Dynamic Natural Resource Paths of Economic Development in Australia and Norway since 1950

Abstract

This paper challenges Ed Barbier's influential contribution to the resources and economic development debate and extends our understanding of the process of resource-based development in two relevant economies since World War Two. We argue that: resource-based development was still a legitimate form of economic development in the 'contemporary era' since 1950; that nations have modernised through continued investment in resource industries; and that it has been innovation frontiers not physical frontiers that mattered for development. We do this by providing a comparative study of two highly successful resource-based economies, Australia and Norway. Our focus is on two distinct growth industries for both nations in this period, aquaculture and offshore oil and gas, the first renewable and of recent origins, the latter non-renewable but with a longer history in other nations. Differences between the two nations are also discussed, particularly the narrower product specialisations of Norway. In both nations and both industries, though, there are common patterns of knowledge-intensive development through three stages – learning from older and imported technologies, the development of national capabilities, and internationalisation – that draw heavily upon the relationship between the resource sector and its supporting enabling sector.

Keywords: natural resources; aquaculture; oil & gas; Australia; Norway

JEL classifications: N50; Q2; N70; O13

Introduction: natural resources and economic development

The contribution of natural resources to economic development was debated among economists more than half a century ago (Prebisch, 1950; Singer, 1950). Interest in the role of natural resources in economic growth, however, re-emerged as policy and academic discourse with the idea of ’the paradox of plenty’, the ‘Dutch disease’ and the ‘resource curse’ during the 1990s. The main conclusion from this line of study was that natural resources are harmful for economic development in the medium and long term. During booms, specialisation in the production of natural resources draws in new investment and factors of production from other sectors. The attraction of foreign investment causes the exchange rate to appreciate, reducing the competitiveness of other sectors. When the commodity boom ends, other sectors of the economy have contracted. Skills and fixed capital may have been disbanded and the status quo cannot be restored (Auty, 2001; Corden & Neary, 1982; Gylfason, 2001; Sachs & Warner, 1995).

The discussion of natural resources’ role in economic development has also had an historical dimension. The conventional wisdom of economic history viewed industrialisation as the end goal of economic development. Abundant natural resources, though, served as a valuable prerequisite of modern economic development, dominating a transitionary stage before industrialisation. Access to cheap and plentiful coal, iron ore and food, in particular, provided the raw materials of manufacturing, its infrastructure, and the sustenance for its growing labour force. This account particularly resonated in explaining the success of the so-called first industrialiser, Britain, from the late eighteenth century but also much of Western Europe and North America in the nineteenth (Pollard, 1982; Wrigley, 1988; Landes, 2003; Clark & Jacks, 2007). Conversely, sparse or unsuitable natural resources often explained belated industrial development elsewhere.

In a series of important contributions over the last decade, development economist Ed Barbier has provided a bridge between the two sets of literature, economic and historical. Natural resources are an important consideration but not all resource abundant nations, he explains, have been successful long term industrialisers. While drawing upon the influential work of Gavin Wright (1990) in explaining the beneficial relationship between resources and industrial development in USA, he also challenges the implied general thesis that there is an iron law linking resource abundance to subsequent economic development. By reference to his 'frontier expansion hypothesis', Barbier analyses the particular conditions under which some nations have exploited their resource abundance more effectively than others as a basis for sustained industrialisation. Developing nations utilise resource opportunities on their 'frontier' – horizontally in agriculture and vertically in minerals – and trade these commodities: 'the earnings from such resource-based development …[are] reinvested in productive economic investments, linkages and innovations that encourage industrialization and economic diversification' (Barbier, 2011, p. 20).

The 'Golden Age' of this mechanism of development, he argues, was 1870-1914, and the most successful example was the USA. A large domestic market for resources, connected by internal transport, but relatively protected from overseas competition, facilitated American economic development. The industrial transition occurred as transformed products derived from resources began to be exported in large quantities, particularly iron and steel goods, copper manufactures, and refined mineral oil (Barbier, 2011, p. 397). The other 'Great Frontier' countries - Argentina, Australia, Chile, New Zealand, Paraguay, South Africa, Canada, and Uruguay – he argues, were less successful in diversifying away from Natural Resource Industries (NRIs). The later development of political institutions and smaller populations were limiting factors for the 'Southern Cone' nations, although Canada did better by dint of its easy access to American and European markets. This transition process for the

US was complete by the 1930s – industrialisation had become self-sustaining and the 'true "closing" of the western land frontier [had] occurred' (Barbier, 2011, p. 492). For those nations seeking to transition from resource-based development to manufacturing after 1950, the link between the two was broken and they faced an uncertain future locked into a resource 'enclave' form of development. In the post 1950 period, he identifies three key differences from earlier periods: frontier expansion was often on unproductive tropical and marginal land; globalisation made commodity exports easily accessible to other nations thus mitigating their value as an economic rent in the transition; and policy and institutional failures inhibited resource-based development.

Barbier's work is a valuable, original and integrating contribution, but we believe it has shortcomings. At its heart lies the assumption that a dominant resources sector, at best, is an intermediate step on the pathway to economic modernisation, which is characterised by manufacturing's rise to pre-eminence. In fact, he conflates this 'industrialisation' with 'economic modernisation', an assumption which is also built into much of the resource curse and economic history literatures. Recent economic historiography, particularly that associated with the Great Divergence literature, describes alternative pathways to economic modernisation and, indeed, draws varying pictures of what a developed economy might look like. In a number of Asian nations, for example, industrial development has relied more upon human capital and social relations than natural resources and the fixed capital generated by their rents in the western model of development (Austin & Sugihara, 2013). Moreover, there are nations such as Australia and Norway that have long thrived as resource-based Economies (RBEs) by continuing to specialise in the production and export of NRIs.

Barbier emphasises the importance of using knowledge and rent spillovers from NRIs to build up manufacturing industries. He argues that further development of NRIs, rather than diversification, would create an economically isolated 'enclave'. His conception of NRIs and their growth-inducing potential focusses on agriculture and mining and, equally, that they require a physical frontier of natural resource abundance in order to flourish. We believe that growth-inducing diversification can equally occur *within* the broad resources sector and at *different stages* of a nation's development that may not include such a frontier. This perspective is consistent with the notion of a 'resource-based economy diversification model' (Ville & Wicken, 2013).

American experience in the period 1870 to 1914 is used by Barbier to generalise about the role of natural resources in economic development. While the experience of other nations is widely discussed, this is largely to gauge their relative 'failure' measured by the degree to which they differ from American experience. Barbier generalises the 'failure' of the southern cone ('Great Frontier') settler nations of the southern hemisphere. Others have described the variety of development patterns and performance among this group of nations (Lloyd, Metzer & Sutch, 2013). Australia is viewed as a failure since it focussed on largely unconnected resource industries, wool and gold, and failed to make a sustained transition into manufacturing. However, Barbier relies on a disputed view that Australia's economic development had lost its way by 1914 (Schedvin, 1990). In the first half of the twentieth century, Australia sought to diversify into manufacturing using tariff protection to offset the challenges of small domestic firms serving the home market in competition with large multinationals. This ultimately proved an abject failure and reduced operational and allocative efficiency within the Australian economy. Tariffs were eventually reduced and mostly abolished in the final decades of the twentieth century. In the interim, the resource-based industries continued to innovate, diversify and remain the principal source of exports. Norway, another RBE, rose to the top of the OECD rankings in terms of GDP per capita in the second half of the twentieth century. It built its long term success upon forestry, fisheries and energy. Norway fits uncomfortably into Barbier's framework and is not analysed by him.

The ‘contemporary era’ since about 1950 is summarised by Barbier as one of overall failure by conflating the development challenges of many nations in the so-called ‘third world’ with the overall performance of NRIs in this period. The stalled economic development of many nations in Latin America and Africa has had less to do with the quality of natural resources available to them on the frontier than with broader institutional questions, especially political stability and human capital.[1] This is discussed in the resource curse literature (Mehlum, Moene, & Torvik, 2006), and a major World Bank report noted over a decade ago that ‘it's not so much what you produce as how you produce it’ (De Ferranti, Perry, Lederman, & Maloney, 2002). Barbier rightly observes that a number of successful economies of this period, such as Japan and Hong Kong, had very few domestic natural resources but were able to draw upon imported commodities. However, this is not a new story. International commodity trades were already booming at the time of American industrialisation, an era believed to be the first phase of globalisation (O'Rourke & Williamson, 1999). Britain's first stage of industrialisation in the mid-nineteenth century, as well as domestic coal, required imports of cotton and wheat from North America, timber from the Baltic, and wool from Australia and New Zealand.

