NATURAL RESOURCE INDUSTRIES AS A PLATFORM FOR THE DEVELOPMENT OF KNOWLEDGE INTENSIVE INDUSTRIES

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ABSTRACT
In the innovation and development literature, natural resources (NR) are generally viewed as a curse for developing nations and NR-based industries as having little potential to innovate and drive long-term growth. This has led policy and development experts to opt for strategies to induce a shift in the pattern of specialization towards other sectors. This paper proposes a different approach. By exploring recent evidence from the Argentinean agricultural sector and the mining industry in Chile, it points to the window of opportunity that NR industries offer as a platform to develop knowledge intensive industries with which to support economic development in resource-endowed countries. The lessons drawn from these findings suggest that development strategies can also promote more innovative knowledge intensive NR-based industries rather than moving away from them.

Key words: Innovation, natural resources, new opportunities, Latin America, Argentina, Chile

INTRODUCTION

The innovation and development literature demonstrates that at particular times some industries are able to innovate and grow faster than others. The success of the Asian Tigers in their process of catching up showed that it is possible for lagging countries to take advantage of favourable situations. Having cheap labour, they engaged in a very successful process of catching up, by specialising in the labour-intensive technologically dynamic industries at that time (e.g. electronics). The window of opportunity used by the Asian Tigers is no longer available to Latin American and African countries. Newcomers need to identify a new technological opportunity space.

We argue that there is a new window of opportunity for natural resource-rich countries (NRRCs). The demand for natural resources is increasing and there are new conditions that make it possible for developing countries to be technologically active and innovative in accessing, producing and transforming them. NRRCs, thus could increase their development potential by taking advantage of the market and innovation opportunities provided by global growth, while developing the capabilities that are likely to be at the heart of the next technological revolution, such as biotechnology, nanotechnology, bioelectronics, and new materials (Perez 2010). Participating in their development in these early stages and embedding the associated supporting network into the local economy could position the NRRCs for a major leap forward when these technologies become pervasive, low-cost and high-growth. This is precisely what the Asians were able to do on the basis of their early involvement with the fabrication of electronic components and products, before the advent of the microprocessor and the personal computer.

To take advantage of this new opportunity, however, requires the development of a concerted strategy and, this can only be designed on the basis of a broad consensus. The generalised view in NRRCs that countries should encourage structural change away from natural resources (NR) is an important barrier to the achievement of such consensus. Ever since the structuralists in the 1950s/1960s, preoccupied with the poor economic performance of NRRCs, reacted to the neoclassical prescriptions to specialise in NRs to take advantage of their resource abundance, there has been a widespread view that NRs have low potential to contribute to a process of growth and development. This view shaped the strategy of import substitution industrialisation (ISI) promoted by Prebisch (1950) from ECLAC since the 1950s and applied, with significant growth results, across Latin America until the end of the 1970s. Its essence was to increasingly tax NR industries and to encourage and subsidise unrelated manufacturing industries, often just the assembly of foreign brand products, using protective measures (infant industry approach). By the 1980s, globalisation and the Washington consensus made those protective policies unviable. Nevertheless, and perhaps due to the fact that the Asian success was based on manufacturing, very little fundamental rethinking of the anti-NR bias has yet taken place. This is reflected in recent influential documents such as ECLAC (2012) in Latin America and UNCTAD-UNIDO (2011) in Africa.

We propose a different policy approach, based on such a rethinking, and provide empirical evidence for its viability. We argue that NRRCs need to encourage structural change and diversification, but that this should be achieved by working with existing capabilities in NRs rather than against them. We present evidence from two key NR sectors, mining (copper and others) and agriculture (seeds, soy, etc). The experiences presented show (i) the extent to which NRs are already prompting the local development of new technologies and (ii) the kind of linkages between the primary activity and manufacturing and services that can and should be encouraged to trigger innovation and economic growth. We highlight that it is no longer useful to think about NRs as isolated primary activities or enclaves, when assessing their potential role for innovation and economic growth. Hence a core proposition of this paper is to change the unit of analysis (and of policy) to the whole network of NR activities encompassing up and downstream linkages, from the initial investment to the final user, as well as the lateral interactions.

The paper is organised as follows. The following section reviews briefly the resource curse literature. The third section challenges the evidence and main rationale of this literature. The fourth section provides a brief analysis of the main changes in the world economy that are opening new opportunities for innovation in NRs. The fifth section presents the empirical evidence. The final section concludes identifying the main challenges for a strategy based on NRs.

THE CASE AGAINST NATURAL RESOURCES IN DEVELOPMENT – BASED ON DATA FROM TWO HISTORICAL PERIODS

Whether, and how, natural resources can contribute to a process of development has been a concern for economists since Adam Smith. However, it was not until the 1950s that these concerns became central to the development agenda associated with the poor economic performance of Latin American and African countries. Structuralists reacting to the neoclassical prescriptions for these countries to specialise in NRs to take advantage of their resource abundance, argued that there were three main objections to specialisation in NRs.

