The dynamics of resource-based economic development: evidence from Australia and Norway

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Keywords

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The Dynamics of Resource-Based Economic Development:
Evidence from Australia and Norway

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Abstract

Australia and Norway have achieved modern levels of development as resource-based economies, thus avoiding the so-called resource curse. Their ability to achieve this rested heavily upon repeated diversification into new resource products and industries. These processes relied largely on innovation, confirming the close ties that have existed between resource-based industries and knowledge-producing and disseminating sectors of society. We develop a resource-based diversification model that analyses the interaction between ‘enabling sectors’ and resource industries and apply it to the historical experience of the two countries.

JEL classification codes: N50; O13; O57; Q01
Keywords: resource curse; enabling sectors; knowledge economy; social technologies

1. Introduction

The notion that natural-resource oriented economies are feted to experience retarded or incomplete development has been around a long time, perhaps half a century. According to this perspective, the ‘windfall’ associated with resource abundance has brought in its wake cognitive, societal, policy, and economic restraints on
development. In the mid-1990s, Sachs and Warner conceptualised this perspective into what is known as the ‘resource curse’ hypothesis. This concept has been supported by data analysis across a large sample of countries which shows, in many cases, negative correlations between resource intensity and indicators of economic performance such as rates of growth, investment, and human capital (van der Ploeg, 2011).

Recent work has provided something of a counterbalance by indicating that the curse is not inevitable and by investigating what resource-based economies can do to mitigate it. The debate is of much interest to policy-makers in supra-national organisations like the World Bank who are concerned at the belated development of many resource-based Latin American nations and a range of oil-dependent economies (De Ferranti et al., 2002).

Some resource-based economies have avoided the curse altogether, and this includes those which have done so through a long period of economic development, although little has been written about them within this context. Our focus is a comparative study of two such successful resource-based economies, Australia and Norway. The comparative approach provides grounds for generalising about the conditions for successful development in resource-based economies. Economic development, by its nature, is a longitudinal process, and yet history has had little to say on this issue of contemporary interest, besides an implicit assumption that truly successful nations will transit from natural resource to manufacturing industries. Australia and Norway have continued to rely heavily upon their resource-based industries. In this paper, we look at how these two economies have continually renewed and extended their
resource base by drawing upon the role of learning and knowledge creation to facilitate innovation in these industries and spill-overs into others sectors.

The following section briefly reviews the resource curse debate. Section three summarises historical perspectives on the developmental role of resource-based industries and introduces our resources sector model of interaction between recipient and enabling sectors. Sections four to seven apply this model to Australia and Norway to explain the dynamics of their successful resource-based economic development. Some conclusions follow.

2. **Resource curse debate**

There is a range of economic, political, and socio-cultural strands of argument that seek to link resource-based economies with retarded development. Prebisch (1950) and Singer (1950) alleged the limited opportunities for innovation in resource industries and their tendency to experience a long term decline in the terms of trade. Hirschman (1958) believed manufacturing provided greater growth-inducing linkages between industries and sectors. Resource production can occur in sudden windfalls, motivated by changes in the conditions of supply such as new mineral discoveries or technologies for exploitation, or through increases in demand with the entrance of a newly-developing nation with large resource needs. The volatility of supply, demand, and prices has motivated concerns that private investment would be discouraged by uncertainty and that resulting government revenues would be unstable (Nurske, 1958; van der Ploeg, 2011). ‘Dutch disease’ is associated with the idea that a resources windfall impacts negatively on other sectors through an appreciation of the real
exchange rate (Neary and van Wijnbergen, 1986) and by causing crowding out in factor markets (Matsuyama, 1992; Sachs and Warner, 1995; Gylafson, 2001).

Socio-cultural explanations also take several forms. Most general, is the idea of slothfulness in the face of plenty, that striving to achieve the best in either public policy or the private sector is muted by easy wealth (Wallich, 1960; Levin, 1960). Alternatively, excessive exuberance has been cited, that private actors are driven by a get rich quick mentality and public policy by unguarded optimism, neither of which provides optimal long term outcomes (Nurske, 1958; Watkins, 1963). The growth-impeding role of dominant elites has been a common argument for the belated economic development of many Latin American nations, the intuition being that their ownership of wealth-generating natural resources constrains policies that favour the relative expansion of other sectors (Mahon, 1992).

A more explicitly political explanation of policy failure in resource-based economies is associated with theories of the rentier state. This particularly deals with the idea that a heavy reliance upon resource tax revenues, especially from foreign multinationals, in place of general taxation, weakens the relationship between a domestic government and its broader domestic constituency, and as a result weakens state institutions (Karl, 1997; Shafer, 1994). The resource curse hypothesis clearly has many elements to it, all of which have been subject to close and critical scrutiny (Ross, 1999; de Ferranti et al., 2002), but at the heart of all of them is the notion that a focus on a particular sector of the economy, natural resource production, provides an explanatory variable for the poor economic performance of many countries.
The plethora of explanations of why there is an inverse relationship between natural resources and growth in the economy indicates the lack of a clear theoretical underpinning of much of the resource curse literature. In fact, Sachs and Warner argue that there is no accepted growth theory. They state:

“Just as we lack a universally accepted theory of economic growth in general, we lack a universally accepted theory of the curse of natural resources. ..a complete answer to what is behind the curse of natural resources therefore awaits a better answer to the question about what ultimately drives growth”.

(Sachs and Warner, 2001: 833)

Nonetheless, most economic analysis still uses growth models to explain the resource curse, particularly endogenous growth models (Romer, 1986) where investment levels as well as knowledge, technology or learning are the main explanatory factors. This is evident in the large number of analyses based on the Dutch disease. The basic idea is that there is more learning (learning-by-doing) or knowledge (human capital) occurring in manufacturing than in other sectors. This is supported by work drawing upon the new economic geography which emphasises the importance of urban agglomeration of manufacturing industry in knowledge creation and dissemination (Greasley and Madsen 2010). Therefore, moving resources away from the manufacturing sector would reduce the capacity for long term growth. The underlying hypothesis of the models explaining slow growth in resource based economies is, therefore, that there is a lower level of knowledge and learning in these economies, and this is due to its industrial structure. (Sachs and Warner, 2001; Gylfasson, 2001; Matsuyama, 1992).
Recent work by Ayres and Warr (2009) throws doubt on the assumption that there is a lack of innovativeness in resource-based industries. Borrowing from thermodynamics, they examine the historical role of increases in energy efficiency (exergy, a coefficient, ‘U’) in terms of the amount of work output generated by a fixed input of energy. They indicate a monotonically rising value of U for Japan and the USA through the twentieth century. The driver of increased U values, they argue, has been the multi-directional feedback processes between energy generating resource industries and downstream user industries that stimulated technical breakthroughs in energy use. The economic benefits have taken the form of lower costs and prices driving increases in demand and production (Ayres and Warr, 2009, 129-30, 168, 297).