In this paper we will investigate the expansion and diversification of NRIs in Australia and Norway since the 1950s. It will demonstrate that economies could expand and prosper through diversification *within* the resource sector. Rather than enduring the disabilities of an enclave, we show that this indicates important interactions with the enabling sector. Moreover, NRIs could continue to prosper *in this period* and without the need for a new physical frontier to exploit. We argue that it is *innovation frontiers* that matter.

[1] Barbier (2015, p. 68) suggests that development based on natural resources may expand ‘fixed’ resources, that linkages may create dynamics in other parts of economy, and that there may be knowledge spillovers from NRI. However, the analysis and conclusion of the paper do not draw on these insights. The focus remains avoiding a natural resource enclave, instead using resource rents to invest in industrial production.

Transforming natural resource industries into knowledge intensive production

During the Second Industrial Revolution in the late nineteenth century, scientific knowledge was more extensively applied to production processes. New types of organisations were established for the systematic development of new knowledge (public and industrial laboratories, research universities), education (universities, engineering colleges), and the application of new technologies for production (mechanical engineering) (Mowery & Rosenberg, 1989; Bruland and Mowery, 2004). This was part of a radical transformation of institutions and production systems in Western economies. The transition of American mineral industries from 1870 to 1914, mentioned in the previous section, confirms the transformative effects on the NRIs of the period. A key contribution (David & Wright, 1997, pp. 204-5) concludes that the development in mining:

> 'embodied many of the features that typify modern knowledge based economies [characterised by] positive feedback to investments in knowledge, spillover benefits from one mining speciality to another, complementarities between public – and private-sector discoveries, an increasing return to scale – both to firms and to the country as a whole'.

This type of transformation was not limited, however, to the mineral sector, nor to the US. Similar development processes occurred in various types of NRIs in Australia and Norway during the first half of the twentieth century (Ville & Wicken, 2013). The emerging knowledge-based production systems made NRIs a potential basis for economic development and modernisation during contemporary history. This is a topic of evolving work in several related fields analysing contemporary resource-based economies as dynamic and innovative – policy institutions (de Ferranti et al 2002), industrial economics and innovation studies (Smith, 2007; Perez, 2015; Iizuka & Katz, 2012; Laestadius & Noor, 2010, Andersen, 2011;

Marin & Smith, 2011) and development studies (Morris, Kaplinski, & Kaplan, 2013; Andersen et al., 2015). A characteristic of the emerging strands of analysis is that natural resource-based development is analysed as the outcome of processes where knowledge and technological development are central factors (Andersen, 2011; Ville & Wicken, 2015; Andersen et al., 2015).

A consistent theme running through the strands of literature is that RBEs are not an undifferentiated group of countries. Smith and Wicken (2016) argue that they have "quite specific and identifiable combinations of characteristics, extending well beyond resource intensity in some abstract sense". These are shaped by each country's history, geophysical environment, location, demography, economic and social structures, and political systems. One way of defining categories of RBEs, they argue, is to specify different types of core processes shaping long term dynamics and structure linked to natural endowment and resources. They point to five channels through which high-growth RBEs connect innovation to economic development: (i) growth and productivity within an existing resource sector; (ii) extending existing resources by identifying new deposits or using resources in new ways; (iii) producing new natural resources by using new parts of the natural environment; (iv) creating upstream and downstream industries; and (v) using revenues from resource booms for productive investment in non-resource industries. This diversity among RBEs is the result of context and historical path dependence. Barbier's approach focusses on the fifth of these possible pathways, which requires diversification from resource industries into manufacturing.

A theoretical basis for this (Smith and Wicken) position is a *dynamic approach* to natural resource based development that draws on a conceptual distinction between a *natural environment* and a *natural resource*. Availability of natural resources is dependent on our ability to transform parts of the environment into resources that have economic value. This approach builds on the analysis of Erich Zimmermann (1933/1951) who argues that a natural resource is defined by its *function*. For example, both coal and oil have been part of the natural environment for millions of years, but it was only when they were defined as major energy sources – performing a function in the economy – that they became a natural resource. Natural resources are not given by nature – as manna from heaven – but are the outcome of dynamic transformation processes that extends our use of the (given) natural environment. When a new natural resource is developed and is endowed with an economic value, production may start in various locations. New knowledge, methods and technology can expand local and global resource bases and result in long-term growth. The main factor determining the availability of natural resources is knowledge: 'resources … are not, they become, they evolve out of tribune interaction of nature, man, and culture' (Zimmermann, 1951, p. 84).

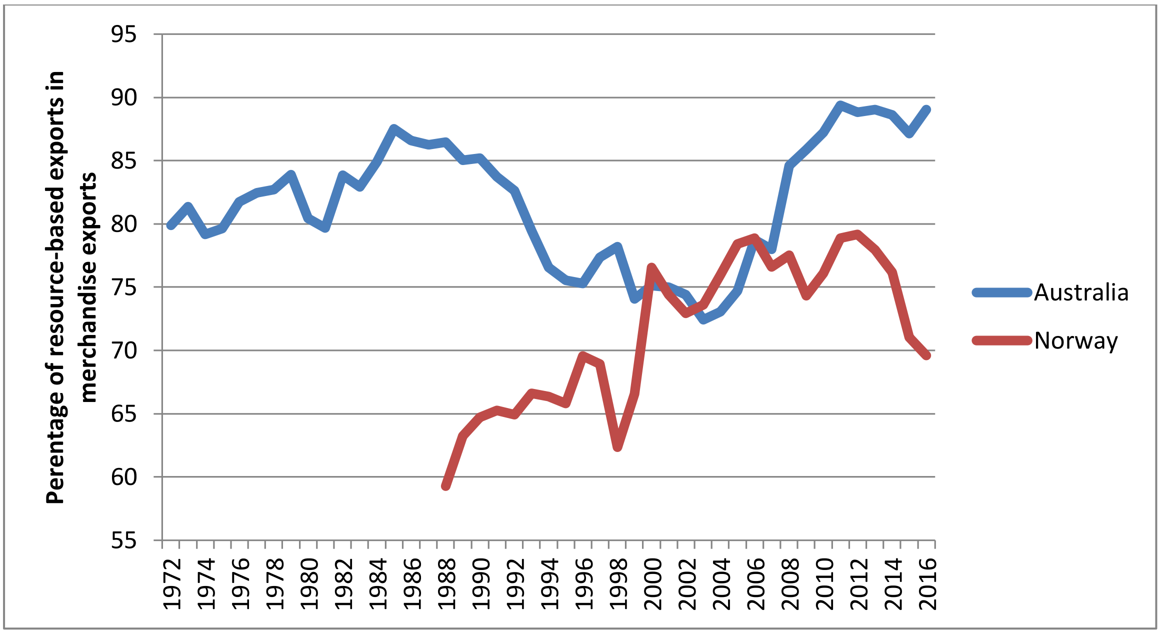
The idea that new NRIs continuously emerge as the outcome of socio-economic processes where new knowledge is the central factor, has implications for the extent to which NRIs may be a basis for industrial development. The 'frontier' is not defined by the natural environment, but rather in the co-evolution of knowledge with specific aspects of the local environment. The perception of natural resources as a social construct is central to the argument of David and Wright (1997) for the success of the American mining industry in the early twentieth century. Resource abundance was not a result of a particularly rich endowment of minerals, but rather the superior ability of American entrepreneurs to discover and extract resources compared with other countries, such as Chile or Australia. Not even non-renewable resources are given and finite, but rather the result of factors that are endogenous to the economy and society (Wright and Czelusta, 2003).

Australia and Norway path: Creating natural resource specializations

Australia and Norway belong to a relatively small group of countries where welfare and long-term growth has followed a trajectory characterized by continuously creating, transforming, upgrading, and extending NRIs. Both countries historically specialised in NRIs; Australia in agriculture and mining, Norway in fish, forestry and later energy. Both confound the pessimism of resource curse advocates by remaining near the top of international rankings of income (GDP/capita), welfare (UN Development Index) and knowledge and innovation (World Bank index). Elsewhere, their evolution as RBEs in the nineteenth and early twentieth centuries has been discussed (Ville & Wicken, 2013; Ville & Wicken, 2015).

The objectives of the remaining empirical sections of this paper are to show how Australia and Norway have retained long-term growth, sustained high welfare and developed into modern knowledge economies following this specific path of continued focus on NRIs. We focus on the recent period from the 1950s – the so-called contemporary era – where, according to Barbier, the link between resource intensity and development has allegedly been severed. During this period both nations continued to focus on resource-based development and feature among the best performing economies. Figure 1 confirms that both countries remain highly focussed on resource-based exports. However, there are differences between the nations as well. Norway has specialised in the production of a limited number of natural resource goods, while Australia, with its large geologically diverse landmass, was able to diversify across a wider range of output.