First, Prebisch (1950) and Singer (1950) emphasised several types of demand and supply rigidities, all of which would explain a continuous downward trend in the relative price of primary commodities relative to manufacturing (the so called ‘price scissors’). On the demand side, they highlighted that: (i) NRs face relatively low income elasticity, so countries with NRs would not benefit from increases in world demand associated with world income growth; and (ii) their demand growth was slower than that for manufacturers, because of the technical change, in particular the capacity to displace natural materials by developing synthetic alternatives. On the supply side they identified that: (i) NRs were not favoured by technological progress, which was concentrated mostly in manufacturing, 'they do not provide the growing points for increased technological knowledge, urban education, the dynamism and resilience that goes with urban civilisation, as well as the direct Marshallian external economies' (Singer 1950, p. 476); and (ii) the little technological progress they experienced did not translate into larger demand or greater profits but in reduced prices, benefiting consumers in foreign countries and not producers in developing countries supplying the NRs.

Other scholars, provided a second set of arguments against NR specialisation by focusing on the instability of export prices. They noted that prices of commodities were very unstable. Countries that relied heavily on commodity exports would therefore be very vulnerable to fluctuations which would affect their economy not only via abrupt changes in tax revenues but also via changes in the rate of exchange and local investments (Nurkse 1958).

Finally, a third group of scholars observed that in developing countries, NR activities were typically dominated by multinational corporations (MNCs), which repatriated the benefits and did not invest locally. This also meant that the local development of backward and forward linkages was very limited, closing off the main way in which the emergence of any activity could contribute to development (Singer 1950, 1975; Hirschman 1958).

Since the 1990s, these concerns have been reinvigorated in association with a wave of empirical studies which argued that since the 1960s there has been a negative association between NR abundance (or specialisation) and growth (Auty 1990, 1993; Sachs & Warner 1999, 2001; Gylfason *et al.* 1999). In these more recent studies have focused on (i) the voracity effects, that is, conflicts between social groups to capture the rent (Torvik 2002), with a rentier state, namely, a government freed from the need to levy domestic taxes and thus less accountable to society (Auty 1990); and (ii) the Dutch Disease, namely, the appreciation of the real rate of exchange caused by NR exports and its concentration of capital and labour, which increases the costs and reduces the chances of the manufacturing sector.

TAKING A LONG-TERM VIEW: WHAT IS LEFT FROM THE NR CURSE?

Many of the main arguments against NRs have been challenged by existing research which shows that when we consider the results from a long term perspective their conclusions no longer hold. Some studies have shown that the Dutch Disease may be less common in developing countries, where resources are typically unemployed and therefore their opportunity cost is lower (Gelb 1988; Fardmanesh 1991). Others have questioned the negative association between instability in export prices and growth (Knudsen & Parnes 1975). More recently, Lederman and Maloney (2008) have challenged the studies that find a negative association between NRs and growth by simply replacing the absolute measure of resource exports as a share of GDP (Sachs & Warner 1995) by the relative measure of net exports of natural resource-intensive commodities per worker. Bravo-Ortega and de Gregorio (2005) went further and showed that this association can turn positive if measures of human capital are considered.

Reacting to the resource curse literature, also, an important body of research, based on historical evidence mostly, has argued that NRs have always been the locus of learning, innovation and linkages, and that the relevant question is not so much whether or not resources are bad for growth and development and why, but under which conditions they might contribute to development and growth (see for instance David & Wright 1997; Smith 2007; Torvik 2009; Andersen 2012; Ville & Wicken 2013). Based on the experiences of countries such as Norway, United States and Australia (in the nineteenth and early twentieth centuries), these studies have emphasised the importance of issues such as previous industrialisation, institutions and learning to explain why some resource abundant countries have succeeded while others not (e.g. Nigeria or Venezuela).

We extend this research by analysing how changing world market and technology conditions are creating a new context for taking advantage of NRs that did not exist before in the developing world. Indeed, we believe that one of the main weaknesses of the literature either doubting or defending the dynamism of natural resources is that they are in search of universal truths that do not change over time.

It is not necessary to defend or deny the dynamic potential of natural resources; capitalism makes all sectors technologically active. It is evident that the oil industry has made an enormous amount of technological advances in all phases, from exploration to final processing and the same can be said about mining and agriculture. However, the important question for us is by which companies and countries and under what conditions have such innovations been made in which periods. From the mid-nineteenth century, in the 'Age of Railways' bold entrepreneurs and engineers could explore, innovate and create new companies that could grow into giants. Towards the end of that century, in the age of 'Steel and Heavy Engineering', lagging countries could use their natural resource endowment to catch up and even forge ahead (this was the case of the US, Sweden, Australia, etc.). From the 1930s, as the 'Age of Mass Production' evolved, innovation was concentrated within the existing giant multinationals and mostly in their own home countries. Developing countries were reduced to charging royalties (against great resistance) and other defensive measures. Local innovations, in the few cases where they were made, tended to be in agriculture or other more accessible and less costly technologies. The low and decreasing cost of raw materials was a deterrent to innovation in NRRCs but, for the advanced world, it was both a convenient and necessary complement to high cost labour in manufacturing. It is in the last couple of decades, as global markets have evolved and divided into multiple segments, and as ICT makes information available and easily processed, that small knowledge intensive companies have been able to innovate in all sectors, including in and around NRs. The rising cost of raw materials and the premium prices for special and customised segments allow covering the costs; world markets and their accessibility, enable scaling up relatively quickly.

