws were argued as important.[15] In accordance with this view, during the twentieth century the political system was gradually opened to the participation of new social sectors.[16] With some exceptions the country was governed by constitutionally elected representatives and is in a Latin American standard, the country with the longest experience with democracy (during the period 1831 to 1973). When it came to private relations it has been argued that the state did not intervene directly; however it supported and guaranteed the leading groups and industrialists often obtained exclusive privileges.[17] Later the state assumed a larger role in the economy with the introduction of import substitution industrialisation (ISI) from 1939. The state then became in a larger degree an investor and employer and became a great source of

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6 Bergh (ed.), *Norge fra u-land til i-land: vekst og utviklingslinjer 1830-1980*, 1983, p. 237
7 Hodne, *Norsk økonomi i det 19. århundre*, 2000.
8 Maddison, *The World Economy: Historical Statistics*, 2006, p. 264
9 Fagerberg, (ed.), "Innovation-systems, path-dependency and policy: The co-evolution of science, technology and innovation policy and industrial structure in a small, resource-based economy", 2008.
10 Smith, "Innovation and growth in resource-based economies", in *Competing from Australia*, 2007, p. 53
11 UNDP Human Development Report.
12 Systems of production in large properties (plantations).
13 Gomá, *Chile y su industrialización*, 1986, p. 44 and www.memoriachilena.cl
14 Pinto, *Chile, un caso de desarrollo frustrado*, 1959, p. 82
15 www.memoriachilena.cl
16 www.memoriachilena.cl
17 Carmagnani, *Desarrollo Industrial y Subdesarollo Económico El Caso Chileno (1860-1920)*, 1998, pp. 28-29 and www.memoriachilena.cl.

credit for the private industrial sector.[18] From the mid-nineteenth century the country developed industrial sectors based on advanced technology of the time, such as textile and clothing production, ship building, brewing, canning, dairy production, mechanical workshops, furniture production etc. These changes were part of a qualitative transformation of the economy which saw an acceleration of economic activities and the entry of various goods and services in the market.[19] In Valparaíso several industries flourished and the city was often called the "Manchester of South America.".[20] The manufacturing sector represented less than 15 per cent of GDP before 1900 and 11 per cent in 1930, which means that it actually declined. Until 1953 it represented less than 20 per cent. Mining, agriculture and services also here constituted the biggest part of GDP.[21] From old economic activities based on natural resources, such as timber, new productions emerged, such as cellulose and paper productions from second part of the nineteenth century. Wine production started with small quantities in the 1870s and became later a big sector. The mining sector grew and the country became one of largest producer of copper in the world. These transformations acquired more and advanced technology. However, there is a general agreement that Chilean industrial development was modest, especially in comparison to European, North American and Japanese developments of the time.[22]

Taking into consideration the two countries' similarities in resources; why have the two countries shown relatively big variations in terms of economic growth? What are the underlying factors of growth in Chile and Norway? There can be many reasons for this, and this project investigates only some of the potential causes. Did knowledge institutions play a role in industrial development in Chile and Norway? If so, how did this occur? What role did they play? What were their purposes, objectives and impacts? This work in progress will need to be much further developed in order to provide a solid base for a productive comparison of the two countries. The analysis is only superficial and does not give an in-depth study. In this sense no firm conclusions are given. My preliminary hypotheses are that knowledge institutions played a crucial role in industrial development in the two countries; however knowledge institutions in Norway encouraged transfer and diffusion of useful knowledge and technological change in a larger degree than in Chile. Differences in the role of knowledge institutions are important when we seek to explain the two countries' different industrial and economic development paths.

First I give an introduction of the theoretical framework. Subsequently a short description of the two countries' mining industries is given in order to have an overview of the development of the sectors. Eventually I present comparable emerging knowledge institutions focussed on mining in both countries and some initial work with regard to mining education.

Historiographical and conceptual contexts

This comparative research project takes as a starting point the fact that both Chile and Norway have in a large degree based their economy on resource based industries. The investigation is also placed within global history which starts with the question why some countries are rich

[18] Carmagnani, *Desarrollo Industrial y Subdesarollo Económico El Caso Chileno (1860-1920),* 1998, pp. 28-29
[19] See for example Ortega, "Acerca de los origenes de la industrialización chilena 1860-1879" in *Nueva Historia* año 1 no. 2, p. 4 and Carmagnani, *Desarrollo Industrial y Subdesarrollo Económico El Caso Chileno (1860-1920),* 1998, p. 28
[20] Gomá, *Chile y su industrialización*, 1986, p. 53
[21] Braun, (ed.), *Economía chilena 1810-1995 Estadísticas históricas*, 2000, pp. 31-33 and 220-222
[22] Ortega, "Acerca de los origenes de la industrialización chilena 1860-1879" in *Nueva Historia* año 1 no. 2, p. 4 and Pinto, *Chile, un caso de desarrollo frustrado*, 1959, p. 70

and some are poor. I will in this section present the general theoretical framework related to my thesis.

Growth in resource based industries

It is often suggested that countries with economies based on natural resources, such as agriculture and minerals, grow more slowly than countries based on finished process industries. It has been suggested that an abundance of natural resources generates sectors with medium and low technological activities and low export earnings, which subsequently leads to slow growth. Due to the fact that importation of industrial goods is generally more expensive, the resource based economies find themselves in a vicious circle or a "resource curse" in which they are always in deficit. As a consequence, this prevents the economic progress that characterises industrialised countries. Scholars often look to many Latin American and African countries to find evidence.[23] However, some of the richest countries in the world, like Norway, Sweden, Canada, New Zealand, Australia (and even the United States) have had and still have an abundance of natural resources. Historically, resource sectors have constituted large parts of the economic structures of these countries, and have been an important source of income for the state. Keith Smith writes that:

> "(t)hese small, open economies have rested their development paths on resource-based sectors, and out of them have developed low- and medium-technology industries that have driven growth within these countries. This has been the case not only historically, but in many instances remains so today."[24]