Figure 1. Indicative percentage of resource-based merchandise exports, Australia (1972-2016) and Norway (1988-2016)



Sources and notes: For Australia, calculated from ABS Cat 5386.0, International Trade in Goods and Services including exports of meat, cereals, wool, other rural exports, metal ores and minerals, coal, petroleum and natural gas, metals and gold. For Norway, calculated from Statistics Norway 8819-1 including export income from Hydrocarbons, fish, pulp and paper, nickel and aluminium.

Building on a dynamic approach to analyse NRIs and their role in long-term economic development and modernisation, we investigate the growth of several important new NRIs, from their initial establishment to ultimate internationalisation. Empirically, our focus is on two distinct growth industries for both nations in this period – aquaculture, and oil and gas – the first renewable and of recent origins, the latter non-renewable but with a longer history in other nations. We analyse the dynamics in establishing a new NRI by drawing on a modified version of the resource diversification model, consisting of two main sectors: recipient sector (the NRI) and enabling sector (capital goods industry, business services, R&D), referred to as RS and ES respectively (Pol, Carroll, and Robertson, 2002; Ville and Wicken, 2013). The outsourcing of non-core activities by NRI firms from the 1980s encouraged the development of specialised firms for technological development and innovation services. Of particular importance is that the ES became a growth sector in its own right. NRI firms specialised in skills and knowledge specific to operating an efficient production system, and through interaction with ES organisations they became a central aspect of modern industrial development (Herrigel & Zeitlin, 2010).

For long term dynamics along a NRI development path, continuous learning processes and access to new knowledge bases are essential. We analyse how knowledge processes – the use of established, and the creation of new, knowledge – are involved in three equential processes linked to NRI development: the establishment of a new NRI, the expansion and continuous upgrading of their production systems, and finally their internationalisation. We focus on how these processes relate to the development of local capabilities by encouraging enabling sectors, and we discuss the role of policy and the public sector in these processes.

Underlying the model is the proposition that economic development processes are path dependent (David, 1985). We assume that the development of new technologies and sectors are shaped by past historical experience. Creation of new sectors will, to some extent, build on capabilities derived from existing production, infrastructure, institutions and knowledge bases (Dosi, 1988). A central aspect of the path dependency concept is that as economies specialise, they develop knowledge bases, technologies, routines, organisations and institutions relevant to these specialisations. Economies, in this way, become competitive within their specialisations – in the case of RBEs, specialisation in NRIs rather than manufacturing. This is consistent with work on the importance of *relatedness* – that new companies and industries have higher success rates when they build on competence from related industries, that is, industries that share knowledge bases and skills with the emerging new industry (Tanriverdi & Venkatraman, 2005). Empirically, we analyse how established organisations and competencies are utilised during the early phases of a new NRI.

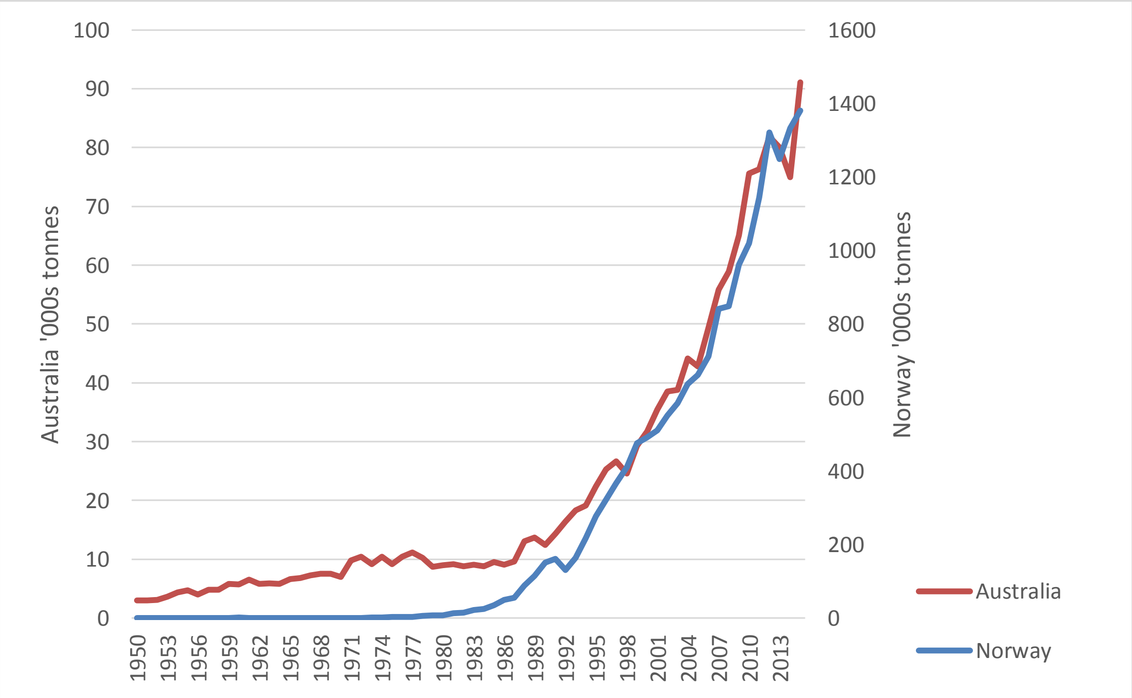
As the new industry gradually expands and is upgraded, the number of knowledge bases used in production will increase, and a wider set of knowledge institutions become involved in improving aspects of the production system. A central factor for long-term dynamics is the extent to which a specialised and well adapted enabling sector is built-up for problem solving within the new industry. Also important are the social technologies that help to shape the relationship and interaction in innovation processes within the ES-RS nexus. Finally, we discuss examples of how new NRIs becomes internationalised by FDI in various parts of the world, and the role of the ES-RS relationship in the internationalisation process.

Aquaculture: developing a new industry sector

Both nations also had a long history experimenting with fish farming. In Australia, Sydney rock oysters were being cultivated from the 1870s (Schrobback, Pascoe, and Coglan, 2014, p. 155), while in Norway scientists experimented with fish breeding and production from the early twentieth century on the coast of Sørlandet (Schwach, 2000). Aquaculture became a major industry in the second half of the twentieth century. Large scale commercial breeding and farming of fish, often in purpose-built structures, became one of the fastest growing resource industries in Australia and Norway in the last couple of decades. As Figure 1 indicates, after a slow start, production increased sharply in the 1990s and continued to grow quickly through the quarter century to the present. Given the broader resource diversification of Australia, its aquaculture catch was much smaller than in Norway.

The structure of aquacultural production differs in the two countries. Norway has specialized in salmonid production, which constitutes more than 90 per cent of the industry with production units located in fiords along the coast of Western and Northern Norway. Australia has a more diverse industry, with pearls, oysters, Atlantic salmon, shrimp, and southern bluefin tuna farmed commercially, largely for domestic food consumption. By far the largest value of output comes from Tasmania where the cool climate suits the production of Atlantic salmon, while South Australia accounts for most of the southern bluefin tuna. Between them, the two states generate 74 per cent of the $1bn aquaculture industry (ABARES, 2013-14, p. 13). Pearl farming is an important commodity for remote parts of Western Australia and Northern Territory. In Australia, aquaculture comprises 40 percent of total fisheries (ABARES, 2015, p. 10); in Norway – the world's second largest exporter of marine resources – the industry comprises 60 per cent.

Figure 2. Aquaculture production in Australia and Norway



Source: Food and Agriculture Organization of the United Nations, http://www.fao.org/fishery/statistics/collections/en accessed 1 November 2017

Early phase: Drawing on existing skills and technologies

The development of aquaculture drew upon existing resources, knowledge and competences from old NRIs, particularly marine industries, fisheries and agriculture. The traditional wild fishing sector was an important source of practical information – fishermen possessed a detailed local knowledge of climate, sea, fish types, and the use of cages and traps. This knowledge underpinned breeding fish far from their natural habitats. For example, salmon ova were imported into Australia from Nova Scotia in the 1960s and a hatchery was established in the Snowy Mountains. In the 1980s eggs were provided to Tasmania as feedstock for the production of Atlantic Salmon (Tasmanian Atlantic Salmon, 2007). Tacit knowledge of the optimum conditions for each fish species has been crucial in managing Australia's many climatic zones. While barramundi is a tropical fish, temperature control means this species has been farmed in tanks in the cooler southern states. In South Australia, many Southern Bluefin Tuna fishermen moved into the new tuna ranching industry. Knowledge was shared via the formation of local and state aquaculture associations.