In essence, we are saying that some form of 'resource curse' was indeed real for the developing world from about the 1930s until recently. Singer and Prebisch were pointing to a real phenomenon as regards export prospects. It was true, for example, that in the 1950s and 1960s manufacturing experienced steady and stable price increases, while raw materials decreased in price and were marked by volatility. Nevertheless, since the mid-1980s the combination of low cost labour in China and the greater productivity brought about by ICT have been lowering the price of manufacturing, while high demand growth due to globalisation has been increasing the price of energy and raw materials (Kaplinsky 2009). Something similar can be said about the relative income elasticities of manufacturing and materials. It has been the case that, after a certain threshold, higher incomes do not increase food consumption. But this is true only if the greater incomes are received by the same consumers, as in the 1950s and 1960s. Current global growth is about constantly incorporating new consumers.[1]

Under 1950s' conditions, Prebisch and Singer were not even discussing technological dynamism, which for manufactures was equally inaccessible. In fact, the whole model for import substitution industrialisation was based, not on innovation, but on the assembly of imported parts into foreign brand products, without much capability accumulation. The importance of the current change of context stems from the new possibilities for innovation in all sectors: in fabricated goods (as the Chinese and other Asians have done), in services and software (as most countries are engaging in) and in natural resource related products (from raw materials to their processing) as NRRCs are slowly beginning to discover.

Thus, the focus of the present paper is on the changing windows of opportunity and on the nature of the present window in relation to NRs. Only countries that are fully aware of these new conditions can design and build the right institutions and do the learning activities that will allow the full exploitation of their new opportunities.

Thus, what we propose is to examine the elements of the new context in technology and global markets. This will allow us to analyse the factors and trends that have opened the opportunity for taking a technologically dynamic path in relation to natural resources in developing countries. Essentially we need to identify the various drivers of technical change in the current global economy, guided by the ICT paradigm, and to signal how this differs from the conditions faced for most of the twentieth century, following the mass production paradigm. This is the object of the next section.

THE NEW (AND RENEWED) FORCES CREATING INNOVATION OPPORTUNITIES IN NATURAL RESOURCE-BASED NETWORKS

This section discusses the historical conditions that are creating new opportunities for innovation in the NR-based networks in this particular period. Figure 1 groups such conditions into four categories of innovation drivers: (i) changes in demand volume; (ii) changes in demand requirements; (iii) changes in S &T; and (iv) changes in the global market context.

Changes in demand volume – The sheer rhythm of growth in volume of materials, energy and food brought about by globalisation puts a strong multiplier on most of the traditional drivers of innovation in NRs, much more so as it is likely to be accompanied by increasing prices.

Given the natural limits to resources, it has generally been the case that increasing supply means the incorporation of new land or the extension to new mines, usually going from the best to the less good (at least among what is known), from the nearer to the most distant, and therefore to higher costs. These shifts to less competitive sites have traditionally been the endogenous drivers of innovation in the natural resource industries. Yet, increasing productivity under less advantageous conditions to

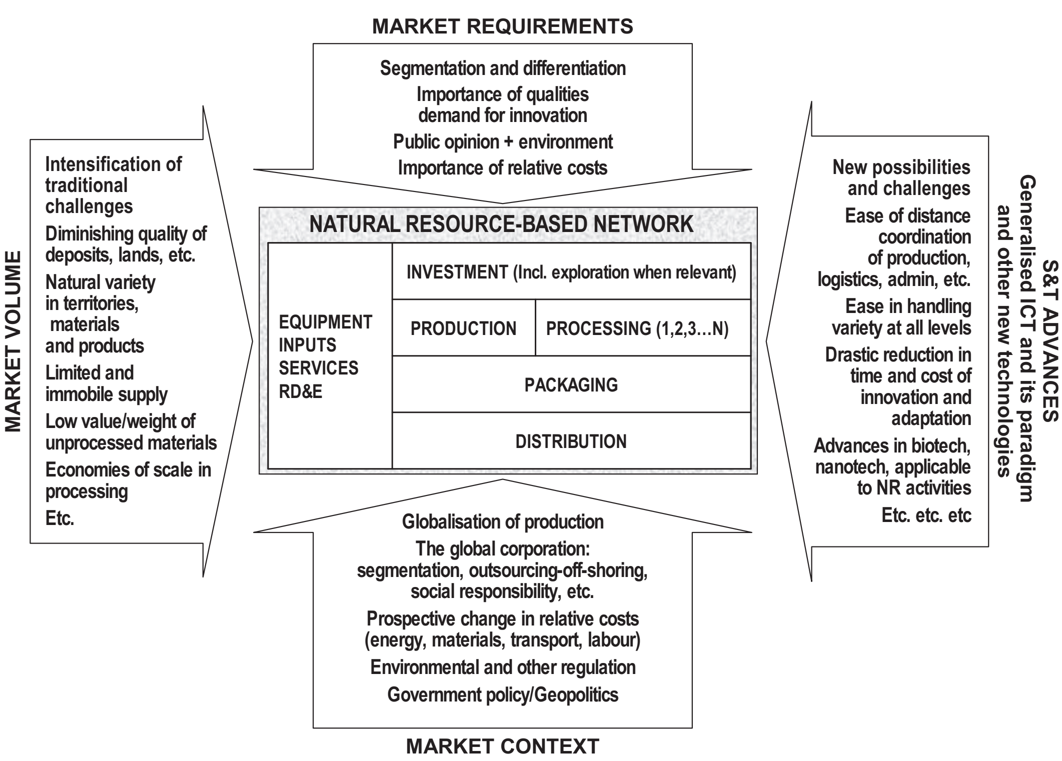

Figure 1. *Forces driving innovation in natural resource-based production networks.*

match the better ones does not mean reaping any technological rents; the advantage tends to remain with the better conditions or is transferred to the consumer in lower prices. This fact underlies some of the doubts about the dynamism of natural resources.