Lately, some economists have questioned the empirical basis for the existence of a general resource curse. Within this literature there is a growing acceptance that what matters for long term growth rates is not the existence of large resource based sectors, but rather the quality of institutions in the economy. Mehlum, Moene and Torvik (2006) argue that the extent to which the institutions are “grabber friendly” or “producer friendly” explains why some resource based economies succeed and many fail. The institutional argument is that the “resource paradox” may be explained by the national political system, as all indexes of “institutional quality” relate to political, bureaucratic, and legal aspects of the society. However, the statistical correlation between indexes for the quality of the political systems and long term growths does not explain to us how some resource based economies actually succeed in growing rapidly over long periods of time.
Even though analysis of the resource curse literature uses models where learning, technology or knowledge are explanatory factors, this strand of literature does not empirically investigate how technological development, knowledge creation and use or learning take place in the economies they study.iii In this paper we show how the resource-based industries in Australia and Norway historically have been characterised by technological change, learning processes, and use of knowledge. This is based on the hypothesis that it is not the differences in industrial structure that matter for long term growth, but rather the rate of technological change and use of knowledge in each sector. As Ferranti et al., (2002, p. 49) have observed: “It is not so much what is produced, as how it is produced”.

3. Historical perspectives: Resource based industries as knowledge economy

In contrast to the resource curse hypothesis, most historical work has regarded natural resource abundance as an important factor in the initiation and transition stages to economic modernisation. Thus, the transition from an organic (charcoal, animal power) to a mineral-based energy economy from the late eighteenth century provided for the easy availability of low cost coal and iron ore necessary for the early industrialisation of Britain focussed on resource intensive industries such as iron and steel production and engineering (Wrigley, 1988; Pollard, 1982; Landes, 2003; Clark & Jacks, 2007). However, it was implicitly assumed that the process of economic modernisation witnessed the relative decline of resource industries to be replaced by manufacturing and services. Similarly, the staple thesis and vent for surplus theories, which addressed the idea of resource rich economies proceeding through commodity export-led development, focussed largely on the early stages of a country’s
modernisation by exploiting idle resources and frontier expansion (Barbier, 2011, 12-13).

Gavin Wright (1990) offers an alternative argument in relation to American industrialisation a century later than Britain. He argues that there was a close relationship between resource expansion and America’s economic expansion during the early twentieth century. In a paper written in collaboration with Paul David (David and Wright 1997), they argued that a country’s resource abundance was not given by the natural environment. When the USA became the main producer of many minerals during the late nineteenth and early twentieth century, this was not a result of a specific rich environment for these minerals but rather the ability of American society to discover and extract resources compared with other countries. The resource abundance, thus, was not destined by geology but rather was endogenous to the economy and was a socially constructed phenomenon.

Their analysis of American economic development went further than previous historical research by arguing that the resource-based industries during the early twentieth century bore many similarities with what a hundred years later is defined as the modern knowledge economy:

“We find … that late nineteenth century American mineral expansion embodied many of the features that typify modern knowledge-based economies: positive feedbacks to investments in knowledge, spillover benefits from one mining specialty to another, complementarities between public- and
private-sector discoveries, and increasing returns to scale—both to firms and to the country as a whole” (David and Wright, 1997: 204-205).

The strength of America’s resource based-economy lay in its ability to create new knowledge (learning) and to involve many parts of the society and economy in the development and implementation of relevant and useful knowledge and technologies. The mining industries built links to universities and geological expertise. They collaborated with engineering firms in developing machinery and technology for improving productivity in the mines. New knowledge and technological investments created opportunities for the profitable extraction of lower grade ore. New infrastructure for the transport and distribution of minerals improved the efficiency of commodity markets. Finally, financial institutions supported the large scale investments necessary for such developments in resource-based industries. In contemporary theoretical perspective, we may argue that the dynamic growth of the American resource based economy was linked to the establishment of an efficient innovation system (Nelson, 1993; Lundvall, 1992) or the creation of a development block (Dahmen, 1950). The dynamic was linked to broad-based economic development that included much more than mining (and other resource activities like agriculture), rather it involved a large number of knowledge-intensive sectors and activities, which enabled the resource sectors to become driving forces in wider economic development.\textsuperscript{iv}

Linkages between natural resource industries and other sectors of the economy enhanced the role of both groups. In particular, resource industries generated a substantial growth in business services including finance, transport, and marketing.
Such demand is evident from many of the properties of natural resource products. The bulky nature of resources motivates a high demand for transport and transhipment services. The volatile and global nature of resource markets requires sophisticated and well-considered marketing strategies. Finally, resource exploitation is a voracious consumer of land and capital goods with consequent financing implications.

Recent analyses involving both Australia and Norway, combine historical studies and innovation systems approaches (Fagerberg, Mowery and Verspagen, 2009; Smith, 2007). They argue that successful long-term economic growth of these countries is closely linked to dynamics within resource based sectors of the economy. Both studies point to the fact that a central aspect for innovation in resource based sectors depends on the degree to which these sectors interact and cooperate with other parts of the economy.

Smith (2007) argues that there are three main mechanisms involved in successful resource based economies: a) Development through knowledge upgrading and investment strategies in resource-based industries, b) Development through the leveraging of resource bases into downstream industries, and c) Knowledge creation via knowledge infrastructure. These processes involve interaction between resource based firms and companies or knowledge institutions in other parts of the economy in a systematic way constituting ‘development blocks’ (Dahmen, 1950).

The strong interaction between resource based sectors and other parts of the economy, as a basis for long term economic development and innovation, is also reflected in Fagerberg, Mowery and Verspagen (2009) which argues that
“Norway’s resource based sectors ... have for decades been highly innovative, drawing on domestic sources of innovation, technology transfer from foreign sources ...and Norway’s universities and research institutes” (p.435)

The dynamic of resource sectors is based on close collaboration between these sectors and companies and knowledge institutions in other sectors, both domestically and abroad. It is knowledge diffusion and cooperation which characterises innovation processes in the resource based sectors and other parts of the economy (Fagerberg, Mowery and Verspagen, 2009, p. 438). The companies utilise “localised search” (Nelson and Winter, 1982) and engage competent other companies and knowledge institutions in problem solving and in innovation processes. “[T]he dominant approach to innovation within much of Norwegian industry relied on interaction with other actors in the system” (p 440).

The idea that economic development is dependent on linkages between sectors in the economy goes back to Hirschman (1958). He emphasised specifically the role of backward linkages, and argued that resource based industries created fewer backward linkages compared with manufacturing. This explained slow development in many resource based economies. The studies discussed above indicate that resource based industries have created strong backward (and forward) linkages in the national economies discussed.