In Norway, the early phase of salmon production was largely based on experimentation by fishermen and farmers who drew on their experiential knowledge from ocean and coastal fisheries. Some early fish farmers had experience in the use of closed net cages near to shore to keep saithe alive. Fishermen's experience and knowledge of the local environment was crucial for decisions about positioning aquaculture production and mooring nets securely to the sea floor. Moreover, technological solutions used in fisheries were introduced into aquaculture; exemplified by the use of pumps on fishing vessels for removing fish from net cages (Berge, 2006, p. 411-12).

Building local innovation capabilities

As production grew, there was a demand for more technologically advanced systems to improve productivity and benefit from economies of scale in such investments. Studies of aquaculture illustrate the complexity and diversity of knowledge bases that evolved to support the development of the industry. These included scientific specialities such as wave analysis, optics, robotics, spectography, chromography, electron microscopy, and various fields of technology including materials technology, surface technology, construction and welding, information technology, gas technology, electron microscopy, control technologies, extrusion technology, monitoring, high pressured air and liquid technologies, refrigeration, bio technology, and nutrition technology (Dietrich, 1995). The need for new knowledge bases was reflected in the expansion of scientific institutions investigating aquaculture in both countries. Many of the research and knowledge needs were common to all firms, which tended to be small and fragmented. The state was an important actor in both countries, supporting the development of a public knowledge infrastructure. The expertise and reach of existing government bodies could be brought to bear on the challenges of the industry.

In Australia, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and its predecessors, has undertaken research into the broad range of natural resource industries since 1916 and in recent decades turned to research on fish breeding, feeds, and diseases to assist the industry.[2] More specifically, the Fisheries Research and Development Corporation (FRDC) was formed in 1991 as a statutory corporation under the Department of Agriculture as an industry specialist facilitating R&D. An early landmark activity was collaborative R&D on farming southern Bluefin tuna with the Tuna Boat Owners Association, the South Australian Government, and the Japanese government. The problem of rising land salinity in Australia has also received attention as a possible opportunity to

[2] https://www.csiro.au/en/Research/AF/Areas/Aquaculture

develop inland saltwater fish farming. In a 2010 paper (FRDC, 2010), it highlighted the application of the Research, Development, and Extension Framework to aquaculture. This policy had been introduced around 2005 to address the complexity of the enabling sector in Australian primary industries by providing a forum for stakeholders to work together. Members of the FRDC strategy group were drawn from government, industry, and its associations. The aspiration was to create "a national system in which end users of the research take a leading role in determining and reviewing strategic directions and priorities" (FRDC, 2010, p. 8).

In Norway, genetics and feedstock were important topics of research. A programme on genetics for survival and rapid growth of Atlantic salmon started in the 1960s at the Norwegian University College for Agriculture. Aquaculture was initially under the umbrella of agriculture, and early research built on the College's experience of genetic selection of breeding livestock. The first dedicated research centre, Akvaforsk, was founded by the Research Council for Agriculture in 1971. As the industry evolved, it continued to draw on various knowledge sources in agriculture such as animal health, fodder, and distribution. The gradual development of an industrial value chain with specialized producers and suppliers for each stage of production was reflected in the variety of R&D programmes. Aslesen (2004) mentions 13 different programmes. By 2008 there were 20 public or semi-public research institutes with 1600 researchers located in various parts of Norway to undertake aquaculture research (Aslesen, 2009, p. 215). Some of the main R&D achievements have been in fodder, resulting in the introduction of dry-feed and the ability to feed fish in their larval stage (Schwach, 2000, p. 23). In health vaccinations have been developed against parasites, bacterial and viral infections, drastically reducing the amount of antibiotics used (Aslesen, Mariussen, Olafsen, Winther, Ørstavik, 2002).

In both countries, a wide range of training has been offered by universities and research institutes. In Australia, Cooperative Research Centres involving universities, CSIRO, and state government primary industries departments, have existed since the early 1990s, and the Seafood Industry Training Package (SITP) was introduced in 2002. In Tasmania the Institute for Marine and Antarctic Studies (IMAS), formed at the University of Tasmania in 2010, has provided a range of training in aquaculture as well as conducting extensive collaborative research. In Norway, specialised education in aquaculture was introduced at secondary level from 1994, and four universities have developed higher education programmes.

In Norway, government policy was designed to stimulate salmon production. It regulated from the 1970s to secure a decentralized industrial structure with small-scale production units. A license system restricted individuals to ownership of one production unit. Before 1990 more than 800 licenses were issued, mainly to fishermen and farmers, supported with a subsidy scheme. The intention was also to provide work for the many small-scale workshops that had experience in providing equipment and solutions for coastal and ocean fisheries as well as for shipping. In some regions of Norway new ideas, practices and technologies diffused rapidly due to open relationships between fish farmers and between fish farmers' consultancy companies, fodder providers, and technology suppliers (Berge, 2006).

From 1991, however, licenses became tradable, and ownership of the industry rapidly fell into the hands of a few large investors. This changed the industry's dynamics, creating demand for technologies and services which could improve efficiency, reduce expenses for all parts of the production chain, and solve fish health problems. As a result there was a growing market for firms that could provide improved inputs, capital goods, and services to the aquaculture industry. The supply industry then entered into a period of consolidation which resulted in a group of strong suppliers enabling the industry to innovate: production of fodder (Ewos, Skretting, Biomar), machinery and transport equipment (Seaside, Melby

Systems, Optimar, AKVA, Aqualine, OCEA, Rolls Royce Marine); fish health (Europharma, Fiskehelsetjenesten, Scanvacc) trading and various types of consultancies and finance institutions.

There is less evidence of the emergence of a specialised capital goods sector in Australia, but the Commonwealth's 2002 Aquaculture Action Agenda was designed to encourage industry and government to work more closely together in an effort to enhance sustainable competitive advantages (AFFA 200).

Internationalisation

Norwegian aquaculture has become the world's leading producer and exporter of salmon, mainly to the EU and to a lesser extent to the USA and Asia (Statistics Norway, 2017). However, when large scale investors entered the Norwegian industry during the 1990s, they also began to systematically invest in facilities in other countries. This internationalization partly resulted from domestic production regulations (Aslesen, 2009, p. 225). Investors turned to countries with less regulated production regimes, including Scotland, Canada, and Chile (Berge, 2002). By 2007 over 1/3 of Chilean aquaculture was owned by more than 60 Norwegian firms. Subsidiaries of multinational corporations played a central role including Marine Harvest in fish farming, CERMAQ in fish farming and fodder, AKVA Group and Ocea as suppliers of equipment, Pharmaq in pharmaceuticals; but a number of small and medium sized service companies were also active (Astroza, 2008). In this way, the internationalization process consisted of the establishment of firms belonging to both recipient and enabling sectors. Parts of the supply industry such as fish fodder producers and R&D organisations followed producers to new markets. Fodder producers, in particular, becoming active in all major salmon producing markets (Aslesen, 2009, pp. 212-13). The development of the Australian industry in Tasmania benefited from the transfer of Norwegian technology and know-how through a joint venture established in 1984 between the State government, local producers, and Noraqua, a Norweigan firm. However the Norwegian partner withdrew once the company began competing with Norwegian companies in the Japanese market. By 2010, four of the leading six global seafood companies were Norwegian (OECD, 2010, pp. 151-2).

By contrast, Australian internationalization has focused largely on exporting with a concentration on the higher value products such as lobster, prawns, abalone and tuna. 46 per cent of Australia's aquaculture output by value was exported to Asia in 2013-14 (ABARES, 2013-14, p. 1); the remainder serves growing domestic demand in the face of falling volumes from 'wild' fishing, and the sale of new varieties of fish locally.