Consequently we can determine that there are differences in growth between countries with natural resource abundance. Based on natural resources, some countries have developed extensively and even progressed and transformed into being the richest countries in the world, while others still remain underdeveloped and relatively poor. This leads to the question; why do some resource countries succeed and others fail? De Ferranti and colleagues propose that:

> "… (t)he fact that Australia, Canada, and the Scandinavian countries succeeded by playing to their resource strengths, suggests that success has less to do with what a country produces in particular, and everything to do with the way in which it produces it."[25]

In order to extract resources and develop resource based industries technology, innovation, knowledge and learning processes are decisive. They further argue that development in resource based economies "…depend(s) on establishing an environment that enables innovation and the adoption of technologies."[26] Moreover, countries can adopt and develop technology in different ways and in this sense they can establish different knowledge bases which in turn encourage specialisations. Olav Wicken in this context states that resource based industries should be analysed "… as dynamic processes which can evolve in different directions depending on social and political contexts as well as by decisions undertaken by organizations and individuals."[27] The specialisations in knowledge are necessary for the

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[23] Different theories have influenced this way of thinking. For example the Prebisch/Singer hypothesis from the 1950s which argued that the "resource curse" derived from the declining terms of trade between resources and manufactures; Sachs and Warner's paper "Natural resource abundance and economic growth" introduced the idea that resources inhibited growth; Neo-Schumpeterian ideas about the sectoral structure of growth arguing that the key issue is that it is what you do, not how you do it, that matters. The basic and general recommendation is to get out of resource based industries and low tech and focus more on elaborated and processed goods and industries.

[24] Smith, "Innovation and growth in resource-based economies", in *Competing from Australia*, 2007, p. 53

[25] De Ferranti (ed.). *From Natural Resources to the Knowledge Economy*, 2002, p. 52

[26] *Ibíd*., p. 52

[27] Wicken, "The Norwegian Path Creating Resources and Building Enabling Sectors", 2010, p. 2

development of competitive firms and industries and can in turn lead to dissimilar trajectories between economies.[28]

Diverging paths

During the eighteenth and nineteenth century European countries experienced an industrialisation process which involved a wide range of transformations and technological innovations in a number of sectors and activities. The societies went from being agrarian to become industrialised. This advance involved large adjustments in the economic and social structures and also the development of a global divergence which implied that some countries (European countries, the United States and later Japan) experienced sustained economic growth with sustained innovation and technological change, while the rest of the world did not. This "great divergence" and the fact that the West took a step ahead and left the rest of the world behind is being discussed by many scholars, however they have come up with rather different theories as to the causes of the Industrial Revolution which, it is argued, started in Britain in the mid-eighteenth century and later spread to other countries.

Various scholars, such as Margaret C. Jacob, Joel Mokyr, Kristine Bruland and others, have began to focus on the knowledge behind the technological change which formed the Industrial Revolution. Kristine Bruland argues that:

> "… however much growth may require capital accumulation and changes in the quantity and quality of labour, its ultimate source is technological capability. Capital and labour can only be deployed around specific technologies, and the capability to use them. Such capability in turn is a function of learning, of knowledge accumulation."[29]

Margaret C. Jacob states that a "Scientific Culture" arose in Europe in the eighteenth century, particularly in England. People started to believe that science and technology could control nature and that science could make profits through improvements in productions. This belief was supported by the political environment and the work of scientists was encouraged. These scientists were part of the Enlightenment and contributed to an industrial mentality in England. Other citizens from the elite started to absorb the scientific culture in the second half of the eighteenth century, which implied that the culture spread.[30] Joel Mokyr agrees with Jacob to some extent, but suggests that historians have not been able to support the idea that the scientific revolution led directly to the Industrial Revolution. Focusing on informal and unsystematic practical knowledge, as well scientific knowledge, Joel Mokyr argues that what was crucial to the Industrial Revolution was what he calls the "Industrial Enlightenment".[31] His argument is that the divergence between the East and the West did not arise from differences in resource endowments, as argued for example by Kenneth Pomeranz[32], but from a "knowledge revolution" that occurred in the West and not elsewhere. This expansion of knowledge implied a deepening, widening and circulation of useful knowledge supporting technological change. Mokyr builds his argument on Nobel Prize winning economist Simon Kuznets who in 1965 identified useful knowledge as one of the main sources of modern

[28] *Ibíd.*, pp. 4-5
[29] Bruland, (ed.), "Knowledge Flows and Catching-Up Industrialization in the Nordic Countries The Roles of Patent Systems", 2010, p. 1
[30] Jacobs, *The Cultural Meaning of the Scientific Revolution*, 1988.
[31] See Mokyr, *Gifts of Athena*, 2005 and Mokyr, *The Enlightened Economy. An Economic History of Britain 1700-1850*, 2009. He links the Industrial Revolution in Britain to the expansion of knowledge.
[32] For different theories about causes of the "great divergence" and the rise of the West see for example Pomeranz, *The Great Divergence*, 2000; Allen, *The British industrial revolution in global perspective*, 2009; Landes, *The wealth and poverty of nations*, 1998

economic growth.[33] According to Mokyr the most successful economies during the Industrial Revolution were those in which connections between the people with different kinds of useful knowledge necessary to make techniques, as well as the people with competence to operate the technology, were the most well-organised and efficient. He states that the lack of knowledge has been the principal reason why societies have been limited in their ability to increase material wealth.[34]

In this context, it is important to have in mind that in smaller countries, such as Chile and Norway, industrialisation, or industrial development, implied acquiring foreign useful knowledge, and not so much developing their own. It was usually harder for smaller countries to implement investments and research in the same degree as industrial powers such as Britain, Germany, the United States and Japan which competed with each other in order to be leader in technology. Therefore, technological change and economic growth in small countries normally implied the acquisition of foreign technology and adjusting and modifying it to local conditions. Whether countries succeed in catching-up, industrialising and remaining competitive depended to a large extent on their skills and capacities to transfer and employ foreign technologies. This is not just a matter of buying machines, however involves the capacity to select, employ, modify and improve the transferred technology. The transfer, diffusion and use of the useful knowledge needed to develop and industrialise often took time. The learning processes in relation to the use of techniques, adoptions and modifications of technology etc. therefore did not necessarily result immediately in economic growth. This is important when seeking to explain technological change and economic growth.