Based on experience from Australian development, Pol, Carroll and Robertson (2002) developed a typology for linkages between sectors in the economy that is useful for an
analysis of the dynamics of resource based economies. The economy consists of two
types of sectors, enabling and recipient sectors. The enabling sectors consist of
organisations producing novel efficiency-enhancing products to be used in other
sectors or the same sector. The recipient sectors are the buyers of these products. The
idea is that there are flows of knowledge (products) between sectors, where some
sectors can enable innovation in other sectors. A central point is that knowledge flows
are multi-directional. There are feedback effects where firms in the recipient sectors
also influence innovation in the enabling sector (Pol, Carroll and Robertson, 2002, p.
67). While this original study focussed on enabling-recipient linkages largely in
manufacturing, we show that this model of growth can also work for resource-based
industries.

This is applied in the model below, which describes the historical interaction between
resource industries and enabling sectors. Enabling sectors develop as problem solvers
for existing resource industries and contribute to continuous improvements and
transformation of these industries. The capabilities developed by the enabling sector
through this process become a crucial resource for the creation of new resource
industries. In turn, the regularisation of interaction between the enabling sectors and
these new resource industries provides scope for a second cycle of new industries.
This is the central dynamics of long term growth of the resource based economies of
Australia and Norway.

**Figure 1. Resource-based economy diversification model**
This model is based on a wide consensus in the analysis of long-term economic dynamics in Australia and Norway that linkages between resource based industries and other sectors of the economy have been essential for rapid economic growth as resource based economies. The resource based sectors have functioned as drivers of knowledge development in other sectors, which have become enabling sectors diffusing technology to many parts of the economy (Rosenberg, 1976). In addition, enabling sectors have supported the development of new resource based sectors. This dynamic interaction between firms and institutions in different sectors of the economy contributed to a diverse economy with high innovation capability and ‘absorptive capacity’ (Cohen and Levinthal, 1990).

In the following section, we will describe some of the key historical and comparative features of Australia and Norway as resource based economies, particularly their ability to generate new resource industries throughout their history. We will then explain the nature of the enabling sectors and analyse how they have interacted with recipient resource industries.

4. **Australia and Norway as Resource-Based Economies**

Australia and Norway share a range of similarities in their economic structure and historical process of development. Both are relatively wealthy economies, measured by GDP per capita (Maddison, 2001, pp. 277, 279), that historically have clustered in export-oriented natural resource and related service industries (primary production, mining, energy, shipping, and mercantile trade) as their principal sources of wealth and economic modernisation. At the same time, Australia has a larger population and one that has grown more rapidly over the last two centuries. Moreover, rates of GDP
per capita growth have differed across periods with Australia doing better for much of the nineteenth century and Norway generally ahead for most of the twentieth.

**Table 1. Comparative Historical Statistics: Australia and Norway**

Each nation has a tradition of small scale cooperative enterprise in many of these sectors, overseen by a positive role for the state, which is now giving way to large scale, corporate enterprise within a highly competitive framework. Both countries have traditionally drawn upon domestically generated new technology in their traditional clusters. While sharing similarities in economic structure and historical development, significant institutional and environmental differences persist between the two nations, particularly in terms of educational and legal systems, migration patterns, colonial history, land mass, climate, and geo-political location.

Irrespective of these differences and similarities, Australia and Norway have both evolved as resource-based economies. There are a number of elements in determining what constitutes a resource-based economy. Resource sectors are not easily defined. In this analysis we use the definition of Sachs and Warner (1995) where the statistical categories are SITC 0, 1, 2, 3, 4 and 68, and attempt to adapt statistical historical data to this categorization. Measurements of actual exploitation of resources are more important than estimates of potential or known stock, and it should be compared with economic activity in other sectors of the economy. This might include the resources sector’s share of GDP or net exports or investment. A share of net visible exports of anywhere between 20 and 40 per cent has been variously suggested as defining a resource-based economy (Stevens, 2003; Nankani, 1979).
Table 2: Resource exports as proportion of total visible exports

The resources share of Australian production or employment has fluctuated over time, between about 10 and 25 per cent (McLean, 2007: 646), with the rise and relative decline of domestic manufacturing, the expansion of services, and the raw materials demands of various industrialising nations. Resources have dominated Australian exports throughout the last century with a share generally above 70 per cent and sometimes beyond 90 per cent. Norway has traditionally, and still does, export about half of its GDP. The share of natural resources in total visible exports was approximately the same in the early twenty-first century as a hundred years earlier, about 80-90 per cent (Statistics Norway, 1978; Statistics Norway, 2009). Norway and Australia may therefore be described as highly resource-based economies both in their historic development and current condition.

5. Creation of new resource based industries

Both countries have long exported traditional resources like food, timber, animal skins and furs, and coal. These product sectors remained significant exports at the end of the twentieth century aided by continuous innovations in production and marketing using emerging new technologies, such as remote control mining, futures markets, and electronic selling. The old industries have been transformed into modern production systems.

However, the ability of Australia and Norway to remain resource based economies was mainly the outcome of a different type of process: the repeated establishment and
growth of new resource based industries that exploit new parts of the natural environment. This is a well-known process in history as humanity gradually introduced new plants and animals or used a wider range of marine organisms for food consumption, or became able to use new types of minerals for production of metals and other materials. Gradually, a wider part of the natural environment has become incorporated into economic activities.

The history of Australia and Norway shows how not only new products created more diversity in old sectors and industries, but also how new resources became the basis for the establishment of new industries of importance for future growth and export specialisation. Table 3 provides stylised historical facts of the nature of the development of the resource industries in Australia and Norway over the last two centuries.

Table 3. Development of resource-based industries in Australia and Norway

Although the table is no more than a broad and approximate timeline of the emergence of additional resource-based industries, it is indicative of the dynamic expansion in their composition, particularly during the second half of the twentieth century when both Australia and Norway generated more new resource industries than at any earlier period in history. This aspect of resource based economic development has been largely overlooked in both economic theory and economic history.
The theoretical basis for this type of dynamics is the difference between *natural environment* and *natural resources*. The environment is given, but natural resources are the outcome of socio-economic processes where the environment is transformed into economic resource. New natural resources depend on the society’s and the economy’s ability to create new resources and to build new industries around them. This idea was early expressed by Erik Zimmerman:

“Resources ... are not, they become, they evolve out of triune interaction of nature, man, and culture. (...) The problem of resource adequacy for ages to come will involve human wisdom more than limits set by nature”.

(Zimmerman, 1951: 841).

This implies that the development of new resource based industries is dependent on the ability of the economy and society to use knowledge and resources to transform the natural environment into economic production. The expansion in technological and scientific knowledge explains the increased number of new resource industries from the second half of the twentieth century.