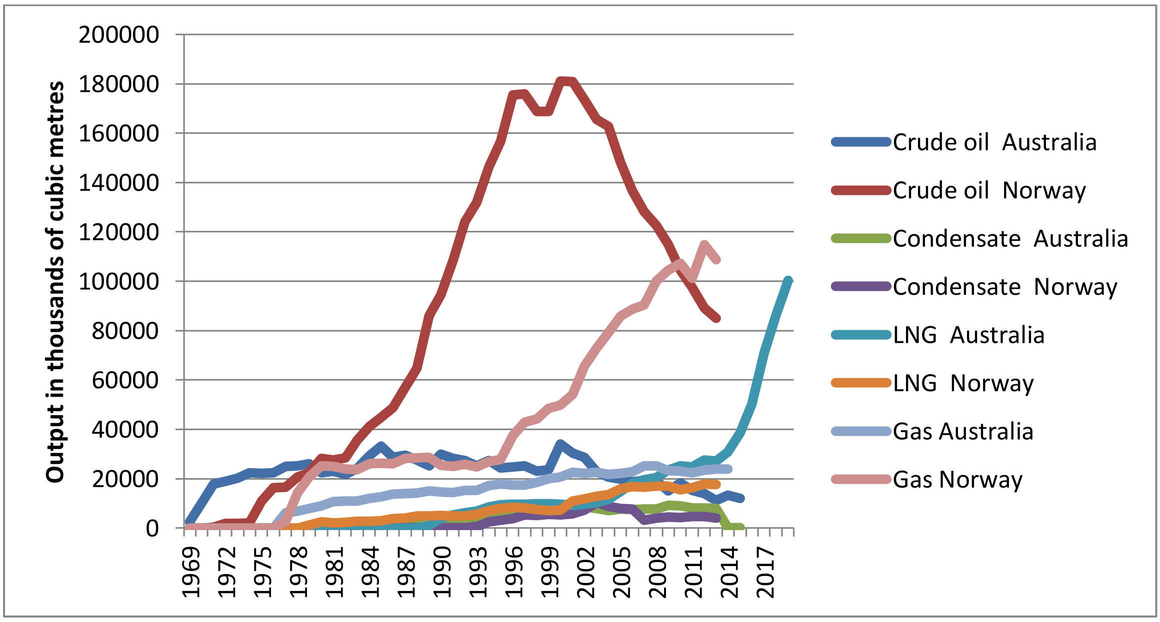
Oil and gas: Transfer and creation of an indigenous industry

During the second half of the twentieth century, offshore oil and gas production became a growth sector in Australia and Norway, with both countries becoming major players in the international market for liquid natural gas (LNG). Australia is currently positioned to become the world's largest exporter of LNG, and Norway is the second largest provider of natural gas to the EU.

Oil and gas (OG) was already a global industry when Australia and Norway began exploration and development from the 1960s. The Gulf of Mexico was the leading offshore oil and gas producing region, and US companies brought to Norway and Australia their suppliers, organisations, technology, expertise, routines and regulations. Australian and Norwegian companies, as recipients of this know-how, were able to absorb these capabilities, modify them, and develop successful local industries.

Australia's on-shore OG exploration began early in the twentieth century, but it was the large discoveries in the mid-1960s (Dongara in 1964, Barrow Island in 1965, Bass Strait in 1967) that started the modern trajectory of the industry. On the Norwegian shelf of the North Sea, exploration commenced in 1966, the first commercial discovery was in 1969 (Ekofisk), and production began in 1971. Many new discoveries followed and by the early twentieth century it was gas that dominated output in both countries.

Figure 3. Oil and gas production, in Australia (1969-2015) and Norway (1970-2015)



Source: APPEA industry statistics, Australia Department of Industry, Innovation and Science, Statistics Norway

In Norway, from the first commercial discoveries it was evident that Norway would become a significant exporter of oil and gas (Stortinget, 1974, p. 5-6). By 2003-4 Norway had was the third largest exporter of oil and gas globally (Regjeringen, 2005). At the peak (2008) of the petroleum era, OG represented 25% of GDP, 53% of total export value, 35% of total state revenues, and 21% of total investment (Norwegian Petroleum, 2017). Norway became a petroleum economy.

In Australia, OG was initially less dominant in the economy as one of many NRIs. The early discoveries were relatively limited and were important for energy security, but not for the overall industrial structure. However, the picture changed with the discovery of major offshore fields and the emergence of global trade in LNG from the 1990s. During the 2010s there was a rapid increase in production and export of LNG and this will continue as the Prelude, Wheatstone and Ichthys projects come on line in the period to 2019. Export income from the seven existing LNG projects is expected to reach AUD37b in 2018-19, which will make LNG Australia's third largest export earner behind iron ore and coal (Cassidy and Kosev, 2015, p. 35).

Early phase: the role of old industries in building the OG sector

The early expansion of the OG sectors in Australia and Norway from the 1950s and 1960s involved major international oil and supply companies, and the development of a local industry engaged in close relationships with the global players. Expansion involved local firms that already operated in global production networks. This was the case for BHP, which was Australia's largest firm for much of the twentieth century. It owned and operated mines, smelters and steel mills, and possessed significant engineering and manufacturing capabilities, including shipbuilding (Fleming, Merrett, & Ville, 2004, p. 104). To develop their capabilities in OG, in 1960 BHP engaged prominent US geologist Lewis Weeks (who had been Esso's chief geologist) and on his advice procured exploration rights over much of Bass Strait. Esso became BHP's partner and provided the know-how for exploration and, after discoveries were made, for construction and operation. In Western Australia petrol retailer AMPOL established a consortium with US oil major Caltex (West Australian

Petroleum) in 1952, which was later joined by Shell. They discovered the Dongara gas field in 1964, and then oil at Barrow Island, which began production in 1967. Similarly, in the early 1960s, Woodside partnered with Shell and Burmah Oil as a consortium for exploration and development of the North West Shelf.

Norway's largest manufacturing company, Norsk Hydro, with international experience in chemical and metal processing, entered into a joint venture with the French Petronord group in 1965. This secured 6.7% Norwegian ownership in the Ekofisk field, but Hydro was the only local company involved in early-stage development of the field. However, some local industries became engaged in the emerging industry as suppliers of services and technology. Shipowners had been involved in oil transport since the 1920s and by 1965 20 per cent of the global fleet of oil tankers was registered in Norway (Ryggvik, 2013). International oil companies encouraged Norwegian ship owners to enter the rig market in the North Sea, and by the mid-1970s Norwegian firms dominated this market, having assembled a fleet of 25 semi-submersible drilling rigs. The local industry's success has been linked to its experience in managing the risks of speculative orders which enabled it to have rigs available when demand increased during the 1970s (Ryggvik, 2013). Through its supply relationship with shipowners, Norway's largest ship building company, Aker, moved into the OG sector. It designed the Aker H-3 semi-submersible drilling rigs, which in 1973 were procured by shipowners. Aker itself was owned by the shipowner Fred Olsen, who had been involved in oil transport for decades and had attempted to enter the North Sea OG industry during the 1960s (Hanisch & Nerheim, 1992).

Building local innovation capabilities

The offshore OG industry has consisted of a value chain involving exploration, field development, construction of production facilities, drilling, production, transportation, refinement and distribution. Each part of the chain involves a number of different capabilities. In total, innovation in offshore OG production has demanded a large variety of technologies and knowledge bases. In both Australia and Norway, the demands from the OG sector has resulted in the development of a diverse supply and services industry, including a significant R&D sector.

In Australia, funding for OG R&D came mainly from the public sector, with a focus on 'pre-competitive' research to identify prospective areas for exploration. In 1946 the Bureau of Mineral Resources, Geology and Geophysics was established to provide a comprehensive survey of Australia's geology (Johns, 1976). By the early 1960s this was extending offshore with the aim of providing information about prospective regions for explorations, without undertaking exploration directly. The Bureau was responsible for the introduction of new survey technologies to Australia, including introducing Vibroseis technology in 1964, which eliminated the need for explosives to create a seismic source in surveys.

In Norway, the demands of the large OG industry had a more profound impact on the overall national R&D sector. The public sector has both funded R&D directly, and established new social technologies encouraging international oil companies to invest in R&D in Norway. From the 1980s the government's Technology Agreements required that, in order to obtain a development license, international companies had to undertake at least half of total research and training related to the development of fields in Norway. This had a strong impact on the size and organization of the national research system (Gulbrandsen & Nerdrum, 2009). In 1979 petroleum related research funding was NOK200m; in 1986 it had increased to 1,600m. Of this only seven per cent was state funding, and more than NOK500m originated from oil companies. Two years later, the total OG R&D funding reached NOK2,000m and only NOK200m was from the state (Ryggvik, 2000, p. 116). These arrangements catalysed interaction and collaboration between many Norwegian firms and international oil companies. The intention was to promote learning and technology transfer to local industry, and to engage local firms with the OG international production chain. The emerging research system was focused on the problems of users of industrial research. Local firms and international companies became engaged in common processes, and integrated their activities with international industrial learning communities.