This is different from the classical situation in manufacturing, where growing volumes have usually led to process innovation in order to achieve economies of scale and other increases in productivity or to adding new plant with improved technology. In most cases, additional products imply less cost and either lower prices or greater unit profits.[2]

An area of natural resources where manufacturing conditions were almost achieved was extensive agriculture. The so-called 'green revolution' based on the mechanisation of the different phases from planting to harvesting, the massive application of petrochemical pesticides and herbicides and the use of standard seeds on very large expanses of land established the greater and determining segment in terms of costs and prices in many agricultural commodities (both vegetable and meat). Although this situation still applies for certain crops –and in some cases has been intensified by genetically modified seeds – the increase in market volume is now shaped by another trend which distinguishes 'niche' segments from standardised commodities in the natural resource sectors.

But if prices increase enough, pushing against the limits of natural resource availability can make it attractive to access almost unreachable deposits, under the sea, deep underground or in inhospitable landscapes such as the Arctic or Siberia. Major innovation is required in those cases for exploration, extraction and transport. The case of the deep ocean oil reserves found in Brazil and the complexities of its exploitation are a vivid example of this. In a previous occasion, when the OPEC price rise in the 1970s drove the developed economies to try to increase their own reserves, Norway not only became an important producer of undersea oil but it promoted the emergence of a whole network of specialised suppliers of equipment and services that are today moving to participate in the Brazilian fields.

Greater demand volume can come from greater use of the traditionally exploited resources or from completely new demands based on the discovery of new uses (or new technological treatment) of natural resources that were previously seen as lacking economic value (Andersen 2012). Production of rubber is one example of these processes, as described by Andersen (2012, p. 307):

> Rubber from the Amazons had been known to westerners for centuries but it was not until Charles Goodyear discovered 'vulcanisation' in 1839, that rubber became a resource (creation). It became a resource because his discovery made it possible to satisfy human wants with the use of rubber. Eventually rubber production from the Amazon region was overtaken by producers in South-East Asia (obsolescing/extension), and both were later overtaken by production of synthetic rubber (obsolescing/creation), which was developed during World War 2.

Growth in demand for raw materials also requires an increase in processing capacity and decisions as to its location. The choice has traditionally been to process near the users. But the impact of the cost of energy on freight rates, together with global warming concerns, may favour more processing *in situ*. Making plants more flexible, perhaps relatively mobile and less dependent on economies of scale are some of the innovation challenges to confront if this trend materialises.

Changes in demand requirements – In mass production regimes the direction of innovation, especially in consumer products, was to standardise shapes, sizes and tastes. In agriculture, for instance, innovation was not only oriented towards the mechanisation of all phases, but also to make a product of standard appearance, easy to harvest and to handle for transport. Better taste was not necessarily among the goals.

Now the main sources of premium prices are variety and quality. Ores richer in metals, lighter or 'cleaner' oil, better grapes for a certain type of wine, more beautiful woods, bigger eggs, sweeter oranges or more aromatic cocoa are segmenting natural resource markets searching for top of the range prices.

The growing importance of 'gourmet' eating and health concerns allows the exploitation of a wide range of possibilities, from the highly mechanised and standardised 'perfect tomato' to the flavourful organic variety that rescues the forgotten original tastes. But the latter requires innovation in natural methods of pest and weed control, in conservation, packaging transport and distribution, and possibly also in normative certification, image and branding.

For the user industries, downstream, having to deal with different grades of ore, different shapes or flavours of fruit, different compositions of oil or variety in the hardness of wood demands innovation and prompts network collaboration with suppliers.

Advances in science & technology (S&T) – From a practical standpoint, the co-ordination of networks of innovation before the advent of Internet and computer processing had innumerable inconveniences. The new information processing and transmission facilities have made it infinitely easier to establish interactive networks of NR producers with intense communication for co-ordination of production and services, logistics, administration, etc.

Seen from the other side, it is also possible for potential suppliers of technical and scientific services to form clusters or associations and to specialise in what could be the needs of the different elements of a particular NR-based network. With time and if they establish a fruitful user-producer relationship with the NR companies, they can form global networks of their own with other knowledge based groups, companies and institutions and not only serve as suppliers to the locally based companies but also export their services or some specialised products.

These new possibilities related to local knowledge-intensive services and technological development are multiplied in their impact by the ease with which information technologies allow the handling of variety at whatever level. It has already been discussed that throughout history the peculiarities of lands, reservoirs, mines, etc., have been the most typical source of impulse for innovating in these sectors. Under the new conditions, this variety is handled easier than before, while the time and cost of acquiring and processing the necessary information for research and innovation have been drastically reduced. The same can be said about testing prototypes and measuring their impact. The availability of specialised digital instruments and the possibility of designing new ones or adapted software have also expanded enormously. An example of this is the computerised system designed and adopted in Chile for adaptable irrigation systems (INNOVA Chile 2007).

Equally important and versatile in their impact are the advances in biotechnology and nanotechnology. We are already witnessing the impact of genetically modified crops, tissue culture, vaccines for cattle and fish, bacteria for mining (leaching) and for digestion of oil spills as well as nanotechnological advances in special materials, coatings, emulsion agents, etc. These technologies have multiplied the possibilities for differentiation and innovation in NRs, and opened up opportunities to develop specialised capabilities, companies and networks.

