Brecha tecnológica y convergencia en economías basadas en recursos naturales. El caso de Chile

Technology gap and catching up in economies based on natural resources. The case of Chile

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Resumen

Algunos países en desarrollo han implementado estrategias exitosas de convergencia basadas en el conocimiento y el desarrollo de capacidades. Aunque este proceso es específico de cada país, puede resultar más complejo en economías basadas en recursos naturales (RN). Desde el prisma de la Economía del conocimiento, el trabajo analiza cuáles son los factores determinantes de convergencia, aplicándolo a Chile como caso de estudio. Los resultados permiten identificar que la apertura y algunos intangibles son elementos clave de convergencia de los países especializados en RN, resaltando las oportunidades derivadas de la adaptación de tecnología y conocimiento foráneos, mientras que la capacidad de innovación y la desigualdad en el ingreso son las principales debilidades de Chile.

Palabras clave: convergencia, brecha tecnológica, desarrollo, Chile, innovación

Abstract

Many developing countries have defined successful catching-up strategies based on knowledge and capabilities upgrading. Although, this is a path dependent country-specific process, that may turn more complex in economies based on natural resources (NR). This paper adopts a knowledge-based economy approach to analyze the key dimensions of catching up applied to the Chilean experience. Results allow to identify development drivers and to derive policy implications that can be generalized to other catching-up economies based on NR. The main contribution is to show how openness and some intangible factors become basic determinants of convergence for NR-based countries due to foreign technologies and knowledge absorption opportunities, while innovation capabilities and the unequal income distribution are still serious weaknesses in Chile.

Key words: catching-up, technology gap, development, Chile, innovation

1. Introduction

Chile has been successful in the implementation of reforms during past decades with notable results in terms of levering economic standard when compared with other Latin America (LA) countries; however, the weakening of economic progress in the last decade urges the need for changes in the national development strategy. The economic specialization of Chile, strongly based on natural resources (NR), adds complex challenges. As the evidence shows, the NR exploitation may negatively affect economic growth due to social, environmental, and economic factors that would explain the so-called “NR curse” (Sachs and Warner 1999; Sachs and Warner 2001; Stijns 2005; Gylfason and Zoega 2006; Rosser 2006; Lederman and Maloney 2007; Van der Ploeg 2011).

The evolutionary vision of development is based on knowledge and technology as main drivers of growth (Versapagen 1993; Nelson 2007). Accordingly, development strategies within the technology gap tradition confer special importance to both the access to foreign sources of knowledge as well as to local capabilities building process, along with an appropriate institutional context (Castellacci and Álvarez 2006). Under this view, economic growth is understood as a dynamic process implying several factors of different nature that evolve over time (Fagerberg and Verspagen 2002; Castellacci 2007), and precisely this combination would become essential to understand a country trajectory and the reasons of growth or stagnation, because they are the key elements that would support development in the long run.

Under this approach, traditional assets (capital, labor, and NR) and exogenous technology are relevant in early stages of development but to build on innovation capabilities is determinant for countries in order to advance in a perdurable progress path (Dosi 1988; Porter 1990; Verspagen 1991; Castellacci 2008). This aspect could explain part of the Chilean decline during the 2000s, and it would justify how different efforts to reach higher economic standard are still pending. Benchmarking and comparison with other economies based on a similar productive structure are good tools to identify weaknesses and opportunities that would support the definition of policies. Thus, this paper tries to identify the current frontier and the possibilities for catching up. For doing this, we first drive a metafrontier analysis and then an study of convergence. The analytical results provide knowledge about the gap determinants as well as general implications for countries dominated by NR industries.

The results suggest that countries specialized in NR should intensify openness and FDI for catching-up, to increase capital investments, and to build innovation capabilities, along with continuing with the exploitation of their NR as development pillar. The opportunities for Chile derived from the resource management improvement are scarce because its technical efficiency is close to the frontier. Despite Chile´s economic progress and convergence with the leaders, a wide gap of technological capability still remains and this is a serious obstacle for achieving and maintaining a better economic standard. Our findings also confirm that growth in Chile has been based more on traditional production factors and exogenous technologies, in line with the reforms and policies implemented since the seventies, while more efforts should be made to definitely take advantage of the opportunities provided by a Knowledge-based economy.