However, the accession by both countries to the WTO in 1995 introduced obligations to treat all suppliers equally, irrespective of origin. This was the end of polices for national control or privileges for local industry. From the mid-1990s, in line with these obligations, the Norwegian government’s strategy shifted to increase public R&D. A broad portfolio of innovation and R&D programs was introduced. The main form of support was tax policy, along with a rapid increase in public funding of R&D. Currently there are 21 different forms of support systems for the OG sector. The funding from the Research Council of Norway (NRC) increased from NOK300m in 2005 to NOK1,300m in 2016 (Norwegian Research Council, 2017, p. 198).

With the discovery of large gas fields and investment from the 1990s in Australia, Cooperative Research Centres (CRCs) connected with the oil and gas sector have been supported by the Commonwealth Government and its key research agency, the Commonwealth Scientific and Industrial Research Organisation (CSIRO). These include the Australian Petroleum CRC (1991-2003), the Australian Geodynamics CRC (1993-2000), the Energy Pipelines CRC (2010-2020), the CRC for Integrated Engineering Asset Management (2003-2013) and the CRC for Contamination Assessment and Remediation of the Environment (2011-2020). The University of Western Australia established a Centre for Offshore Foundations Research. CSIRO developed interests in petroleum research. For example, the Subsea Pipelines Collaboration Cluster, formed in 2008 from a collaboration of six universities and the CSIRO, has contributed technology to the development of the Gorgon gas province. Some private R&D is also linked to OG sector. For example, CISCO established an innovation centre at Curtin University with Woodside Petroleum as a foundation partner. Woodside provides a holistic view of the platform's operations, and gains productivity benefits.

Both countries developed an enabling sector with relevance in global markets. The build-up of the Australia's enabling sector has been assisted by the changing relationship between global oil companies and local supply firms. BHP's partner Esso was the developer and operator of the Bass Strait fields, as we saw earlier. The platforms for Bass Strait were initially fabricated at the supply base established by Esso in Gippsland, drawing on Esso's experience in the Gulf of Mexico. Nevertheless, over time, BHP emerged as an operator in the OG sector in its own right, building on their experience, and through acquisitions and recruitment of expertise. Similarly, Woodside, initially partnered with Burmah Oil and Shell, emerged as an explorer and operator in its own right. These local majors in turn developed close relations with the emerging enabling sector from within Australia.

In 2016 the Australian Trade Commission identified around 95 Australian enabling sector companies that have capabilities in global markets, often driven by working in the remote and hostile environments of Australia. Australian companies, often small and medium enterprises, have developed advanced tieback, (connection from a new field to an existing production facility) flow assurance and foundation modelling technologies and innovation around construction productivity, safety, computational geosciences and subsea production. Separately, based on a review of a database maintained by the Commonwealth Department of Industry, Innovation and Science, there were about 400 Australian firms directly involved in supporting the offshore oil and gas sector, including around 150 that are exporters.

In a similar way, local oil firms became operators on the Norwegian Shelf from the 1980s. Statoil, a state-owned oil company established in 1972, became the dominant player in the oil region, but Norsk Hydro was also an important firm. Both developed skills and expertise through international collaboration and systematic training of personnel. Statoil exemplifies the important role of oil companies in developing the service and supply industry. It became the main actor providing contracts to local industry in the development of new fields and operations, deliberately strengthening interaction between supply firms and oil companies.[3] The 1973 recession added impetus to this approach, as the crisis in the shipbuilding sector, caused a shift to exploiting the high local content opportunities in the OG sector. Accordingly, local content increased from 18-25 per cent prior to 1975, to 50-60 per cent after 1977 (Ryggvik, 2013, pp. 44-6).

Aker typified the results of the local content policy. In the 1970s, it designed and produced the concrete Condeep platforms[4], which became the core of the 'Norwegian technological style' (Sejersted & Olsen, 1997). To a large extent, the local content was characterised as 'cement bashing'; with large quantities of material with little demand for advanced knowledge. Instrumentation of the platforms continued to be imported, and mainly provided by American companies (Ryggvik, 2000). By the late 1980s this technology was no longer profitable, and the government initiated policies to reduce costs (through NORSOK) and to develop new technological concepts and processes.[5] A core idea was the development of standards for a modular production process, allowing different companies to produce different components. This became the basis for a dynamic innovation system where the

[3] Aker and (particularly) Kvaerner developed strong engineering departments. Pushed by Statoil, the two companies engineering departments merged and became the basis for Norwegian Petroleum Consultants (NPC); planned to become the national engineering company for OG sector. NPS were partner to leading international/American engineering firms during first phase as part of competence building.

[4] The first two platforms were sold to Mobil and Shell to be used on the British shelf, and therefore not linked to national policy.

[5] NORSOK was introduced in 1994 to set industry standards regulating such matters as safety and cost-effective design.

industrial actors – oil companies and main suppliers – enjoyed greater freedom in choosing technological solutions, partners, and the geographical location for production (Engen, 2009, p. 201). A new technological trajectory emerged, characterized by greater use of unmanned installations and computer based technological solutions linked to subsea technologies and new drilling techniques. By the early 2000s, Norwegian firms supplied technology and services to major international oil companies and main contractors; covering most of the upstream production chain from exploration and drilling to production and operation (Ryggvik, 2013). This had become Norway's largest manufacturing sector, and also a significant producer of knowledge intensive businesses (Wicken, 2016).

In Australia, local fabrication of platforms and the gas trains was initially undertaken close to their locale. However, modularisation and the development of Floating LNG has made it feasible to import infrastructure of this type. It was reported that there was 70% local content for the first three phases of Australia's first major LNG project, however this has decreased in subsequent projects – perhaps to 30 per cent in places (Parliament of Australia, 1998, p. xiv). In line with WTO obligations, the focus of government policy has been on 'Australian Industry Participation' (AIP). The objective has been to ensure Australian suppliers received 'free and fair' access to opportunities to bid. The cornerstone of AIP has been to bring the capabilities of Australian suppliers to the attention of purchasers further up the supply chain, in the belief that international EPCM (Engineering, Procurement, and Construction Management) firms lacked knowledge about local supply capabilities.

Transforming and going global: subsea and LNG

During the 2000s, the OG industry in both Australia and Norway globalised, through large scale investments in many producing regions. Statoil (merged with Norsk Hydro in 2007) invested widely in new offshore oil fields in Asia (Azerbaijan), Africa (Algeria, Angola, Libya, Nigeria), Australia, and the Americas (Brazil, Venezuela, USA). They have also developed capabilities in unconventional resources such as oil sand in Canada and shale in USA. By 2015, BHP's Australian assets were only one sixth of its global petroleum asset value. Its move out of Australia has operated onshore and offshore in the US, Algeria, Trinidad and Tobago, Pakistan, and in the North Sea (BHP Billiton, 2015, pp. 73-4). Woodside has projects in the US and Canada, and exploration rights in Peru, Gabon, Senegal, Morocco, Ireland, Myanmar, New Zealand and Korea (Woodside Petroleum, 2017). Oil Search is an LNG partner with ExxonMobil in Papua New Guinea, and has exploration sites in the Middle East and North Africa.

The are several contrasts in the globalisation experience of the two countries. In Australia, internationalisation from the mid-1970s drew on experience developing large offshore gas reservoirs in local waters, as well as building infrastructure for the distribution of natural gas domestically. Growing industry capabilities gradually fostered offshore investments by Australian firms (BHP, Woodside and Oil Search). From the late 1980s, large discoveries and the development of new fields created potential for the export of gas. However, it was the development of gas liquification, along with specialised shipping, that enabled global expansion of the Australian OG industry through large scale exports.

In Norway, the number of new OG fields was more limited from the late 1980s and future expansion was linked to engagement in emerging oil regions. Government policy aimed to develop a wider industrial strategy by combining OG production with the development of a strong supply industry. A new organization, INTSOK (Norwegian Oil and Gas Partners), was established in 1997 to promote Norwegian standards globally. Norwegian firms became dominant in several sectors of the OG supply industry. By 2012 Norwegian companies covered 50% of global market for sub-sea technology; 80% for drilling equipment, 50% for seismic equipment (Rystad Energy). This success was the result of long term experimentation with sub-sea technology in the North Sea, which became a 'global field laboratory' of innovation (Ryggvik, 2013, p. 106),[6] and formed the basis for global OG operators using Norwegian industry and technology. By the end of the super boom, supply was Norway's second largest export sector, only trailing the OG industry itself (Mellbye, Fjose, & Jakobsen, 2012). In addition, many companies had invested in production and service offices in major OG regions in Africa, Latin-America, and Asia. For the first time, Norway had a large high-tech industry operating globally.