Changes in the global market context – The question of who controls the levers of technology, investment and markets is a crucial one when considering the innovation space available for firms or countries. Extractive industries have traditionally been under the control of giant international corporations with an enclave-type behaviour (Singer 1950, 1975). However, in the last decades, MNCs have become aware of local knowledge and capabilities and going from just exploiting centrally created technological assets to 'actively seeking advantages originating in the global spread of the firm' (Hedlund 1986, p. 20). They are increasingly decentralising their innovation activities and using specialised capabilities in the host economies (Cantwell & Sanna-Randaccio 1993; Dunning 1994; Cantwell 1995, 2001; Kogut 2002; Marin 2007; Marin & Arza 2009). Developing countries can further encourage this sort of behaviour through negotiating strategies that put Asia and the West in competition for guaranteed access to NRs.

Finally, environmental concerns are probably the most transcendental contextual factor driving innovation in products, processes, logistics and business models. Their impact is felt from the demand side as a shift in consumer preferences, from the policy context side as a growing set of regulations and economic (dis)incentives and from the supply side as increased risk and costs. Hence, there are pressures to redesign products and processes to use less energy and materials and to reduce waste. A differentiation strategy geared to environmentally friendly production and consumption patterns opens a technological opportunity space that could be exploited by the developing countries.

TWO EMPIRICAL ILLUSTRATIONS

This section discusses two cases – the agricultural sector in Argentina and the mining sector in Chile. These cases clearly show two things: (i) the extent to which NRs are already prompting the development of new technologies such as biotechnology; and (ii) the kind of linkages between the primary activity, manufacturing and services that should be encouraged to trigger innovation and economic growth. They evidence that there is innovation in NR sectors and that it is possible to be a world leader in specialist areas if you can draw on the performance of the network.

The agricultural sector in Argentina – The agricultural sector has been historically considered a backward sector, with little possibilities to expand by itself and/or generate linkages with others sectors in the economy. Recent transformations in agriculture in Argentina challenge this view.

In the mid-1990s, agro crop production in Argentina was performed by solitary/isolated farmers (*chacareros*) – who owned the land and machinery and centralised most of the knowledge and decisions. The sector did not have links to many other economic activities in Argentina, and experienced a very slow rate of change and growth. It grew less than the rest of the economy, with the total volume of output in 1990 being barely higher than it had been in the 1960s. It was also very slow in adopting the new technologies and organisational arrangements associated with the Green Revolution.

In 2012, the same activity is performed by a complex network of production involving a number of new actors (*contratistas* –entrepreneurs that rent the land to organise agricultural production; the producers of seeds, herbicides, fertilisers, and machinery; and, the national institutions of S&T, investment funds, etc.). The sector is characterised by several sectoral interdependencies (e.g. with chemical and IT suppliers), the rate of growth has increased too and the rate of technological change is unprecedented (Bisang *et al.* 2008). Between 1990 and 2005 the production of the sector grew by 5.7 per cent per year on average (while GDP growth was 3.4%) and the total production of grains (mainly soya, maize and wheat) more than doubled, from around 30 million tonnes at the end of the 1980s to around 70 million tonnes. Besides this economic dynamism, however, the sector acquired during this period a technological dynamism that differed from anything in the recent past (Bisang & Kosacoff 2006).

These changes have been associated with the massive diffusion in the country of a technological package which requires the integration of several components: genetically modified (GM) seeds resistant to herbicides, Zero Tillage (ZT) technologies (planting crop seeds in previously unprepared soil) and highly specialised agricultural machinery and herbicides.[3] A particularly important feature of this package is that it is very sensitive to ecological conditions, and its individual component parts require substantial integrated adaptation for small variations in local conditions (Ekboir 2003). Interestingly, therefore, the new technology (or management system) is encouraging local innovation and collaboration to an extent never experienced before. The case of agricultural machinery and seeds provide some examples.

By developing agricultural machinery for special ecological conditions, the rapid and widespread diffusion of ZT technologies in Argentina in the 1990s provided new opportunities for the agricultural machinery sector. These opportunities did not emerge simply as a consequence of the general scale and growth of demand – associated with the impressive expansion of the sector – which favoured imports more than domestic production of machinery. Probably more importantly, they emerged in association with the appearance of particular market niches that facilitated the evolution and consolidation of specific producers of agricultural machinery.

The favoured segments were the specialised self-propelled sprayers and seeding/planting machines. By contrast, the more generally applicable tractors and harvesters produced locally lost market share in the 1990s, in parallel with the diffusion of ZT technologies. The favourable position of seeding machinery and self-propelled sprayers can be explained by the combination of two factors: (i) ZT technologies require complex and precise planters as well as implementers, including spraying machines, which have to be adapted to the local ecological and organisational characteristics of their operational conditions; and (ii) Argentina, was a pioneer in the diffusion of ZT technologies.[4] The necessary equipment was not available to import by innovative agricultural producers. Some domestic producers, in association with institutions of agricultural technology (such as INTA) responded very well to this challenge by incorporating several product innovations for the producers adopting ZT managements systems. Indeed, several observers have argued that the rapid diffusion of this technology would not have been possible in Argentina and Brazil, without the active participation of these specialised suppliers of machinery.