How did countries facilitate the creation, acquisition and transfer of useful knowledge? Douglass C. North (and others) claims that a requirement for innovation is an institutional framework which promotes, or at least not hinder technological change and learning. He states that institutions determine transaction and production costs in relation to economic activities. There are lower transaction costs when institutions are efficient, and the costs are higher when institutions are inefficient or a hindrance to economic growth. Institutions are in this sense as sets of rules which regulate economic behaviour; they are the rules of the game and include written laws and unwritten codes of conduct which provide the framework in which firms work. Institutions can therefore be formal and informal. North writes that:

> "… history…[…]… is largely a story of institutional evolution in which the historical performance of economies can only be understood as a part of a sequential story. Institutions provide the incentive structure of an economy; as that structure evolves, it shapes the direction of economic change towards growth, stagnation, or decline."[35]

In this sense, institutional settings are important when aiming to explain differences in economic development between countries. A large share of the literature analyses the different institutional settings with regard to the role of the laws related to property rights, the enforceability of contracts, financial systems, freer entry and exit conditions, and the framework for employment.[36] These institutions can be important premises for technological change. Other scholars argue, however, that it is also relevant to analyse institutions at lower levels, such as technical societies, organisations and universities, among others, since they are decisive for the transfer and diffusion of necessary and essential useful knowledge to

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[33] Kuznets, *Economic growth and structure*, 1965, pp.85-87
[34] Mokyr, *Gifts of Athena*, 2005.
[35] North, "Institutions" in *The Journal of Economic Perspectives*, Vol. 5, No. 1., 1991, p. 97
[36] Bruland (ed.), "Knowledge flows and catching-up industrialization in the Nordic countries: the roles of patent systems", pp 63-94

industries. The focus on local knowledge institutions must be considered in relation to the fact that industrialisation implied in many countries a broad process in which a wide range of sectors and activities went through a process of learning, change and growth.[37] This leads to the question: which institutions were involved in transferring, diffusing and distributing useful knowledge in smaller, late comer, resource based countries?

Concepts and definitions

Technology and innovation

It is common to use a wide definition of technology. Technology is usually seen as the knowledge, methods, techniques and organisational processes needed to produce goods or services. The knowledge related to production implies the understanding and know-how that are necessary to implement a production. Technology further involves techniques which are machines, tools, equipments and processes needed to employ, repair and modify these. The organisation implies the administration, management and coordination systems through which economic activities occur. These different aspects of technology are integrated in production processes.

Innovation, on the other hand, means changes in the production processes or the products and services that are used. The way in which a product or service is made is modified or the output is changed. Modern economic growth is characterised by a constant transformation of production processes and the products that are produced. This includes for example the introduction of new machines, techniques, other methods of production, manners of organising production, new resources and products.

Useful knowledge

In order to make technological changes new knowledge is acquired. Useful knowledge is an analytical concept and a tool used to identify knowledge utilised for economic purposes. This can involve all from abstract, theoretical and scientific knowledge concerning natural laws to technical and engineering know-how, skills or expertise. This knowledge is often “tacit”, unwritten knowledge and can be difficult to explain. Joel Mokyr divides useful knowledge into “sub-knowledges”, which all form part of the knowledge involved in the technological change and innovation processes. He makes three main points. Useful knowledge consists of (1) “propositional knowledge” which is knowledge about natural phenomena and regularities, principles and natural laws (knowledge “what”, nature laws). (2) Useful knowledge also consists of “prescriptive” or “instructional knowledge”, which can be applied to create techniques (knowledge “how”, how things work). It is described as “sets of executable instructions or recipes for how to manipulate nature”. In this sense, it consists of all the techniques that has been developed based on propositional knowledge. The two aspects of knowledge are connected together or based on each other in the development of new techniques and technological change processes. Both knowledges serve as support for the invention or innovation of techniques and the implementation of them in production. Mokyr states that the distinction between propositional and prescriptive knowledge is different from the distinction between “science” and “technology” and between ”theory” and “empirical knowledge”. He characterises propositional knowledge as the knowledge that is discovered, while prescriptive knowledge is related to knowledge that is invented. Propositional knowledge can be widely accepted, and in this case “right” or it can be generally neglected, and in this case “wrong”. However, prescriptive knowledge can lead to technology which works or does not

[37] See for example Bruland, ”Kunnskapsinstitusjoner og skandinavisk industrialisering” in Engelstad (ed.), *Demokratisk konservatisme*, 2006, p. 249 and Bruland, “Skills, Learning and the International Diffusion of Technology” in *Technological Revolutions in Europe*, 1998, p. 167

work, or functions differently and in better or worse ways. (3) Third, Mokyr argues that after technology is implemented in production, useful knowledge about how it is used, operated, repaired etc. is needed. The workers can be taught the necessary instructions needed for the technique to work without knowing all about the knowledge needed to invent or innovate it; Mokyr calls these skills "competence".[38] People in possession of different useful knowledges can share each others information, interact, communicate and cooperate in order to develop new practices, methods and products.[39]

Knowledge institutions

Knowledge institutions are institutional and organisational mechanisms through which useful knowledge for economic activities are regulated, obtained, adopted, used, modified, transmitted and distributed. These included for example education systems, intellectual property systems and economic regulations. Knowledge institutions can also imply formal and informal local organisations such as scientific and technical societies, government policies for travel and immigration, technical education institutes, prize systems, scientific and engineering journals and magazines, industrial exhibitions, industrial espionage activities, as well as the business firm.