Conclusion

This paper extends an important developing literature on the role of natural resources in economic development. It builds on recent work that shows that resource-based economic growth is not merely a transition stage to modernisation, nor is persistence along this pathway feted to general economic failure. Barbier's work brought together both of these traditional views in an historically specific manner. He argued that resource led development reached its apogee, or golden era, in late nineteenth and early twentieth-century America but that this important pathway to growth was closed after 1950.

Building on earlier scholarship that demonstrated that Australia and Norway, both resource-based developers, were among the most successful nations in this golden era, we analyse their development after 1950. In this period both nations continued to be among the best global performers on most socio-economic indicators. We focus on two of their NRIs, aquaculture and the offshore oil and gas sector, one a relatively new NRI; the other with a much longer international history. In both countries, these industries expanded rapidly and progressed

[6] Norwegian authorities and industry became interested in sub-sea technology development during the early 1970s. The government decided that oil and gas from the North Sea should be transported to Norwegian mainland and not directly to the European market. The pipes had to cross the Norwegian Trench which was deeper than 300 m, and this was below the technological limits for sub-sea operations of the time. Ten years later construction of the pipeline was technologically feasible. Norwegian regulations did not permit diving below 300 m, and therefore deep-sea mechanical devices (robots, ROV) were introduced to handle the operation.

through three stages from importing knowledge and skills, the expansion of domestic output and capability, to internationalisation by export and foreign direct investment. Within these common patterns there were, nonetheless, some differences in experience between the two nations. In particular, Norway's range of resource industries was much narrower than Australia's. Such specialisation brought both benefits and challenges. It fostered directed government policy support and provided Norway with the opportunity to establish global leadership in several products. On the other hand, Australia's diversity of resources enabled it to move flexibly between products in response to shifts in demand and changing technologies.

A range of forces help to explain their success and the progression through the three stages. The adaption of legacy knowledge from older industries, the interaction between recipient sector and enabling sector, and the growing strength of the latter all played key roles in building capabilities and competitiveness. The broad sectoral linkages implicit in these interactions – including science, engineering, business services and even manufacturing – testify to the fact that economic development can occur through diversification and specialisation *within* the resources sector but without creating enclaves. Finally, the cases confirm our theoretical perspective that natural resources are not a fixed value in the environment, rather their extension relies heavily upon innovations that push back the technology frontier, not the physical frontier.

References

AFFA (Department of Agriculture, Fisheries and Forestry). (2002). *Aquaculture Industry Action Agenda National Aquaculture Development Committee's Report to Government and Industry*, Canberra

Andersen, A. D. (2011). *Innovation Systems and Natural Resources – the case of sugarcane in Brazil* (Unpublished doctoral dissertation). Aalborg University, Aalborg.

Andersen, A. D., Johnson, B., Marín, A., Kaplan, D., Stubrin, L., Lundvall, B.Å., & Kaplinsky. R. (2015). *Natural resources, Innovation and Development: Globelics Thematic Review*. Aalborg: Aalborg University Press.

Aslesen, H. W., Mariussen, Å., Olafsen, T., Winther, U., & Ørstavik, F. (2002). *Innovasjonssystemet i norsk havbruksnæring [Innovation system of the Norwegian aquaculture industry]* (Report No. 16). Oslo: STEP.

Aslesen, H. W. (2004). *Knowledge intensive service activities and innovation in the Norwegian aquaculture industry* (Report No. 5). Oslo: STEP.

Aslesen, H. W. (2009). The Innovation system of Norwegian aquacultured salmonids. In J. Fagerberg, B. Verspachen, & D. Mowery (Eds.), *Innovation, path dependency and policy: The Norwegian case* (pp. 208-34). Oxford: Oxford University Press.

Astroza, A. (2008). *Norwegian multinational firms in the Chilean salmon farming industry: Developing prerequisites for innovative activities in host countries* (Unpublished master's thesis). University of Oslo, Oslo.

Austin, G., & Sugihara, K. (Eds.). (2013). *Labour-intensive industrialization in global history*. London: Routledge.

Australian Bureau of Agriculture and Resource Economics and Sciences (ABARES). (2016). *Australian fisheries and aquaculture statistics 2015*. Canberra: Department of Agriculture and Water Resources.

Austrade. (2012). *Austrade Industry Capability Report – Oil and Gas*. Canberra: Australian Trade Commission.

Austrade. (2016). *Austrade Industry Capability Report – Oil and Gas*. Canberra: Australian Trade Commission.

Auty, Richard M. (2001). The political economy of resource-driven growth. *European economic review 45*(4), 839-46.

Barbier, E. B. (2011). *Scarcity and Frontiers: How Economies Have Developed Through Natural Resource Exploitation*. Cambridge: Cambridge University Press.

Barbier, E. B. (2015). Scarcity, frontiers and the resource curse. In M. Badia-Mirò, V. Pinilla, & H. Willebald (Eds.), *Natural Resources and Economic Growth. Learning from history* (pp. 54-76). London: Routledge.

Berge, Dag Magne. (2006). Havfiske inn i nye næringer [Ocean fisheries entering new industries], in O. Bjarnar, D. M. Berge and O. Melle (Eds.), *Havfiskeflåten i Møre og Romsdal og Trøndelag [Ocean fishing fleet in Møre & Romsdal and Trøndelag]*. Trondheim: Tapir Akademisk Forlag.

Berge, D. M. (2002). *Dansen rundt gullfisken: Næringspolitikk og statlig regulering i norsk fiskeoppdrett 1970-1999 [Industrial policy and state regulation of Norwegian aquaculture 1979-1999]* (Unpublished doctoral dissertation). University of Bergen, Bergen.

BHP Billiton. (2015). *Resourcing Global Growth: Annual Report 2015*. Melbourne: BHP Billiton Limited.

Bruland, K. & Mowery, D. (2004). Innovation Through Time. In J. Fagerberg, D. Mowery, & R. Nelson (Eds.), *The Oxford Handbook of Innovation* (pp. 349-79). Oxford: Oxford University Press.

Cassidy, N. & Kosev, M. (2015). *Australia and the Global LNG Market*. Sydney: Reserve Bank of Australia.

Clark, G. & Jacks, D. (2007). Coal and the industrial revolution, 1700-1869. *Review of European Economic History, 11*, 39-72.

Corden, M. & Neary, J. P. (1982). Booming Sector and De-Industrialisation in a Small Open Economy. *The Economic Journal, 92*(368), 825-848.

CSIROpedia. (2017). Earth Science and Resource Engineering. Retrieved from https://csiropedia.csiro.au/earth-science-and-resource-engineering-2009.

David, P. (1985). Clio and the Economics of QWERTY. *The American Economic Review, 75*(2), 332-7.

David, P. & Wright, G. (1997). Increasing Returns and the Genesis of American Resource Abundance. *Industrial & Corporate Change, 6*(2), 203-45.

De Ferranti, D., Perry, G. E., Lederman, D., & Maloney, W. F. (2002). *From Natural Resources to the Knowledge Economy*. Washington DC: IBRD.

Dietrichs, E. (1995). *Adopting a ‘High-Tech’ Policy in a ‘Low-Tech’ Industry: The Case of Aquaculture* (Report No. 2). Oslo: STEP.

Dosi, G. (1988). Procedures, and Microeconomic Effects of Innovation. *Journal of Economic Literature*, *26*(3), 1120-71.

Engen, O. A. (2002). *Rhetoric and Realities. The NORSOK programme and Technical and Organisational Change in the Norwegian Petroleum Industrial Complex* (Unpublished doctoral dissertation). University of Bergen, Bergen.

Engen, O. A. (2009). The Development of the Norwegian Petroleum Innovation System: A Historical Overview. In J. Fagerberg, D. C. Mowery, & B. Verspagen (Eds.), *Innovation, Path Dependency and Policy. The Norwegian Case* (pp. 179-207). Oxford: Oxford University Press.

Fisheries Research and Development Corporation (FRDC). (2010). *Working Together: The National Fishing and Aquaculture RD&E Strategy 2010*. Canberra: FRDC.

Fleming, G., Merrett, D. & Ville, S. (2004). *The Big End of Town: Big Business and Corporate Leadership in Twentieth-Century Australia*. Cambridge: Cambridge University Press.

Gulbrandsen, M. & Nerdrum, l. (2009). Public Sector Research and Industrial Innovation in Norwy: A Historical perspective. In J. Fagerberg, B. Verspachen, & D. Mowery (Eds.), *Innovation, path dependency and policy: The Norwegian case* (pp.61-88). Oxford: Oxford University Press.