PLA, a leading company in the segment of self-propelled sprayers exemplifies the successful trajectory. PLA started as a private family firm in 1975, and became public in 1995. In 2011, it had 400 employees and is ranked in 54th place in terms of sales in Argentina. In the early stages the company produced a varied range of machinery, equipment and parts. However, in the 1990s it specialised in sprayers and planters and subsequently developed world leading innovations resulting in 20 national and international awards. Its more innovative products are: self-propelled sprayers (e.g. interseeders and sprayers controlled by computer and satellite), and systems for variable dosage of herbicides and fertilisers. As a result of these innovations, PLA is the leader in Argentina with 30 per cent of the market. Recently, it has started to internationalise to other countries in Latin America and has opened production plants in Brazil, Paraguay, Uruguay and Bolivia, to serve these countries. It also exports to distant locations such as Russia, Ukraine, Kazakhstan and South Africa where it has exclusive distribution points. These also provide after-sales service and are used to identify the specific requirements of local demand.

Although international seed suppliers drawing on innovation undertaken largely outside Argentina captured a large part of the seed market opened up by this transformation of the sector; a striking feature of the last decade has been the emergence of significant local innovation in the seed industry with a group of domestic firms becoming world class innovators (Marin *et al.* 2012). Two of these companies stand out: Bioceres, and Nidera. These companies provide an excellent example of how growth and dynamism in an NR sector, can be used to promote innovation in new technologies.

Bioceres is unique in Argentina because of its focus on the transgenesis approach. It has been very successful in discovering new genes that are then licensed to foreign companies to be inserted into adapted plant varieties. Nidera follows a more diversified technological approach and develops plant varieties of different crops. It has followed a strategy similar to the large MNCs in seeds, by making alliances with large chemical companies to supply the market with a package including both seeds and associated chemical products.

Bioceres is a private company created in 2001 by a co-operative of 23 agricultural producers, associated with the Argentinean No Till Farmers Association (Aapresid) and Argentinean Regional Agricultural Experimentation Consortium Association (AACREA). The company was created to improve the links between the agricultural needs in Argentina and the biotechnology projects being carried out by research groups working in public institutions (National Institute of Agricultural Technology – INTA – and universities). The company created the seed unit in 2007 and its own research lab in 2008. The starting point of the seed unit was a technological agreement with INTA (BIOINTA programme) in which the public institution developed the wheat seed and Bioceres sold it to the market. For other crops, the company started by buying biotechnological events[5] from MNCs and using them to carry out the activities related to the development of genetic material (basic or foundation seeds). Over the years, the unit shifted towards the development and production of its own branded seeds and the discovery and isolation of genes.

As a result of this process of evolution the company managed to register three patents with the United States Patent and Trademark Office (USPTO). The first patent resulted from a joint venture between the firm, the Argentinean Research Council (CONICET) and a National University (Universidad Nacional del Litoral). It protects an enhancer of genes (Hahb4) that gives transgenic plants resistance to hydrid stress and salinity. The second (COX5c) protects a gene promoter or enhancer that increases the expression level of genes in plant cells. The third protects the gene Hahb-10, which confers transgenic plants shorter life cycles and tolerance to oxidative stress.

Bioceres was the first Argentinean firm to export an agricultural biotechnology development. It licensed a gene that confers resistance to drought to the multinational Advanta. In recent years, Bioceres has also been successful in setting up technological alliances with foreign counterparts (University of Illinois, the American firm Arcadia, and SemBioSys Genetics Inc.).

Nidera (1,400 Employees) is a multinational company of Argentinean origin created in 1929. Currently, 55 per cent of the capital is Argentinean and 45 per cent Dutch. The creation of R &D facilities at Nidera responded to the interest of the firm in developing its own feedstock (germplasm) for the production of grains and oil. It started by hiring a group of researchers from an Argentinean subsidiary of an international company (Continental Seed). At the same time, Nidera bought the local subsidiary of Ashgrow Seed Company. By the middle of the 1990s, Nidera was the first company to sell transgenic soybean with the RR gene in Argentina. In 2000, Nidera created the agricultural chemicals and fertilisers division (seed, fertilisers, agrochemicals). In 2005, through the purchase of Bayer's subsidiary in Brazil, the firm founded Nidera Sementes, in order to come up with products on Brazilian territory.

Nidera concentrates its main innovative efforts in the area of agronomic seeds in Argentina. Despite operating in a highly concentrated market, dominated mostly by a few large multinational corporations (today, the top ten MNCs control half of the world's commercial seed sales), the company has managed to capture a leading market share in soybean, sunflower, and maize seeds. This has been supported by an extensive proprietary germplasm base and a strong applied genomics competence. This market position is globally significant because Argentina, with 21 per cent of world soybean grain production, is one of the main world markets for soybean seeds. The main innovations of the company in the area of seeds have been developed largely on the basis of strategic alliances with other companies. One important example is the BASF/Nidera new 'clearfield' sunflower trait (CLHA-Plus)—a new genetic trait for the 'clearfield' sunflower production system, which was developed by Nidera in alliance with BASF.

The mining sector: examples from Chile – Like the agricultural sector, the mining industry has recently experienced a major transformation with enormous implications for the enclave model, which predominated in the past. Its model of production has shifted from a highly integrated to a highly de-integrated one, where key knowledge services, that used to be conducted within the large mining companies, are now outsourced. Every step of the mining process can now be outsourced to local independent firms (Urzúa 2007). As a consequence, a new sector of specialised knowledge intensive mining service suppliers (SKIMS) has emerged. These are not pure knowledge intensive providers; they incorporate high-tech specialised services, capital goods and equipment and consumable inputs such as chemicals.