The creation of modern resource industries often demands complex scientific, technological, economic, political and social processes. An example of this type of process is the international development of hydro-electric power during the early twentieth century. It illustrates how part of the natural environment (water-falls) which earlier lacked significant economic value was turned into an energy resource that became the basis for production of both electricity and energy intensive industries (metals, fertilizers, chemicals, paper). The development of electricity required not
only new technologies, but also new types of organisations and public regulations, which included the creation of very large socio-technological systems (Hughes, 1983; Thue, 1994). In a similar fashion, the international development of nuclear energy systems during the second half of the century created demand for Australian-sourced uranium, a mineral which had low commercial value before it became an integrated part of a wider energy-producing technology.

New resource based sectors often emerge not because new natural resources are discovered, but because new technologies create the basis for commercial production and marketing of a known resource. The story of natural gas in Australia and oil in Norway illustrates the transforming capabilities of technology to develop a large scale export market for a resource product. In Australia, natural gas was captured from the 1970s. While Australia has long been known to have extensive supplies of natural gas, demand for it had been limited to use within Australia: its large volume as a gas meant very high transport costs. Twin technological developments have enabled it to become a major export product to serve the growing energy needs of populous Asian nations such as Japan. Liquification is achieved by reducing gas into its liquid form which reduces its volume by about 600 times. Liquification has been combined with the design and construction of specialist LNG ocean tankers to make it safe and economical to transport. The benefits of the new technologies has motivated the search for additional sources of natural gas which, in the last decade, led to the adoption of increasingly efficient extraction techniques for Australia’s immense reserves of coal seam gas.
In a similar way, the establishment of an offshore oil sector in the North Sea during the 1970s was dependent on the introduction of new methods and technologies for the detection of oil reservoirs, for drilling, new types of drilling platforms, and new regulations and control technologies related to environmental safety (Olsen and Sejersted, 1997). This involved large and very expensive concrete platforms with very high levels of security systems. New technologies were introduced to improve the efficiency and volume of petrol that could be extracted. The development of drilling technologies, particular horizontal drilling, made it possible to increase the percentage of the existing oil that could be extracted from the reservoirs, increasing the rate from about 20 per cent in the 1970s to around 50 per cent at the end of the century (Storting, 2001-02).

The historical evidence from Australia and Norway indicates that long term growth in resource based industries was the result of the development of new resource based industries. In both countries, the natural environment was exploited to develop new natural resources. The examples above illustrate that the establishment of new resource based industries was the outcome of complex and costly processes involving high levels of capital investment, use of a diverse field of knowledge bases, and the ability to draw on international actors and resources. The resource based industries alone did not embed the necessary knowledge or resources to build-up science-based and knowledge intensive production systems. Their successful development was dependent on close interaction with other sectors of the economy and society involving technology, knowledge, financial resources, and various kinds of expertise. These enabling sectors played a key role in linking the resource industries with available resources in the rest of the economy and internationally.
6. **Creation and transformation of enabling sectors**

A central aspect of the economic dynamics of Australia and Norway has been the strong linkages between resource based sectors and other parts of the economy. This is a reflection of how innovation processes most often take place within the resource based sectors: problem solving occurs mainly through the search for knowledge and competency in other parts of the economy. Most search processes are localised, that is, companies first search among established contacts in the same economy. In Australia and Norway, which have large resource based industries, this interaction has strongly shaped the wider patterns of innovation and the structure of the national innovation system (Fagerberg, Mowery and Verspagen, 2009)

Through this type of interaction, resource based industries have influenced the direction of knowledge production and technological development in the economy.

**Natural resources and capital goods industry**

Many successful resource based economies, including Australia and Norway, share a common structure regarding specialisation of capital goods industries: there are strong local suppliers of technology-intensive capital goods and specialised services directed towards domestic markets (Thue, 2009; Maloney, 2002; Bigsten, 2001; Hiernesnemi et al., 1996). These capital goods industries and the specialised services have been important for problem solving in existing resource based industries as well as for the development and production of new natural resources.
The role of backward linkages is regarded as specifically important for successful industrial development, and historically we find strong links between the resource sector and the capital goods industry, business services, and research and knowledge organisations in both nations. The resource industries have searched for new technologies, which made it possible and profitable to improve efficiency, extract a larger percentage of the known stocks or reserves, or to develop areas for production. Domestic producers of capital goods as well as business services have specialised in domestic markets, particularly in developing technologies and services for resource industries.

This type of interaction between sectors goes far back. Agriculture was from an early period closely linked to advances in scientific and technological knowledge. In Australia, the natural environment faced by primary industries has few parallels in other regions of the world, necessitating domestic solutions to many production problems. Such challenges as drought, poor soil quality and pestilence questioned the viability of farming in Australia and, at any rate, emphasized its vulnerability to low productivity and output vicissitudes that have been marked even for a notoriously volatile sector. Early innovations in the farming sector, therefore, focused on overcoming development obstacles and mitigating cyclical instability. These included the jump stump ploughs to plough cleared fields around tree stumps, drought and disease tolerant wheats, fertilizers to improve poor soils, merino sheep breeding, dams and artesian wells to mitigate water shortages, and wire fencing and nets to keep livestock in bounds and protect crops from rabbit infestation. Local agricultural and pastoral societies played an important role in sharing and disseminating information about new techniques among farmers (Raby, 1996). In addition, stock and station
agents, business intermediaries who organised auctions and loans for farmers, served as information conduits between the farming community and producers of agricultural inputs and equipment (Ville, 2000).

The transformation of Norway’s forestry industry from sawmill production to wood processing (pulp) involved close interaction with local engineering companies, in addition to foreign expertise. The emerging wood processing industry demanded water turbines and other sorts of machines. Modern sawing and planning machinery and energy technologies (steam power and water turbines) also supported the transformation and growth of the sawmill industry between 1860 and 1890. The transformation of the old sawmill industry and the emerging wood processing industry became an important market for local mechanical works. Mechanical engineering companies specialised in supplying machinery for investors in the emerging wood processing industries. The engineering industry provided machinery and other capital goods. Some became exporters of machinery for the wood-processing industry (Thue, 2009).

The processes that made Australia a technological leader in mining by the end of the nineteenth century similarly involved strong links to the capital goods industry. Orders for pumps, crushers, engines and similar equipment provided good business for local foundries. In the following century, a large and highly innovative industry of specialist engineering companies emerged to supply the vast capital equipment needs of the mining companies. The economic impact of these linkages is further emphasised by the substantial export earnings of these companies.
The close relationship between the resource based companies and capital goods industry has made Australia and Norway substantial exporters of production technology and forms of expertise used in the resource based sector. Mining technology has become a major export article for Australia (Maloney 2002). In 2009 Austmine, the industry body for mining technology companies, had over 100 members and predicted that its members would achieve exports to the value of A$3.8bn, which adds more than 10 per cent to the value of coal and iron ore exports. In a similar way, close interaction between oil companies and capital goods industries and business services since the 1970s, have made Norwegian technology suppliers world leading providers of oil services and some types of oil technologies, that is, sub-sea production technology where Norwegian companies control more than half of the world market (Engen, 2002, 2009; Intsok, 2011).