An introduction to development in Chilean and Norwegian mining sectors

The mining industry in Chile grew to be an important economic sector (including gold, copper, silver, coal, saltpetre, iodine and sulphur); it represented 12 per cent of GDP in 1860, 23 per cent in 1900 and 26, 4 per cent 1930: 3 per cent of the total labour force worked in the industry in 1860, a little bit more than 3 per cent in 1900 and 6 per cent in 1930. This implied 21 367 workers in 1860, 35 551 workers in 1900 and 83 418 workers in 1930.[40] Workers were frequently paid by salary in this sector, which was not common in this period in Chile. It has been argued that the economic growth in the nineteenth century was largely linked to this sector.[41] A key metal for production was copper, but silver, gold and coal also represented important industries. In 1870 Chile became the biggest exporter of copper in the world.[42] After the War of the Pacific (from 1879 to 1884, from which Chile achieved the territory which today is the Northern part of the country) the country also became a large producer of saltpetre (until WWI when the production went into crisis due to synthetic saltpetre). New technology was acquired and introduced to the industry from the mid-nineteenth century such as new types of ovens for smelting, steam engines, electric generators and transport infrastructure, which improved products and production.[43] However, in spite of some technological progress Chilean scholars argue that the working system in the nineteenth century mining had not changed much since colonial times.[44] The techniques were primitive compared to other countries and metal deposits were mined exclusively on the surface of the metal deposits. Scholar underline, however, that advanced methods of the time were introduced in the refining industry and infrastructure even though the technology with regard

[38] Mokyr, *Gifts of Athena*, 2005, pp. 4-12
[39] Mokyr, Knowledge, Enlightenment, and the Industrial Revolution: Reflections on *Gifts of Athena*, 2006, p. 2
[40] Braun (ed.). *Economía chilena 1810-1995 Estadísticas históricas*, 2000, pp. 31-33, 216-218 and 220-222
[41] Carmagnani, *Desarrollo Industrial y Subdesarrollo Económico El Caso Chileno (1860-1920)*, 1998, p. 14
[42] www.memoriachilena.cl.
[43] Sutulov, "Antecedentes históricos de la producción de cobre en Chile", 1975; Pinto, *Expansión Minera y Desarrollo Industrial: un Caso de Crecimiento Asociado (Chile 1850-1914)*, 1990, p. 109 and www.memoriachilena.cl.
[44] Pinto, *Chile, un caso de desarrollo frustrado*, 1959, p. 47

to extraction remained simple.[45] From the first part of the twentieth century big foreign investments with advanced technology (British and North-American) permitted exploitation also in low-grade mines.[46] A much deeper description of the technology that the companies used in the mining industry at any time is needed in order to understand the knowledge that was acquired to operate them. How did companies acquire the technology they used? If the Chilean mining lacked technology and the techniques were primitive, why was not the technological level improved? Did it have anything to do with lack of knowledge to transfer, adopt and use it?

Metals and minerals have represented important productions in Norway for centuries. Essential metals in the nineteenth century were silver, copper and iron, however sulphur, nickel, cobalt, zinc, and others, also represented important productions. It is stressed that the metal extraction sector had stronger organisation of workers in the early nineteenth century than other sectors and was a pioneer in relation to modern system of salaries, as in Chile. Iron works represented a capitalistic way of organisation with strong economic concentration of power.[47] The sector involving mining (not exclusively) represented 17, 8 per cent of GDP in 1865, 24, 3 per cent in 1890 and 30, 1 per cent in 1930. In 1890 0, 6 per cent of total work force worked in mining, in 1910 0, 9 per cent and in 1930 0, 6 per cent. This implied 4 400 workers in 1890, 8 100 workers in 1910 and it had reduced to 7 200 workers in 1930.[48] During the nineteenth century new smelting methods, railway transport and other infrastructure, new explosives, steam engines etc. were introduced. The use of less efficient and traditional labour intensive operations was reduced.[49] In the 1860s many mining companies had problems and many were closed down. Later, from the 1870s and onwards, new technology such as compressed air methods, drilling machines and other refraction methods both in opencast and underground mines increased productivity and encouraged new productions. New technology based on electricity from waterpower was established from the late nineteenth century and was important for exploitation and ore processing. The industry represented a technologically advanced sector, and it has been stated that for example Røros Copper Works was technically one of the most modern mining companies in Europe.[50] In addition to metal extraction large-scale metallurgical and electrochemical industries and the production of aluminium based on the generation of electricity were established in the early twentieth century.[51] In Norway too, as in Chile, foreign companies, especially German and English, played an important role in the mining sector, and in particular the in development of the metallurgical industry after 1900.[52]

Both countries developed new industrial activities during the nineteenth century and had a growing mining industry. Even though a deeper analysis of the techniques and technology employed in the sector is needed in order to obtain a total overview of the companies and their technology, it appears at first glance that the Norwegian mining industry developed to be more technologically advanced than the Chilean sector. Norway created a large scale metallurgical and electrochemical industry, apart from the metal extraction and refining

[45] Pinto, *Expansión Minera y Desarrollo Industrial: un Caso de Crecimiento Asociado (Chile 1850-1914)*, 1990, p.109
[46] Sutulov, "Antecedentes históricos de la producción de cobre en Chile", 1975 and Pinto, *Expansión Minera y Desarrollo Industrial: un Caso de Crecimiento Asociado (Chile 1850-1914)*, 1990, p.109
[47] Hodne, *Norsk økonomi i det nittende århundre*, 2000.
[48] Bore (ed.), "Fra håndkraft til høyteknologi – norsk industri siden 1829", 2008, p. 49
[49] Nissen, *Røros Kobberverk 1644-1974*, 1976, p. 188-201
[50] Carstens, *…Bygger i Berge*, 2000, pp. 94, 77.109
[51] Thue, *Samarbeidets kraft*, 2000.
[52] Carstens, *…Bygger i Berge*, 2000, p. 33

industries, which indicates industrial diversity. If the Norwegian sector was technologically more developed than the Chilean one, how was the necessary technology and useful knowledge acquired?

Comparable knowledge institutions in the mining sectors

Can the technology and useful knowledge in the two mining sectors be linked to local knowledge institutions? There are examples in the two countries of apparently similar local knowledge institutions which aimed to diffuse knowledge and stimulate and promote industrial development in the mining sectors. The two countries established mining societies, research institutions, mining journals and mining education institutions. The institutions presented here are apparently similar and comparable, in the sense that it seems they have the same aim, namely encourage mining or promote transfer and diffusion of knowledge in the two sectors. The list presented here is not exclusive and a further mapping of local knowledge institutions is needed.