This transformation has opened up opportunities for new actors – including those from NR-rich emerging economies – to become global providers of high tech services to the industry. The case of SRK consulting from South Africa is an excellent example. This company started as a service provider for the Anglo American company and has now turned into a global provider of advice and solutions for earth and water resource industries. Just for mining they offer services from exploration through feasibility, mine planning and mine closure.

Access to SKIMS is now a critical factor for success of first tier mining companies. Global mining corporations are therefore committed to develop world-class SKIMS suppliers. BHP Billiton Metals Base, for instance, in facing the unprecedented increase in demand for copper, has implemented a very ambitious supplier development programme in Chile. It aims to support a selected group of service providers to move up from production and adaptation capabilities to developing the competencies necessary to design and carry out R&D at the frontier.

In what follows we summarise the cases of two companies – Aguamarina and CMM –from a report developed by Benavente and Goya (2012), produced within a project funded by IDRC and directed by the first author: Opening Up Natural Resource-based Industries for Innovation: Exploring New Pathways for Development in Latin America.

Aguamarina,[6] is a biotechnology startup located in the northern Chilean region of Antofagasta, founded in 2007 based on the potential demand for bioleaching services in copper mining.[7] The company started with biolixiviation, but rapidly moved to more general application of microorganisms to develop innovative and effective biotechnology-based solutions for mining operations. To develop these solutions, the company works both with public funding and private funding from mining companies. They currently employ over 20 people, most of them highly qualified women, in a male-dominated industry. Most of their business has been creating new solutions or services for problems in mining operations (Benavente & Goya 2012).

One of Aguamarina's defining characteristics is that their solutions are non-polluting, providing them with an important additional source of value for mining companies: using microorganisms they can improve their efficiency and production levels without any harmful environmental effects. The main areas where Aguamarina has been working are biolixiviation, biocorrosion, biorremediation, biorreactors, water treatment and dust control. Most of these lines have a significant potential for lateral migration, first to other mining industries,[8] but also to different industries that face similar problems.

Aguamarina is filling the key void that exists between scientific research and industrial needs. On the one hand, they are attentive to scientific developments that could have industrial applications, and on the other, they have an excellent understanding of mining operations and their problems (Benavente & Goya 2012).

Among its clients are MNCs like Codelco, BHP-Billiton, Barrick, Xstrata, Anglo American and Antofagasta Minerals. The firm in increasingly providing services in other countries, such as Brazil, Peru and the US, and it has developed relationships with universities, Endeavor (a non-profit organisation that promotes high-impact entrepreneurs) and participated in BHP-Billiton's cluster programme through which it has been awarded projects which helped the startup to develop its sales and products strategy (Benavente & Goya 2012)

Aguamarina illustrates how the demands of the mining sector are encouraging knowledge intensive activities in the new technologies. The case of the Center for Mathematical Modeling's Laboratory of Geomechaniscs (CMM)[9] for Mining (University of Chile) is another example of this type of diversification, but in this case towards ICT (Benavente & Goya 2012).

The CMM based at the Mathematical Engineering Department of the University of Chile was established in 2000 to conduct research in advanced applied mathematics and develop solutions to industrial and scientific problems in areas such as transport systems, regulated services' rates, mining, medical diagnosis, forestry, and fishing resources management (Benavente & Goya 2012). Over the years, the centre has had 40 researchers, over 90 visitors and over 40 Ph.D. students. In the area of mining, since 2002, CMM has concentrated its efforts collaborating on projects with Codelco's Rock Mechanics group in the underground exploitation of El Teniente mine. More precisely, CMM's applied mathematical research is helping Codelco to better understand the rock bursting phenomena, one of the main challenges for underground mining that is the source of many tragic mining accidents and which require innovative technologies to enable a safe and quick exploitation of large reserves of copper contained in deeper rocks (Benavente & Goya 2012).[10]

As a result of this fruitful collaboration with Codelco, CMM created its Laboratory on

Geomechanics for Mining in 2008 to supply services on developing mathematical software that assist mining engineers in better understanding underground mining for planning and operational purposes (Benavente & Goya 2012). It has further extended its work with other users, such as the French CNRS, Universidad de Concepción, other Departments at Universidad de Chile, as well as industrial counterparts like Dassault Aviation (Benavente & Goya 2012)

As ore grades continue to decrease and new mines go underground, the expertise of CMM will become even more valuable, not only in Chile, but globally, making the commercialisation of its world-class research results (e.g. software applications) very promising (Benavente & Goya 2012). To date, the centre has been granted one patent, and another is under review. There is also significant potential of applied mathematical modelling for spillovers in other productive sectors, opening a window of opportunity for researchers that have been formed at CMM for establishing new consulting firms that respond to the challenges and knowledge demand generated by the mining sector. CMM illustrates the increasing knowledge creation and learning that can take place at universities as well as their capacity to work together with large multinationals in the development of cutting edge research and technologies with high innovation impact.

CONCLUSIONS

This paper highlights an opportunity that is either questioned or not commonly acknowledged in the current innovation and development literature: using natural resource industries as a platform to develop knowledge intensive industries, which could support economic development strategies by NRRCs. In the process of highlighting this opportunity, our analysis provides theoretical contributions to the literature which are supported by case study evidence.