**Natural resources and the direction of science**

In a similar way to how the resource sector has shaped the direction of the capital goods industry of Australia and Norway, it has also strongly influenced the national science systems. Studies of national differences in specialisation in science show that resource based economies tend to focus on scientific areas relevant to the exploitation of natural resources. This type of specialisation is defined as the “bio-environmental model” where bio- and geo-sciences are strongly represented (Glänzel, 2000; Glänzel and Schubert, 2003). Australia and Norway are key cases for this specialization, a pattern that has long historical roots.

From the late nineteenth century, new scientific knowledge and technical equipment provided for broad surveys of the natural environment. This enabled a more
systematic search for natural resources, particularly linked to geology (mining) and biology. In both Australia and Norway organisations conducting geological surveys and the mapping of the biological environment were established, and became an important driver for discoveries of new natural resources. The establishment of Norges Geologiske Undersøkelser (NGU, Geological Survey of Norway) in 1866 became the basis for mapping resources in Norway, and the work by NGU and professors at the University of Oslo established an overview of known minerals by the early twentieth century. Systematic searching for minerals was crucial for the growth of Australia as a major producer and exporter of minerals by the late nineteenth century. Geological surveys were established in each colony (Victoria 1852, Queensland 1868, South Australia 1882), and in addition to the private search for minerals, this gradually became a basis for the documentation of potential mineral sources for the mining industry. The blossoming of Schools of Mines from late nineteenth century, located in major mining centres at Ballarat (1870) and Bendigo (1873), fostered increasingly effective and efficient exploration techniques. In a similar way oceanography became an instrument to map marine resources and movement of various fish species in the ocean. (Schwach, 2002) The increasing sophistication of surveys in the twentieth century, informed by scientific advances in exploration and harvesting of bio-products, laid the grounds for the expansion and diversification of the mining and fishing industry, particularly during the second half of the century.

In Australia the establishment of CSIRO (Commonwealth Scientific and Industrial Research Organisation) in 1949 and its predecessor CSIR (Commonwealth Scientific and Industrial Research, 1926) (Schedvin, 1987) was designed to foster scientific
research for the benefit of both primary and secondary industries. It built upon the work of the state based departments of agriculture, a series of agricultural colleges and experimental farms all designed to link scientific research with farming practices. Through a series of laboratories and field stations, it engaged with challenges and opportunities facing the primary industries, particularly where national solutions were necessary. On the one hand, this involved counteracting pests such as codling moth, locusts, prickly pears or rabbits. On the other hand, it worked with resource-exporting industries to enhance their value and sustainability, for example in wool, timber, cereals, meat and dairy (Bashford and Hobbins, 2012)

Both in geo- and bio-sciences strong scientific communities related to resource industries emerged from an early period. In Norway, the specialization in these scientific fields originated during the formative period for the institutionalization of modern science from the late nineteenth century. In marine biology, Norwegian scientists (G.O. Sars (1837-1927), Johan Hjort (1869-1948)) were in the forefront of developing theories on the movement of herring and other fish species at specific periods of time. The development of physical oceanography analysing currents, saliency, and other factors of importance for life in the ocean, created the basis for a leading scientific community (H.U. Sverdrup (1888-1957)) in Norway providing data relevant for fisheries. The creation of modern meteorology (Wilhem Bjerknes (1862-1951) was also linked to demand from fisheries for improved weather forecasts (Friedman 1993). In a similar way, researchers in geo-sciences became international leading scientists developing theories and useful analytical data for mining and refining industries. This is exemplified by the emergence of geo-chemistry as a new sub-discipline from this small research community (Victor Goldschmidt (188-1947)),

and development of scientific theories related to specific challenges in industry (Johan H.L. Vogt 1858-1932). Knowledge and technologies developed for studies of Northern Lights (Kristian Birkeland, 1867-1987) became crucial for development of the modern chemical industry (Kyllingstad og Rørvik, 2011: 336-341).

A characteristic of these research communities was the strong links to, and interaction with, relevant industries. The leading scientists actively engaged with firms in many ways. They worked closely with the research projects in laboratories in the modern large scale electro-intensive industries (Sogner 2003: 56). In mining, professors gave advice or worked as consultants for companies, investors and owners of companies, developed plans for new investments and technologies (Børresen, 2003). Norwegian scientists within marine biology collaborated closely with local fishermen and became an important conduit for the diffusion of new technologies and fishing methods (Schwach 2002). In this way, strong interaction and cooperation between the resource based industries and scientific institutions were established from an early phase. This relationship has been reproduced throughout the twentieth century, and the development of a large oil and gas sector in the Norwegian economy strongly strengthened the “bio-environmental” model. The scientific community was more specialized in this type of research towards the end of the twentieth century compared to 30 years earlier (Norwegian Research Council, 2003).

7. **Building linkages between resource based and enabling sectors**

The interaction between the resource based industries and the enabling sectors explains how Australia and Norway remained specialised in natural resources but avoided a resource curse. As we saw above, the main argument is that in both nations
the resources sector expanded and diversified by developing new technologies that draw upon and contribute to learning and knowledge broadly across the economy. However, our description cannot offer much insight into why these particular countries historically have developed strong abilities in technological change, promoting learning processes, and utilising acquired knowledge.

In order to address these underlying questions, we need a better understanding of the institutions governing the behaviour and interaction processes of firms and organisations. Douglass North’s analysis explains differences in economic development by moving the discussion towards institutions, “the rules of the game” of the economy. The role of institutions is designed to bring order to production and exchange, and it is their effect on the cost of exchange and production that largely explains their influence on economic performance. Particular codes of conduct will be conducive to low transaction costs, thereby making exchange more efficient. For North and writers in his tradition, institutions are thus central to explaining comparative levels of economic development between nations.

However, he also recognises the inter-relationship between institutions and technological change:

“Technological change and institutional change are the basic keys to societal and economic evolution and both exhibit the characteristics of path dependence” (North, 1990: 103)

Moving the focus to technological change (here identical to learning and the use of knowledge in the economy) does not take us away from an institutional approach. Rather, understanding why some economies succeed where most fail demands an
improved understanding of the specific institutions that promote learning and the ability to use knowledge efficiently. An institutional approach for technological change will have to focus on the “rules of the game” for how individuals and organisations (firms) learn and use knowledge generated by others (Mokyr, 2011).