Several industrial societies were formed during the nineteenth century in both countries and represented industrialists from various sectors or one specific industry. In many cases their aims were to ensure industrial interests, create networks, discuss technological issues, and promote education and industrial development. Many of the societies were focussed on what happened in foreign countries with regard to new technologies and industrial development. In Chile the Institute of Engineers, established in 1888, represented Chilean professional engineers and collaborated often with foreign engineering organisations in projects. The National Mining Society which represented Chilean miners was founded in 1883.[53] The Norwegian Society for Engineers and Architects was founded in 1874. From around mid-nineteenth century several organisations and meeting places emerged and represented forums where technicians and engineers could exchange experiences, discuss problems and acquire information.[54] The Norwegian Mining Engineer Association and the Norwegian Mining Industry Association were both established in 1900.

The National Mining Society in Chile published a newsletter of technical, legal and gremial character from 1883.[55] The newsletter included descriptions about the current situation of the national mining industry and that of other countries, articles about specific companies and information about national and foreign technology. Discussions with regard to the national and foreign mining education were also presented throughout this period.[56] In Norway a journal focussed on mining, the Journal of Chemistry and Mining, started later than in Chile and was also published from 1913 by the Norwegian Mining Engineer Association. There were examples of other mining journals before this year; however, they stopped publishing after a couple of publications. This journal presented information about the Norwegian mining sector as well as the situation in foreign mining sectors. New technology and methods available in the sector were continuously published and there were in this journal, as in the Chilean one, articles about specific companies and it also included articles about technical education, and specifically the education focussed on mining.[57] Technical Journal was published by the Norwegian Society for Engineers and Architects (founded in 1874) from

[53] Villalobos, *Historia de la Ingeniería en Chile*, 1990 and Urrutia, *La Escuela de Minas de La Serena*, 1994
[54] Bruland (ed.), “Knowledge flows and catching-up industrialization in the Nordic countries: the roles of patent systems”, pp 63-94
[55] Urrutia, *La Escuela de Minas de La Serena*, 1994
[56] National Library in Santiago, “Boletín de la Sociedad Nacional de Minería” 12A; years 1890-1940
[57] National Library in Oslo, NB/BRU, NAZ-film:”Tidsskrift for Kemi og Bergvæsen” years 1913-1940

1883.[58] The Journal published was more general the mining journal and covered also other industries, however included specific information about national and international technology with regard to mining, new possibilities for development and discussions with regard to the role of technical education, also mining education.[59]

In Chile Chemical and Industrial Laboratory was established in Iquique in 1898. It provided analysis, tests and services to the saltpetre and mining industry, among other sectors. It also provided courses of two years in chemistry, chemical analysis, industrial chemistry and others.[60] In 1858 the Geological Survey of Norway, a public research centre was established. This institution was to provide research and knowledge, data and information to authorities, industries and others with regard to geology, mineral resources, sediments and ground water. The Public Laboratory for Raw Materials was established in 1917 and aimed to do research of the country's geological resources through chemical analysis. Geophysical Exploration Ore, founded in 1934, used geophysical methods.[61]

Formal mining education was introduced relatively early in Norway. The Mining Seminar in Kongsberg was established in 1757 and was one of the first higher technical mining institutions in Europe. In Chile, the Mining School of Copiapó, founded in 1857, was the first of its kind in Latin America.[62] During the nineteenth century and the early twentieth century mining education was in Chile provided at mining schools near mines and at the University of Chile and in Norway at the University of Oslo (from 1821 to 1914) and from 1914 at the Norwegian Institute of Technology.

We also find examples of students from different disciplines studying abroad and returning back to their countries after finished studies.[63] Both Chilean and Norwegian mining engineers and technicians travelled and studied abroad, often in Germany and England. In Norway the government granted stipends for Norwegian students who wanted to study abroad, and granted a total of 1006 travel stipends during the second half of the nineteenth century, of which 187 went to "mechanics", according to Norwegian scholars.[64] People moving around may have contributed to knowledge and technology transfers. There were also many examples of foreigners coming to the two countries to work. In both countries British immigrants constituted a big part of the work force in many sectors. For example in the Chilean coal industry Scottish workers worked as technicians and engineers from the beginning of the nineteenth century. Also in copper production foreign workers, often British, were hired during the nineteenth and twentieth centuries.[65] German professionals had a long tradition in Norway and were often hired in Norwegians mines from the seventieth century and onwards.[66]

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[58] Thue (ed.), *Statens kraft 1890-1947*, 2006
[59] National Library in Oslo, NB/BRU, NAZ-film: "Teknisk Ukeblad" years 1883-1940.
[60] Muñoz Sierpe, *Enseñanza Universitaria y Técnica de Chile*, 1909, p. 31
[61] Carstens, *…Bygger i Berge*, 2000, pp. 72-73
[62] Boletin Centenario, *Escuela de Minas de Copiapó 1857 – 1957*, 1957, pp. 8-18; Carstens, *…Bygger i Berge*, 2000, p. 94 and 107; Sutulov, "Antecedentes históricos de la producción de cobre en Chile", 1975; Pinto, *Expansión Minera y Desarrollo Industrial: un Caso de Crecimiento Asociado (Chile 1850-1914)*, 1990, p.109 and Nissen, *Røros Kobberverk 1644-1974*, 1976, p. 188-201
[63] See for example Urrutia, *La Escuela de Minas de La Serena Derroto de sus Orígenes*, 1992, p. 29 and Børresen (ed.), *Bergingeniørutdanning i Norge gjennom 250 år*, 2007.
[64] Bruland et al., "Knowledge flows and catching-up industrialization in the Nordic countries: the roles of patent systems".
[65] See for example Mazzei de Grazia, *Los británicos y el carbon en Chile*, 1924 and Millán, *La minería metálica en Chile en el siglo XIX*, 2004.
[66] Carstens, *…Bygger i Berge*, 2000, p. 86

In order to understand the impacts and effects of the knowledge institutions detailed analysis of their role in transfer and diffusion of useful knowledge is needed. So, I further ask: how did the knowledge institutions develop and what was the motivation behind their establishment? Did they encourage transfer and diffuse useful knowledge and if so, to what extent? What role, if any, did they play in industrial and technological development? Underlying these questions is the focus on finding the similarities and differences between the similar institutions in the two countries.