The theoretical contributions of this paper are based on a systematic review of the main arguments in the literature which reject the innovation potential of NR-based industries. This review resulted in three findings: first, we argued that most of these studies (whether in favour or against the NR potential) covered selected short periods of time, where their conclusions may have been verified, but when looking at long-term historical trends, many of their conclusions no longer hold. Second, we introduced an analytical framework which describes how recent changes in global markets' characteristics and requirements in addition to advances in science and technology including ICT's, nanotechnologies, biotechnologies and new materials have transformed the context for innovation in natural resource industries and either minimised or eliminated most obstacles for developing countries to engage in knowledge-intensive industries based on natural resources. Third, we emphasised that knowledge intensive industries based on natural resources have always existed, especially when the unit of analysis expands from depicting the basic raw materials extraction to include its wider network of service and input providers as well as backward and forward linkages from investors to users. The difference, we point out, is that the developing world can now enter a space that used to be exclusive to the industrial complexes of the advanced world

Case study material from two NR-based industries in Latin America (agriculture in Argentina and mining in Chile) finds evidence of the validity of these emerging findings. The enabling effects of recent global changes in S&T, market demands and structure (e.g. outsourcing of key knowledge-intensive processes to suppliers and service providers; use of microorganisms for non-pollutant cleaning services) were present in both cases. As to the unit of analysis being the network instead of the basic raw material extraction, our findings suggest that this would support the design of better policies to facilitate innovation. We therefore propose that the network be used not only as the unit of analysis but also as 'the unit for policy'.

Given the pervasiveness of a negative bias from policy-makers and academics towards natural resources, one of the main contributions of this paper is therefore the provision of a systematic, evidence-based argument to support more constructive views on the role of NR-based industries in any economic development strategies by NRRCs.

We acknowledge that concerns regarding the need for improved governance and institutional strengthening when dealing with natural resources remain. The range of actors and change agents in the local, national and global networks related to the specific natural resources is wide and the task of building up the national knowledge base as well as the negotiating capacity will require wide-ranging participation and clear consensus goals. The quality of the system of innovation built around the chosen resources and the strength of its global linkages will determine how far the country can go in taking advantage of the window of opportunity. The structure of ownership of the resources in question and the legal framework regarding their exploitation will define the extension and the limits of the possibilities.

Nevertheless, we argue that for NRRCs to acknowledge that there is an opportunity to leverage their endowments is already an important first step. After that would come the task of analysing the market opportunities in each of the specific resources available in order to define a strategy for supporting the various agents, private and public, large and small, aiming to increase innovation rents and to support economic growth. As with any strategy, concerns and risks can be factored in and mitigation measures can be designed. NRRCs have never stopped investing in NR-based industries; during recent commodity booms those investments have actually increased and so have the exports of primary commodities. Wasting the opportunity to move up towards knowledge intensive NR-based industries deterred by the fear of risks would be 'throwing out the baby with the bathwater'.

Notes

1. Singer, himself in an article published in 1975, questioned some of his earlier 1950 views, thus recognising the historical nature of his previous observations.
2. The greater unit profits may no longer apply in the case of commodity manufactures (Kaplinsky 1993, 2005, 2009)
3. In 1990, the proportion of the area cultivated under ZT was almost negligible; in 2000, it was applied on 50 per cent of the total cultivated area; and in 2005/6 it had reached 70 per cent. Previous to 1996, the year in which the first GM soybean was approved in the country, there were no GM seeds, but in just 6 years, 91 percent of the seeds used for soybean production were transgenic (Bisang 2003).
4. ZT research and extension programmes have been implemented in over 40 countries, but large-scale adoption only occurred, where robust networks that used participatory research and extension already existed, such as Argentina and Brazil (Ekboir 2003).
5. Genetic engineering techniques allow us to identify, isolate and transfer exogenous gene sequences, that is, between different species, with the purpose of providing seeds with a code for characteristics that they did not have to begin with, for example, pest, drought, and other resistances, higher oil contents, etc. The identified gene sequence and the process of transfer are patented by the companies that identified the innovation and sold as a biotechnological event.
6. This case draws heavily from a report developed by Benavente and Goya (2012), produced within a project funded by IDRC: *Opening Up Natural Resource-Based Industries for Innovation: Exploring New Pathways for Development in Latin America.*
7. The application of microorganisms in the copper lixiviation process (a technology that can process minerals with very low ore grades) was initiated in the late 1940s in the US, but it was only four decades later that the first commercial exploitation started in Chile as better knowledge and experience facilitated its use in productive processes (Benavente & Goya 2012).
8. Different from copper, for example, iron.
9. This case draws heavily from a report developed by Benavente and Goya (2012), produced within a project funded by IDRC: *Opening Up Natural Resource-Based Industries for Innovation: Exploring New Pathways for Development in Latin America.*
10. One of the main challenges for underground mining is rock blasting. The rock is fragile, and it can suddenly explode and project material in all directions, similar to glass being broken. The effects of rock blasting can be dramatic, the worst of several accidents since that date was in January 1990, with seven casualties and many more trapped miners. The effect of that accident resulted in the dismissal of previous long term plans and a complete rethinking of how mining ought to be done. It was clear that to perform underground mining safely, it was essential to

understand as much as possible about how the rock works, and why and when there could be blasts.

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