In a recent paper, Nelson (2008) develops the concept of social technologies to describe the set of interactions and co-ordinations among organisations and actors in the process of developing or deploying a physical technology. The degree to which these social technologies succeed depend, in turn, on the set of institutions that support them. The underpinning institutions can take many forms – belief systems, organisational structures, legal systems, for example. As such, Nelson provides a convincing link between the technology literature, focussed on the physical aspects of innovation, and the institutional literature that looks towards economic development.

Nelson’s insights help inform our paper by representing the relationship between enabling and recipient sectors as a form of social technology. We will describe examples of different types of collaboration between resource industries and enabling sectors that we observe from the history of Australia and Norway. They are: local and national networks, supply chains, internalisation, and state direction. The examples illustrate that there are a diversity of institutional settings for linkages in the economy. In addition, we will stress that there is a demand for more in-depth and systematic analysis of the institutional arrangements for dynamic collaboration between resource industries and enabling sectors.

*Networked interaction – fishery and electricity Norway*
Historically, much equipment and production technology for traditional industries like farming, forestry and fishing, was produced by the farmer or fisherman. Gradually, local specialised producers of equipment and input to the primary industries emerged. There was a close social relationship between the user of the equipment and the producer. The smith or workshop made equipment tailored for the local market. The local user-producer interaction has been important for the direction of Scandinavian industrialisation, where the technology producers became problem solvers for local industry (Lundvall, 1992)

Such collaboration was common in small scale communities, often in rural areas, between equal social actors who regarded themselves as independent producers. Farmers, fisherman-peasants (combining fishing and farming), and fishermen, as well as the smiths or mechanics of the small workshops, were entrepreneurs and businessmen with a common economic interest in introducing new technology. Norway has a strong tradition of localism (Thue 1994) which implies a strong feeling of common identity for all inhabitants of the community. The shared vision shaped a platform for informal interaction in order to improve efficiency in the resource based sectors.

This type of informal local interaction remained important for economic dynamics in small scale resource industries throughout the twentieth century. Local smiths copied and developed the production of small engines for fishing boats. They adapted the engines to the traditional boats for each region, and a large number of small factories and workshops were erected along the coast before 1920. The informal relationship between the fishermen and local workshops remained important for the technological
development of equipment for vessels into the twenty-first century. Informal interaction gradually formalised, often involving contractual agreements between ship owner, ship designer, and the ship yard in the design and construction of ships tailored to the demands of specific user (Nås, 2000)

This type of localism is also reflected in political initiatives at the level of the municipality. There are examples of communities that funded travel by local smiths to other countries in search of new technologies to solve the problems of local industries (Sanden, 1985). During the early twentieth century, a number of municipalities constructed relatively small scale electricity plants to provide industries and household with energy. This was a cooperative effort to create an infrastructure for more efficient production in both resource industries and enabling sectors (Thue, 1994)

In larger cities there was close social interaction between representatives from resource industries and enabling sectors. Members from various parts of the national elites – the industrial bourgeoisie, the leading state officials, and the professors of the university – met regularly at dinners or in various associations (Andersen and Yttri, 1997: 18; Kyllingstad and Rørvik 2011: 318). As discussed earlier, collaboration between university professors and resource based industries became common from the late nineteenth century. There was a functional aspect to these relationships. Industrial success often implied successful research processes. Large companies established internal laboratories to solve industrial problems (Andersen 2005), and technology companies solving problems for other industrial firms were established
Moreover, the demand for scientific knowledge by the industrial bourgeoisie opened the elites’ social arena for professors.

In addition, there was a shared belief system among the national elites that industry and science should contribute to nation building through modernisation (Sejersted 2011). Professors often supported applied science more than basic research, and defined research projects that were useful for local industries (Kyllingstad and Rørvik 2011).

More specific institutions supported close collaboration between professors in scientific organisations and modern industrial firms. Universities and public science organisations often lacked resources to establish high quality laboratories, and salaries were relatively low. Modern enterprises with well-funded internal laboratories were an attractive alternative science infrastructure for professors and scientists. In many cases, university professors could use the private labs for research projects. (Kyllingstad and Rørvik 2011: 340). The absence of formal regulations of how professors engaged with private industry was an important institutional arrangement to support interaction. When the Norwegian Technological College (NTH, established 1910) introduced new regulations that restricted how much time professors could spend on private sector projects and how firms could use NTH’s new laboratories in 1921, the outcome was weakened university-industry interaction. Professors were forced to choose between undertaking more basic research at the university or industrial research in industrial labs. Some professors left NTH to become researchers in modern industrial enterprises, while others remained at NTH and ended their strong involvement with firms (Hanish and Lange 1985: 83-91).
Coordinated supply chains: agriculture Australia

Since most of Australia’s resource output has been bulky and destined for export, this required the development of a supply chain stretching from the farm gate or minehead to the wharves of the nation’s emerging commercial port cities by the middle of the nineteenth century. In its wake, this shaped the development of radial road and rail systems connecting the two ends of the chain and along it the activities of a range of service providers supporting these industries. Information flowed along the supply chain in both directions – market statistics to producers and technological feedback to equipment manufacturers. A key actor in the supply chain of agricultural products was a class of business service firms unique to Australasia, stock and station agents, who coordinated many stages of the supply chain. These firms organised the local sale or international consignment of produce, especially wool, livestock and rural property. They acted as a go-between in the supply of raw materials and capital equipment to farmers, seeking out good sources of these inputs and forwarding farmer feedback to suppliers. In the 1890s, for example, agents played an important role persuading farmers to produce meat and dairy products for the emerging international refrigeration trade. They argued for the operational flexibility it provided farmers and began the process of establishing freezing works (Ville, 2000: 158-59).

Agents began as mostly local firms embedded in farming communities. Some were former farmers themselves and, similar to the Norwegian fisheries example, fostered their close connection with farmers to build strong stocks of social capital. Leveraging relationship marketing strategies, they were able to build up large loyal customer bases. From the late nineteenth century, a process of consolidation began to take hold
of the agent industry with emergent large stock and station agents building a national network of branches by acquiring many small local firms. They continued to emphasise their sense of localness through embedded local staff and additionally offered scale economies and a broader sense of expertise through their national standing. About four or five of these firms dominated the industry for much of the twentieth century – Elders, Dalgety, Golsbrough Mort, New Zealand Loan and Mercantile Agency, and Australian Mercantile Loan and Finance Company – handling about half of all wool sales.

At the forward end of the supply chain, local auction markets for Australian products began to emerge, beginning with wool from the last decade or so of the nineteenth century. Agent companies played the key role as commodity selling brokers, as such they laid the foundations for the development of organisations, behavioural norms, and routines necessary for modern markets to operate effectively (Merrett, Morgan and Ville, 2008). However, for modern commodity markets to work it required high levels of cooperation among firms accustomed to intense competition. Brokers shared auction rooms and infrastructure, while brokers and buyers developed agreements on standard practices and procedures for the wool market. This was achieved through the formation of a set of regional then national trade associations.