It is also relevant to ask to what extent the society was able to take advantage of the circulating useful knowledge? In order to understand how to use complex machines and read technical manuals skills in reading (at least), writing and numeracy were often necessary. The literacy in a country is in this sense a measurement for how good a country is able to benefit from and employ the available useful knowledge. Chile had around 36 per cent illiteracy in 1950[67] while Norway at the turn of the twentieth century illiteracy was practically non-existent and the country became top three in literacy in Europe.[68] The fact that the Norwegian population became literate long before the Chilean one does not explain how useful knowledge was taken advantage of and used, however it implies that technical information and useful knowledge eventually were easier distributed or spread in this country. Moreover, it can indicate that the Norwegian population was more receptive to absorb knowledge.

Mining education in Chile and Norway

The mining industries were important sectors in the two countries, and this makes it relevant to further investigate how learning processes for technicians and engineers played out and how they eventually influenced competence building in these industries. In this context it is relevant to mention the mining education in the United States and its role in developing the mining sectors. Paul David and colleagues argue that natural resources were exploited to a far greater extent in this country than in other countries after 1850 and that this was in a large degree due to the fact that it became the leading location for education in mining engineering and metallurgy in the same period. More than 20 schools in the country educated mining candidates from the 1860s to the 1890s. In 1893 it was noted that the United States had more mining students than any country in Europe, except Germany. Mining engineers assumed more and more managerial and executive roles within large firms. “The Mining and Scientific Press” wrote in 1915 that “nearly every successful mining operation, old or new, is today in the hands of experienced technically trained men.”[69] The education system played in this sense a role in developing the country’s mining industry. The question here is if the mining education in Chile and Norway encouraged competence building in their respective mining sectors, and if so, how? What kind of study was acquired to prepare good mining workers?

In order to answer these questions it is relevant to present a major debate with similar characteristics which emerged in both countries. This debate was about what shares should be given to “theory” and “science” on the one hand and “practice” on the other. This issue was related to the question: what kind of education was optimal to get competent technicians and engineers for industries? What should be included in teaching?

[67] Blomström (ed.), *Diverging Paths Comparing a Century of Scandinavian and Latin American Economic Development*, 1991, p. 7 (De Ferranti (ed.) operates with 20 per cent in 1952)
[68] Hodne (ed.), *Norsk Økonomi i det 19. Århundre*, 2000, p. 151
[69] David (ed.), “Increasing Returns and the Genesis of American Resource Abundance”, 1997, pp. 229- 231

This matter was hotly debated in many countries in the nineteenth and twentieth centuries.[70] However, it has not always been clear what was meant "theory", "science" and "practice" and if and how it was reflected in the curriculum. Throughout the nineteenth and twentieth centuries technical schools and universities took different approaches with regard to technical instruction. Typically, they either focussed on practice or on theory and science, yet with some choosing to emphasise both equally. Many scholars argue, however, that several European and North-American institutions changed towards science and theory in the later nineteenth century. In the United States, for example, education in engineering had focussed on apprenticeship as opposed to "formal" training in science and mathematics, however started to focus more on science and mathematics in the 1880s and 1890s, although combined this with practical exercises and experience in order to obtain a "balance between theory and practice."[71] A similar trend has been identified for Europe, where many institutions strengthened the share of science and theory and lessened that of "practical training." In Germany, this was met by scepticism from contemporaries, who argued in the 1890s that technical education was "over-theorised" with an emphasis on mathematics and science. Methods of demonstration, observation and experimentation were not prioritised and visits to industrial firms were, it was complained, "the only means of obtaining any impression of the problems of engineering practice."[72] One solution to such conflicting views was, for some colleges in Germany and England, to introduce laboratories, which combined "theoretical analysis of machines" with practical "experimental work."[73] Why did colleges take different approaches to technical education? There were undoubtedly many different factors involved; however, it has been argued that the different standpoints reflect different opinions with regard to how better to solve technological problems. Some believed that technical problems were solved by applying scientific theories, methods and instruments, others thought solutions were practical in nature, and often emphasised what was economically and practically viable.[74] In Chile and Norway, how were the technical and engineering mining studies designed? How was the curriculum organised? Was there any communication between the universities/schools and industries, and if so, how was this reflected in the courses? Were there any changes over time?

In Norway mining education was transferred to the University of Oslo in 1821. The University took a theoretical and scientific approach, while practical instruction was located to the country's silver mines at Kongsberg, a small town 87 km east of Oslo. While in the eighteenth century the aim was solely to educate engineers for mining, the University now had a twofold objective; to provide the country with experts in mining and research.[75] In this sense, the role of the engineer expanded to include scientific research in mineralogy and geology. The study accordingly included a wide range of subjects such as physics, chemistry, advanced mathematics, geology, mineralogy and metallurgy. The students worked in laboratories and went on excursions to learn about geological conditions and mining companies. It was argued that after the study the students must be able to read maps of mines and geological findings, draw their own maps, survey geological findings and mines, handle instruments to find mines, know how the most important machines used in mines operated and the laws that applied to mining.[76] Perhaps surprisingly, in the 1860s criticism arose that