The rest of the paper is organized as follows: Section 2 presents a short revision of the main arguments found in the literature, and Section 3 provides a brief description of economic structure, performance and trajectory of Chile. Section 4 presents the methodology and data description. Section 5 includes the most relevant results from the Metafrontier and GAP analysis with a discussion thereof. Finally, Section 6 presents the main conclusions, some policy implications, future research lines, and limitations.

2. Literature background

A wide body of literature shows how countries can face development challenges by exploiting their endowments and increasing productivity. The traditional growth theory emphasizes the transition towards the steady state, being capital, labor, and crucially productivity the basic components of the cumulative process that guarantees economic progress (Sala-i-Martin 2000). Under this lens, countries may converge taking advantage of the leaders' technology, while the international diffusion of technology is seen as the main driving process. However, it is well known that growth path is country-specific and while some economies actually converge other fall behind.

In the neo-Schumpeterian and evolutionary tradition, the explanation of growth differences across countries are built over a complex and dynamic vision of development that pays more attention to the role of technology and knowledge (Verspagen 1993; Nelson 2007). This perspective is at the core of the knowledge-based economy framework and goes beyond the traditional productivity approach, claiming the crucial role of intangible assets as drivers of wealth creation (Edvinsson 2003; Dunning 2009). In this line, the results of convergence analysis coincide to show that although countries can follow different development trajectories, they also share similar patterns resulting in clubs or groups of convergence (Verspagen 1993). According to Castellacci (2008), these clubs are mainly defined on the basis of their innovative ability and absorptive capacity, being the relevance of technology in economic progress, the confirmation of the capacity to absorb and adapt international technologies, and the creation of local innovations, some remarkable factors that explain long-term differences in growth patterns (Castellacci and Álvarez 2006; Fagerberg et al 2007).

A crucial idea in this sense is that the international diffusion of technologies is not an automatic and effortlessly process. On the contrary, countries require domestic capabilities to select, imitate, adopt, and adapt foreign technologies and to create new ones, where the human capital and the institutional framework play a determinant role (Verspagen 1991 and 1993; Nelson 2007). The opportunities to advance using knowledge from abroad also depend on the technology gap, because a closer proximity to leaders reduces the potential options for catching up. Authors such as Porter (1990), Verspagen (1993), Nelson (2007), Castellacci (2008), Ville and Wicken (2012), point out that in early stages of convergence, where countries face a wider technology gap, imitation is the main channel for economic development, while innovation become the most important driver for those in more advanced stages.

Moreover, the technology gap is not static but it is constantly changing due to the combined actions of followers and their decision to catch up on the one hand, and the decision of leaders to innovate permanently on the other, which explains the differences in growth rates between countries. The literature underlines that developed economies can growth to a higher speed because they are able to create and to accumulate knowledge faster than others thanks to their better institutions and well-instructed human capital (Verspagen 1991; Nelson 2007). In addition, international protection of intellectual property, along with other regulatory mechanisms, act as barriers for international technology flows and knowledge spillovers, highlighting the relevance of internal capabilities to address this adverse situation. In this regard, Verspagen (1993) argues that total convergence is not reached by means of catching up alone, but the backward country has to increase the domestic research efforts up to a level comparable with advanced economies, which also support their progress on other innovation related activities.

The experience of countries such as Korea and Taiwan are illustrative of the catching up process along which they have become developed economies taking foreign technologies, investing in human capital, improving their institutions and economic structures, and using their comparative advantages (Verspagen 1993; Nelson 2007; Ohno, 2009). Others, such as Japan and Singapore, have continue managing their intangibles and specializing in knowledge-intensive sectors, taking innovation as pillar of development, and finally achieving higher economic standard (Felipe et al 2012).

On the other hand, the exploitation of comparative advantages without appropriate investments in knowledge capacities can make development problems persistent if countries do not move toward more innovative bases of competitive advantages (Porter 1990; Verspagen 1993). Additionally, countries with low efforts in education, institutions, R&D, and innovation can be trapped in a slow growth path and also can fail in the transition from middle income to high income economy due to rising costs and competitiveness decline (Griffith 2011). The literature widely describes cases this middle-income trap, such as Morocco, Philippines, Romania, Tunisia, Uruguay, and Venezuela (Felipe et al 2012), whose economies have fallen as a consequence of the definition and implementation of wrong policies and the inadequate growth strategies, mainly related to innovation and institutional factors that support the required changes of the development process (Pérez 2012).