**Internalisation: mining, sugar in Australia**

Linkages between resources and enabling sectors can be launched internally in major corporations. Strategies of vertical integration and product diversification by major Australian resource companies have provided an opportunity to embrace manufacturing innovation. Capabilities initially established in resource industries
were often extended forward into processing and final good production through firm-based research capabilities. CSR (originally Colonial Sugar Refining Company Ltd) and BHP (originally Broken Hill Proprietary Company Ltd) are both notable examples of this.

CSR’s initial success in the second half of the nineteenth century rested on being the first company to install technologically advanced sugar refining plants on a scale that dramatically lowered costs. By the 1930s, its research laboratories, supported by foreign licences, visits to overseas plants, and international joint ventures led the firm to new downstream products. Leveraging economies of scope through the use of its by-products of sugar refining enabled it to enter the alcohol and chemicals industries. After World War Two, related diversification into building materials became the focus including the production of vinyl flooring (1949), insulation and hardboard (1959), particle board (1960), and pre-mixed concrete (1965) (Hutchinson, 2001: 109-10). Technical efficiency became the company’s watchword. From about the 1970s CSR pursued more ambitious unrelated diversification into the energy and minerals sectors.

BHP had positioned itself as a leading miner of silver, lead and zinc by the beginning of the twentieth century, initially through control of strategic leases but increasingly by technological leadership. It leveraged this powerful position to vertically integrate forwards from mining and become the steel industry leader in Australia through operating major plants in Newcastle from 1915 and Port Kembla from 1935. Subsequently, it diversified into a range of related downstream products, which included steel alloys, hot water systems, fence posts, and tools. BHP built up in-house
technological capabilities by hiring engineers and metallurgists to follow through on the imaginative strategies of its leaders, particularly Essington Lewis and G. G. Delprat. However, it also drew upon outside advice, for example through the Collins House Group of mining companies, and by inviting the opinions of overseas experts such as American engineer David Baker who in 1912 provided the company with a report on its plans to commence iron and steel production (Wills, 1962).

Significantly, both companies now leverage their technical leadership overseas, CSR in the American building materials industry as Rinker, and BHP-Billiton, now separated from its steel making capability (Bluescope), in many overseas resource industries including the operation of coal mines in New Mexico, a major copper mine in Chile, and a diamond mine in Canada.

*State directed: oil in Norway*

The public sector and politics in Norway played a crucial role engaging many knowledge intensive sectors with the large oil and gas sector during the late twentieth century. There was a conscious policy decision to engage the emerging oil and gas sector in research, engineering, services and the production of oil rigs, platforms and production equipment. Foreign oil companies were “forced” to relate to Norwegian scientific communities, political authorities, and industry in order to gain permission to drill for oil in the North Sea. This ‘Norwegianization’ policy gradually became widely accepted in politics.

The main international oil companies had long established stable links to overseas providers of capital goods, research and services. They preferred to continue to work
with the established suppliers making it challenging for local providers to become involved. The first major instrument to direct foreign companies towards local enabling industries was the decision to create a specific ‘Norwegian technological style’ in the offshore oil sector (Olsen and Sejersted, 1997). Offshore oil platforms used in the Mexican Gulf and other overseas oil fields at that time were constructed of steel, but the harsh weather conditions in the North Sea, strict safety conditions set by the Norwegian government, and technological initiatives from local industries, required oil companies to use large, expensive concrete platforms (Hanisch and Nerheim, 1992). This technological style was based on local expertise in the design and production of dams for the hydropower sector (Engen, 2009).

The institutional arrangement responsible for ensuring the global oil companies interacted with Norwegian enabling sectors, rather than their traditional overseas suppliers, were the Concession Laws established during the early twentieth century to regulate foreign ownership of hydropower. Norwegian authorities granted concessions to several international oil companies, and did this in a series of competitions. At every new round of concessions, the authorities re-negotiated the terms to direct the oil companies to work with local industries and organisations (Hanisch and Nerheim, 1992; Engen, 2009).

Governments established various organisations to control the ‘Norwegianisation’ strategy. The state owned oil company, Statoil, became the operating organisation for the transfer of knowledge to Norway and to create links to enabling sectors. Foreign oil companies had to train Statoil to be able to lead operations on future fields and to support the wider build-up of local education in the petroleum sector (Hanisch and
Nerheim, 1992). Statoil would use its position as owner of oil fields to enter into contracts with local industries. The system was effective. In 1974 the Norwegian portion of the supply business was 28 per cent (Engen 2009), and increased to 58 per cent by 1980. In order to engage Norwegian scientists and research organisations in the oil sector, the government introduced the ‘Goodwill agreements’ in 1979. This gave foreign oil companies ‘goodwill points’ if they entered into R&D contracts with Norwegian firms and research institutions. The policy transformed parts of the national research system. As a result, Sintef (Trondheim), Christian Michelsen’s Institute (Bergen) and Rogaland Researech (Stavanger) became major R&D performers (Engen 2009).

The high investment levels in the offshore sector created a market for local knowledge intensive sectors, including high-tech industries. Information and communication technologies became integrated parts of production systems and development processes of the resource based industries (Sogner, 2009). By the end of the twentieth century, the oil and gas sector were the main customers for the local ICT industry, but also for many research institutes, consultancy firms, engineering companies, machinery industry, and other parts of the knowledge intensive business sector (Engen 2009). The close interaction between oil and gas producers and knowledge intensive organisations in Norway created over time a strong cluster of companies and research institutions, which shaped technological development in the petroleum sector and became potential export sectors. These clusters became important elements of the economy both as producers and as competence centres for other sectors of the economy.
8. Conclusion

Australia and Norway, two nations that differ in many aspects of their historical development, climate and geo-political location, have a common story of successful resource-based economic development. Commonality is that of shared success in taking a route to modernisation often regarded as prone to failure. Common also is the way they succeeded – by continual reinvention and extension of their resource products and industries. This provided them with new sources of growth and blunted the ‘curse’ blights of volatility and emasculated control of strategic resource assets.

As noted earlier, resource exploitation is much more about society’s capabilities than nature’s reserves. Our motivation is to explain why these two nations were able to develop broad-based capabilities that permitted resource industry exploitation domestically and in other nations. We have emphasised how the continuous development of enabling sectors created a strong knowledge base distributed in various parts of the economy and society. This knowledge base could be exploited to improve productivity in old resource based industries and to develop new industries. These enabling sectors were themselves developed in interaction with resource based industries and often driven by the demand from these industries. This dynamic interactive relationship between natural resource industries and enabling sectors is regarded as the core aspect of the successful economic development of Australia and Norway. It is this historical development that makes it reasonable to regard the countries today as ‘resource based knowledge economies’.