[70] Harwood, "Engineering Education between Science and Practice: Rethinking the Historiography", 2006
[71] *Ibíd.*, 2006, p. 56
[72] Fox (ed.), *Education, technology, a industrial performance in Europe, 1850-1939*, 1993, p. 76
[73] Harwood, "Engineering Education between Science and Practice: Rethinking the Historiography", 2006, p. 59
[74] *Ibíd.*, p. 54
[75] Blom, *Fra Bergseminar til teknisk høyskole*, 1957, p. 132
[76] Børresen (ed.), *Bergingeniørutdanning i Norge gjennom 250 år*, 2007, pp. 39-41

there was not enough emphasis on practical subjects. The newspaper Morgenbladet published articles by an anonymous mining engineer who argued that instruction was "only theoretical" and that no "practical exercises" were carried out during the study. The course was too much dominated by advanced mathematics at the expense of mining construction, metallurgy, the study of mines and other "practically emphasised subjects". He referred to mining candidates who after four years of study arrived at the Kongsberg silver mine to start the practice were not able to "…climb the mining ladders or not even to hold a mining lamp without burning their fingers." This, he held, was why half of the students who graduated soon turned to other professions, and leading positions at mines were filled by foreigners or people with only practical experience. In his opinion, the mining candidates were better suited as professors and scientists than for industry. Other mining engineers suggested, in the same newspaper, that the requirements in mathematics should be reduced and that the practice period at Kongsberg should be extended. Some changes were made in the curriculum, ten years later in 1870; the study on machines was introduced and the amount of mathematics in exams was reduced. One year later it was the students themselves who wanted reform. They requested changes in the University regulations to allow for more practical assignments. In 1872 the Kongsberg miners' union suggested that teaching should be carried out by mining engineers with practical experience "…so that students could get in close contact with the practical aspects of mining." As it happened, both requests were denied by the University.[77]

So far the participants in the debate on "theory versus practice" in mining education were engineers, students and industry on the one hand and the University on the other. Still, after a further debate in the press, the Ministry and different departments of the University became involved at the end of the 1880s. The result was a new system of examination based on assignments in mechanics, practical geology and laboratory analysis, in addition to four months practice at different sections of a mining plant and a "technical test" after the practice.[78] In other words, the argument in favour of more practice won through after the debate had been raised to the political level. Compared to the late nineteenth century trend in northern American and European technical education, which saw an increased role for science and theory mentioned above, we find in Norway an opposite tendency.

However, in 1914 when mining education was moved to the Norwegian Institute of Technology (NIT) in Trondheim things changed. As had been the case at the University of Oslo, NIT was to educate students as scientists and engineers with the aim to prepare them to be leaders in Norwegian industry. There were seminars which included practical and experimental assignments, but most historians believe that the practical engineering subjects of the mining study were in fact accorded lower status. In this sense, theoretical subjects, such as mathematics, physics and chemistry were given priority and scientific achievements were emphasised most. Moreover, NIT admitted that even though this was a profession -oriented study, or vocational education, graduates were not ready for their profession, in the same way journeymen were.[79] This comes close to an admission that the candidates actually needed more practice in order to work and function as mining technicians. Historians argue that there was a general divide between professors at the NIT and industry. Often professors' sole concern was science, while industry was concerned not to break with practice. Some teachers emphasised that even the most practical industrial chemist would have a lot to gain from

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[77] My translations: Blom, *Fra Bergseminar til teknisk høyskole*, 1957, pp. 140-142, 148-149 and 152-156
[78] *Ibíd.,* p. 154
[79] Hanisch, *Vitenskap for industrien*, 1985, pp. 149-176; Brandt (ed.), *Turbulens og Tankekraft Historien om NTNU*, 2010, pp. 108-110 and Børresen (ed.), *Bergingeniørutdanning i Norge gjennom 250 år*, 2007, pp. 52-53, 60 and 103

methodical research and learning how to present work in publishable form. Contributors to the Technical Magazine, published by the Norwegian Engineer and Architect Association, expressed concerns that instruction in engineering was too theoretical. There are examples of mining students complaining about a lack of practice. For instance, one graduate stated that the curriculum was far removed from the practical work students were confronted with later, when employed in the mining sector. The first years after college were therefore "disproportionately difficult." The debate thus carried on into the twentieth century at the NIT, as at the University of Oslo, and it became an element in explanations of why the NIT, in the first decades of its operation, found it difficult to live up to its goals and role of pioneer to industry.

In Chile education in mining was, from the mid-nineteenth century, given at the University of Chile and at technical schools in towns near copper mines. The mining schools were intended to provide more practically oriented education than the University. Instruction at the Mining School of Copiapó included geometry, history, Spanish, mathematics (advanced mathematics was removed from the curriculum in 1896), geography and chemistry. The course in industrial mechanics included construction and use of pumps and extraction machines, foundries, and methods of mining exploitation. Excursions to mines were a part of the study and the students did six months practice working in mines as if "they were employees."[80] The Mining School of La Serena had a laboratory and instruments with the capacity to do analyses of minerals and the director informed in 1892 that smelting furnaces had been installed in order for students to "learn by doing."[81] Nevertheless, in spite of these incentives and practical exercises and trips for the students, members from the National Mining Society argued in 1902 in the Mining Newsletter that the education at the mining schools should be "intensified with exercises of processes used to exploit the minerals." Accordingly, three years later, it was decided that the three year mining study should be "eminently practical" and that theoretic classes should be limited to six months. The students were to do tests of minerals, mills, foundries, concentrations, mine surveying and topography.[82] This reform was apparently not enough; the director of the Mining School of La Serena stated in 1912 that the reform in mining education had focussed too much on theory without "practical utility." He argued that practice and working methods were being neglected. Students took "technical exams" but graduated without knowing how to operate instruments or how to manage an installation. He stated that one should not confuse classroom learning with "technical visits" to mines and foundries and suggested that all the mining schools should acquire a mine for the students to exploit. Following this line of thought, ten years later, the professor and civil mining engineer G. H. Páez suggested in the magazine "International Engineering" that in order to improve mining education professors of "technical courses" should have experience in their fields of teaching, and that a period of obligatory practice for the students, of some months, should be implemented before they were given their title. This, he said, would encourage more contact with the mining industry. At the beginning of the twentieth century it was argued that there was a gap between the professional studies given at the institutions and the practical training which was needed in the mining industry, and that technical studies therefore were lagging behind in encouraging productive activities.[83] These examples show

[80] Villalobos (ed.), *Historia de la Ingeniería en Chile*, 1990, pp. 158-159; Boletin Centenario, *Escuela de Minas de Copiapó 1857 – 1957*, 1957, pp. 7-8 and 12
[81] Urrutia, *La Escuela de Minas de La Serena,* 1992, pp. 89-91
[82] *Ibíd..*, pp. 89-91
[83] Boletin Centenario, *Escuela de Minas de Copiapó 1857 – 1957*, 1957, p. 5 and Urrutia, *La Escuela de Minas de La Serena*, 1992, pp. 29, 89-95 and 100

that the technical schools, which in principle were to focus most on practice, were criticised for the lack of practice and experimental exercises.