Gylafson, T. (2001). Natural resources, education and economic development. *European Economic Review, 45*(4), 847-59.

Herrigel, G. & Zeitlin, J. (2010). Inter-firm Relations in Global Manufacturing: Disintegrated production and Its Globalization. In G. Herrigel (Ed.), *Manufacturing Possibilities. Creative*

Action and Industrial Recomposition in the United States, Germany and Japan. Oxford: Oxford University Press.

Katz, Jorge, and Michiko Iizuka (2012) "Natural Resource Industries,? Tragedy of the Commons? and the Case of Chilean Salmon Farming." *Institutions and Economies* 3.2 (2012)

Johns, R. K. (Ed.). (1976). *History and role of government Geological Surveys in Australia*. Canberra: AB James, Govt. printer.

Laestadius, S. & Noor, C. (2010). *The disequilibrium path in natural resource economics*. Stockholm: KTH Royal Institute of Technology.

Landes, D. (2003). *The unbound Prometheus: Technical change and industrial development in Western Europe from 1750 to present* (revised ed.). New York: Cambridge University Press.

Lloyd C., Metzer, J. & Sutch, R. (Eds.). (2013). *Settler Economies in World History*. Leiden: Brill.

Marin, A. & Smith, A. (2011). Towards a framework for analysing transformation in Natural Resource-based industries in Latin-America: The role of alternatives. Retrieved from http://nrpathways.wix.com/home.

Marin, A., Navas-Aleman, L. & Perez, C. (2015). Natural Resource Industries as a Platform for the Development of Knowledge Intensive Industries. *Tijdschrift Voor Economische en Sociale Geografie*. *106*(2), 154-168.

Mehlum, H., Moene, K. and Torvik, R. (2006). Institutions and the resource curse, *Economic Journal 116*(508), 1-20.

Mellbye, C., Fjose, S. & Jakobsen, E. W. (2012). *Internasjonalisering av norsk offshoreleverandørindustri [Internationalisation of Norwegian offshore supply industry]*, Oslo: Menon Report.

Morris, M., Kaplinsky, R. & Kaplan, D. (2012). One thing leads to another- Commodities, linkages and industrial development. *Resources Policy*, *37*(4), 408-416.

Mowery, D.C & Rosenberg, N. (1989). *Technology and pursuit of economic growth*. Cambridge: Cambridge University Press.

Ministry of Petroleum and Energy. (2017). Norway's petroleum history. Retrieved from http://www.norskpetroleum.no/en/framework/norways-petroleum-history.

Murray, R. (2002). Weeks, Lewis George (1893-1977). *Australian Dictionary of Biography, 16*.

Norwegian Research Council. 2017. *Det norske forsknings- og innovasjonssystemet – statistikk og indikatorer 2017 [The Norwegian research and innovation system: Statistics and indicators 2017]*. Oslo: Norwegian Research Council.

OECD. (2010). *Globalisation in Fisheries and Aquaculture: Opportunities and Challenges*. Paris: OECD.

Olsen, O. E. & Sejersted, F. (Eds.). (1997). *Oljevirksomheten som teknologiutviklingsprosjekt [Oil sector as technology development project]*. Oslo: Ad Notam Gyldendal.

O'Rourke, K. H. & Williamson, J. G. (1999). *Globalization and History*. Cambridge, MA: MIT Press.

Parliament of Australia. (1998). *A sea of indifference: Australian industry participation in the North West Shelf project*. Canberra: House of Representatives Standing Committee on Industry, Science and Technology.

Pol, E., Carroll, P. & Robertson, P. (2002). A new typology for economic sectors with a view to policy implications. *Economics of Innovation and New Technology, 11*(1), 61-76.

Pollard, S. (1982). *Peaceful Conquest, the Industrialization of Europe 1760-1970*. London: Oxford University Press.

Prebisch, R. (1950). *The Economic Development of Latin America and its Principal Problems*. United Nations: New York.

Regjeringen. (2005). The Petroleum Sector – Norway's largest industry. Retrieved from https://www.regjeringen.no.

Ryggvik, H. (2000). *Norsk oljevirksomhet mellom det nasjonale og det internasjonale. En studie av selskapsstruktur og internasjonalisering [Norwegian oil sector between the national and the international. A study of firm structure and internationalisation]* (Unpublished doctoral dissertation). University of Oslo, Oslo.

Ryggvik, H. (2013). *Building a skilled national offshore oil industry: The Norwegian experience*. Oslo: NHO.

Sachs, J. D. & Warner, A. M. (1995). *Natural resource abundance and economic growth*. (working paper no. 5398). Cambridge, MA: National Bureau of Economic Research.

Schedvin, C. B. (1990). Staples and regions of Pax Brittanica. *Economic History Review, 43*(4), 533-59.

Schrobback, P., Pascoe, S., & Coglan, L. 2014. History, status and future of Australia's native Sydney rock oyster industry. *Aquatic Living Resources*, *27*(3-4), 153-65.

Statistics Norway. (2017). Fiskeoppdrett – i Noreg og verda. Frå attåtnæring til milliardindustri [Aquaculture in Norway and globally]. *Samfunnsspeilet 1/2017*, Statistics Norway, Oslo.

Schwach, V. (2000). *Havet, fisken og vitenskapen. Fra fiskeriundersøkelser til havforskningsinstitutt 1860-2000 [Ocean, fish and science. The Norwegian Institute of Marine Research 1860-2000]*. Bergen: Ocean Research Institute.

Sejersted, F. & Olsen, O. E. (1997). *Oljevirksomheten som teknologiutviklingsprosjekt. Perspektiver på utviklingen av det oljeteknologiske systemet på norsk kontinentalsokkel [Oil sector as a technology development project. Perspectives on the development of the oil technological system on the Norwegian Shelf]*. Oslo: Ad Notam Gyldendal.

Singer, H. W. (1950). The Distribution of Gains Between Investing and Borrowing Countries. *American Economic Review,* 40 (2), 473-85.

SINTEF 2010, *Regional verdiskaping i norsk sjømatnæring*. [Regional value creation in Norwegian sea food industry], Report SINTEF Fiskeri og havbruk.

Smith, K. H. (2007). *Innovation and Growth in Resource-Based Economies, Competing from Australia* (Project paper no. 3). Melbourne: Committee for Economic Development of Australia.

Smith, K. and Wicken, O. (2016, February). *Resource-based Growth in Small Open Economies: Towards a Theory*. Paper presented at the Asia Pacific Economic and Business History Conference, Adelaide.

Stortinget. 1974. *Petroleumsvirksomhetens plass i det norske samfunn* (White Paper no. 25). Oslo: Ministry of Finance.

Tanriverdi, H. & Venkatraman, N. (2005). Knowledge relatedness and the performance of multibusiness firms. *Strategic Management Journal*, *26*(2), 97-119.

Tasmanian Atlantic Salmon (2007). History. http://tasmaniansalmon.com.au/consumer/about/history.html

Thurtell, D. (Ed.). (2017). *Resources and Energy Overview*. Canberra: Department of Industry, Innovation and Science.

Ville, S. & Wicken, O. (2013). The Dynamics of Resource-Based Economic Development: Evidence from Australia and Norway. *Industrial and Corporate Change*, *22*(5), 1341-71.

Ville, S. & Wicken, O. (2015). The institutional foundations of natural resource based knowledge economies. In M. Badía-Miró, V. Pinilla & H. Willebald (Eds.), *Natural Resources and Economic Growth: Learning from History* (pp. 294-312). Abingdon: Routledge.

Wicken, O. (2016). Industrial Diversification Processes and Strategies in an Oil Economy: Norway. In S. Mahroum & Al-Saleh Yasser (Eds.), *Economic Diversification Policies in Natural Resource Rich Economies* (pp. 295–323). London: Routledge.

Woodside Petroleum. (2017). Global interests. Retrieved from http://www.woodside.com.au/About-Us/Pages/Global-Interests.aspx#.WIAhG2U4I24.

Wright, G. (1990). The origins of American industrial success, 1879-1940. *American Economic Review*, *80*(4), 651-68.

Wright, G. & Czelusta, J. (2004). Why Economies Slow: The Myth of the Resource Curse. *Challenge, 47*(2), 6-38.

Wrigley, A. (1988). *Continuity, Chance and Change: The Character of the Industrial Revolution in England*. Cambridge: Cambridge University Press.

Zimmermann, E (1933/1951), *World Resources and Industries: A Functional Appraisal of the Availability of Agricultural and Industrial Resources* (1933) New York: Harper & Brothers/ *World Resources and Industries,* 2nd revised ed. (1951) New York: Harper & Brothers.