The development of a strong distributed knowledge base in resource based economies is not trivial. Relatively few nations have made the transition to a ‘resource based
knowledge economy’. In our discussion, we argue that Australia and Norway historically have succeeded in establishing the institutional support for social interaction between resource based firms and actors with ‘useful knowledge’ (Mokyr 2002, 2011). It is not trivial that this type of linkages is created within a local or national economy. There are specific historical processes underlying the establishment of the ‘social technologies’ of close interaction between resource based industries and enabling sectors in Australia and Norway. We have illustrated the role of social relations between actors in small local communities and national elites with a shared vision in Norway. The development in Australia was more defined by relationships in business chains and by larger companies’ ability to incorporate the enabling sectors within the firm. The case studies indicate there are many forms of institutions that can foster collaboration between resource based industries and knowledge organisations or enabling sectors.

Our arguments, therefore, centre around a ‘deeper determinant’, in this case the role of a knowledge generating and disseminating institutional structure. While a strand of recent work on successful resource-based countries adheres to the role of effective institutions, there has been an unwillingness to unpack this heavily used concept or embed it within the technology literature. We have attempted to address both of these issues by drawing attention to knowledge generating ‘enabling sectors’ and the ability of these sectors to link with resource industries to achieve innovation into new products and industries. The question of why it is possible to establish this type of interaction in some sectors and countries, but is more difficult to achieve in others, has only been touched upon. This demands a much deeper analysis of the social,
political and cultural basis for economic behaviour that extends beyond the scope of
this paper.
Table 1. Comparative Historical Statistics: Australia and Norway

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<td>Australia</td>
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<td>2,36</td>
<td>1,44</td>
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<td>Norway</td>
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<tr>
<th>GDP per cap growth rates (% annual compound)</th>
<th>1820-70</th>
<th>1870-1913</th>
<th>1913-50</th>
<th>1950-73</th>
<th>1973-98</th>
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<td>Australia</td>
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<td>49,4</td>
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<td>Norway</td>
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<td>24,4</td>
<td>35,7</td>
<td>47,3</td>
<td>52,2</td>
<td>57,2</td>
<td>70,3</td>
<td>77,3</td>
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</table>

*First year (1861) = Australia, (1865) = Norway
Norway: urban areas defined as communities with more than 2000 inhabitants

Table 2: Resource exports as proportion of total visible exports

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<tr>
<th></th>
<th>1871/3</th>
<th>1881/3</th>
<th>1888/90</th>
<th>1898/00</th>
<th>1900/1</th>
<th>1910/11</th>
<th>1920/1</th>
<th>1930/1</th>
<th>1940/1**</th>
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<tr>
<td>Australia</td>
<td>86</td>
<td>90</td>
<td>92</td>
<td>83</td>
<td>94</td>
<td>94</td>
<td>94</td>
<td>96</td>
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<tr>
<td>Norway</td>
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<td>89</td>
<td>92</td>
<td>91</td>
<td>95</td>
<td>91</td>
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<tr>
<td>Australia</td>
<td>94</td>
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<td>73</td>
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<tr>
<td>Norway</td>
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<td>85</td>
<td>73</td>
<td>85</td>
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Norway – calendar year (1871, 1881 etc)

** Norway = 1939


Note: Visible exports refers to all physical exports and excludes services
<table>
<thead>
<tr>
<th>Period</th>
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<th>Norway</th>
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<tr>
<td>- 1850</td>
<td>Sealing and whaling</td>
<td>Fisheries</td>
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<td></td>
<td>Pastoral land boom: wool</td>
<td>Timber</td>
</tr>
<tr>
<td></td>
<td>Coal mining</td>
<td>Mining</td>
</tr>
<tr>
<td>1850-1900</td>
<td>Gold mining</td>
<td>Wood processing</td>
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<tr>
<td></td>
<td>Wheat</td>
<td></td>
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<tr>
<td></td>
<td>Sugar</td>
<td></td>
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<tr>
<td>1900-1950</td>
<td>Refrigerated food</td>
<td>Electricity (from 1900)</td>
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<td></td>
<td>Sugar by-products</td>
<td>Metals</td>
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<tr>
<td></td>
<td></td>
<td>Fertilisers</td>
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<tr>
<td></td>
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<td>Mining (1880-1920)</td>
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<tr>
<td>1950-2000</td>
<td>Oil (1950s)</td>
<td>Frozen fish (1950s)</td>
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<td></td>
<td>Rutile/ilmenite (1950s, 1960s)</td>
<td>Fish oil/meal (1950s)</td>
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<td>Aluminium (1960s)</td>
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<td></td>
<td>Natural Gas (1970s)</td>
<td>Electricity- metals (1950s, 1960s)</td>
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<td></td>
<td>Uranium (1980s)</td>
<td>Oil (1970s)</td>
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<tr>
<td></td>
<td>Fish farming (1990s?)</td>
<td>Fish farming, marine resources</td>
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<tr>
<td></td>
<td>Coal seam gas (1990s)</td>
<td>(1980s)</td>
</tr>
</tbody>
</table>
Figure 1. Resource-based economy diversification model

Established NRBIs:
• Agriculture/fishery
• Mining
• Oil and gas

Enabling sectors:
• Capital goods
• Business services
• R&D/ICT

New emerging resource sectors:
• new marine species
• new renewable energy sources
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i For a very recent survey of much of this literature see Van der Ploeg (2011),

ii Exceptionally, Dutch disease has been subject to more formal modelling, particularly Neary and Corden (1982) but with no universally agreed model.

iii In part of the literature using the Dutch disease model (Sachs and Warner, 1995) the natural resource sector is assumed to have no learning or use of knowledge at all. The assumption is that there is no labour or capital used in this part of the economy. In this way, the model discusses the consequences of windfalls (free financial gains) for economic growth.
iv Greasley and Oxley (2010) use patents data to argue that a more narrowly-based development block drove New Zealand’s economic development through the interactions among gold, meat, printing & publishing, butter, and cheese.

v In addition there are two relevant articles analysing Norway’s development as a natural resource based economy from a political-institutional (Cappelen and Mjøset, 2009) and geographical perspective (Sæther, Isaksen and Karlsen, 2011)

vi For Australia, the key works of synthesis are Meredith and Dyster (1999); White (1992); Maddock and McLean (1987). For Norway Hodne (1975, 1983), Sejersted (2011), Thue (2009). There is no worthwhile comparative study of the development of the two economies.

vii Regarding definitions, see http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=14

viii Of particular importance are: Hirsch & Lounsbury (1996); North, (1990); North (1993); North (1999).