Engineering studies was also provided at the University of Chile. The head principal in 1867 pointed out that the study should avoid extremes with regard to practical and theoretical teaching, and promoted a mix of the two. He stated that if the knowledge was limited to only being practical, it was weak, and if it was only concentrated on theory and abstract concepts, it was too "sterile" and could not be taken advantage of. A wide range of courses were offered, such as high level mathematics, linear and geometric drawing, topography, physics, geometry, topography, mineralogy, operation of mines, general and particular metallurgy, electro-metallurgy, bridge building etc. The students had to do laboratory work, had a practical test after completing their courses, and later, in 1919, it was decided that students were not allowed to start the last year of study without having worked for six weeks during the preceding summer in metallurgical industrial establishments.[84] Practice undoubtedly was included, but even so a contemporary writer claimed, in the mid nineteenth century, that although graduation from the University was more prestigious than from the technical schools, few of the students actually worked as engineers in the Northern mines after graduation and almost all the copper mines were led by "practical miners." He argued that practice was more important than "science" and "theory" in the mines; a good miner with practical experience and understanding could perform more efficiently and use tools better and with more accuracy than an engineer.[85] Even though this does not cover the whole period, we have examples of how much emphasis was put on practice in the mining profession. It is often held that excessive focus on theory, until the first decades of the twentieth century, meant that the engineering studies had problems with adapting to the reality in the industries.[86] Can this debate be related to the role of mining education in industrial development? If Chile's backwardness in terms of mining technology was in any way related to mining education, did the call for practical rather than theoretical knowledge play a part? To test such a hypothesis requires more research, perhaps in particular on the career paths of graduates from Chile's higher educational institutions in mining.

If we look at the meaning of "theory" and "science" it possibly was meant theoretical courses based on learning scientific theories in advanced mathematics, physics, chemistry and others, and "practice" were practical courses that involved practical and experimental exercises and technical and industrial training. Simon Kuznets argued that both the "theoretical level of scientific work", meaning observations as well as mathematics and logic, and "practical work" were involved in technological change processes.[87] Joel Mokyr is one of many historians who find the term "science" unhelpful when discussing technological change in the eighteenth and nineteenth centuries. To him, useful knowledge was mostly "unsystematic and informal," and being "practical" was of great importance. However he does, together with a host of historians, give science a much larger role in the second half of the nineteenth century. It is often held that in industrial leading countries, for instance Germany, scientific knowledge was a main contributor to encourage the country's to develop into becoming a major industrial power. Such knowledge was recognised as crucial for the development of major

[84] Sierpe, *Enseñanza Universitaria y Técnica de Chile*, 1909, pp. 11-12; Urrutia, *La Escuela de Minas de La Serena*, 1992, p.33; Villalobos (ed.)., *Historia de la Ingeniería en Chile*, 1990, p. 159 and Mellafe (ed.), *Historia de la Universidad de Chile*, 1992, p. 123

[85] Aracena, *La industria del cobre en las provincias de Atacama y Coquimbo y los depósitos carboníferos de Lota y Coronel*, 1884, pp. 326-327

[86] Villalobos (ed.)., *Historia de la Ingeniería en Chile*, 1990, pp. 158-159

[87] Kuznets, *Economic Growth and structure*, 1965, p. 84

innovations, and this was why education changed towards theory and science in these countries.

Technological change and economic growth in small countries relied perhaps, as we have seen, more often on the acquisition of foreign technology, and in order to industrialise they needed to develop the skills and competences to use foreign techniques and adjust and modify them to local conditions. This required practice. Does this mean that there was less need for theoretical learning and scientific research in Chile and Norway? If we take a closer look at the critical voices in the debates we can classify them as students, professors and principals, engineers, industrial organisations and contemporary writers. At this stage it is difficult to generalise, however all of the debaters criticised the instruction for having too much emphasis on theory, and interestingly there are no examples of criticisms of the curriculum being too focussed on practical subjects. Some refer to how lack of practical experience hindered graduates to work successfully. This suggests that practical knowledge was important. It is possible that the hands-on practical skills that the mining workers should acquire, according to these debaters, can be related to what Mokyr calls "competence," which is the ability to implement instructions of prescriptive knowledge in industry. In his discussion of the Industrial Revolution he says that in order for a technique to work skilled workers did not need to know all about the knowledge underlying the creation and formation of the technology.[88] So, what was perhaps just as important, or possibly more important than the useful knowledge needed to invent the machinery, was the ability to operate the machines in the mines and maybe modify and adjust them to local conditions. These included the equipment to extract the metals and minerals and the machinery used in foundries, among other things. In this sense, to make use of and manage foreign, new technology in mines, maybe it was unnecessary too know very much about mathematics, chemistry and physics? Can it be that for this reason the focus on scientific research and theory was less valued in the two countries? I need further to explore research material in order to fully reveal the different aspects of the mining education, its role in the building of competence and development of these sectors in Chile and Norway and the differences between the two countries.

The research project

This project seeks to examine the role institutions in economic development. This will be done by examining apparently similar knowledge institutions, which were principally concerned with transferring and diffusing useful knowledge, and their role in the development of the mining industries in Chile and Norway. This implies analysing:

1) the technological changes, innovations and useful knowledge in the two mining sectors and changes over time
2) how the knowledge institutions were created and their aims
3) their interactions and relation with other institutions, people and societies
4) their impacts and effects with regard to the transfer and diffusion of useful knowledge.

These points must be further analysed for two countries in order to be able to compare them and reveal eventual differences. My preliminary hypotheses are the following:

- Knowledge institutions played a decisive role in building industries in the two countries
- The Norwegian knowledge institutions played a more important role in transmitting and diffusing useful knowledge than the Chilean ones.

[88] Mokyr, *Gifts of Athena*, 2005, p. 14

- The Norwegian education system contributed in a larger degree than the Chilean one to competence building, technological and industrial advances in the mining sector.
- These differences are important when we seek to explain the two countries' different economic development paths.

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