This adverse situation can be faced by countries through the acquisition of capabilities that permit the development of an appropriate national industrial strategy and the implementation of the most effective measures. According to Ohno (2009), it is required to introduce and to create innovations in the production system, paying attention to education for the improvement of human capital; the reason is that income convergence cannot be sustained over time unless it is accompanied by capability convergence (Pérez 2012). Thus, the key aspect to avoid this trap and to converge with leading economies would be related to both institutional reforms and innovations capabilities that lead a continuous updating of technologies and diversified exports of higher added value contents, maintaining high growth rates in the long term.

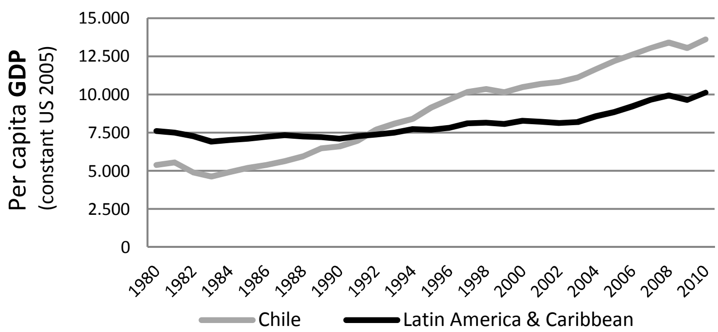
Likewise, evidence of middle-income trap is found in economies based on natural resources (NR) due to the fact that these endowments tend to adversely affect growth because several reasons, such as the easy generation of high incomes as a result of price booms, the low growth potential of a fixed production factor, the negative effect of currency appreciation over manufacturing exports (also called Dutch disease), the generation of a wrong feeling of economic security that discourages investments in other assets and industries (Gylfason and Zoega 2006), high levels of corruption and the reduction of the institutional quality (Sachs and Warner 1999), an inadequate distribution of human capital among industries (Bravo-Ortega and De Gregorio 2005), the negative effects on innovation systems (Fagerberg and Srholec 2008), and the environmental damage (Smulders 2005; Stavins 2011). However, the literature on NR also suggests that countries could face sustainable growth if they foster human capital, strengthen their institutions and invest in knowledge and technology (Bravo-Ortega and De Gregorio 2005; Manzano 2006; Iizuka and Soete 2011).

Therefore, countries that expect to reach a better economic performance should walk through of path that combines their natural endowments with investments in physical assets, and fostering the knowledge capabilities and innovation activities. In sum, closing the technology gap and the creation of innovations should be at the core of growth strategies that support a sustainable progress.

3. The Chilean trajectory

Located on the southwestern edge of South America and with less than 17 million people (INE 2012), Chile has shown positive and outstanding signs of economic progress in the global context. A large part of the policies and structural reforms applied along the last four decades have been oriented to increase the economic activity, transforming exports and investment into the main engines of growth (García 2006). The economic trajectory of Chile shows that per capita GDP increased by more than one and a half time since 1980 (Figure 1), reaching the highest GDP growth within LA and indeed, in the last WB classification Chile is found among the high-income countries (World Bank 2013). However, the results have not always been as positive as the overall picture seems to show; at the beginning of the seventies, when the first economic reforms took place, the Chilean economy exhibited poor indicators in terms of inflation, fiscal deficit, and even growth rates. In addition, custom tariffs were in average about 105%, the State controlled about 600 enterprises that accounted for about 40% of the GDP, being the exports very scarce (Corbo et al 2005). All these aspects resulted in a negative scenery for investment and progress. Thus, early studies classified Chile as a poor economy, among those called “missed opportunities or falling-behind countries" (Verspagen 1993).

Figure 1. Per capita GDP of Chile and Latin America, between 1980 and 2010



Source: data from WB.

In the 1970s, Chile began its international trade orientation and opening strategy through a reduction of protection at the multilateral level followed by bilateral free-trade agreements, which also attracted FDI flows (Meller et al 1996; Álvarez and Fuentes 2006; Pérez 2012). Macroeconomic reforms related to stabilization and openness followed with the different governments, and some microeconomic policies were also applied to increase efficiency and productivity, while the constitutional changes tried to strengthen democratic governance in the country. Since the early 90s, four main policy areas have been prioritized: Infrastructures, human capital, productive development (support to SMEs and raise of R&D level), and economic institutions (mostly regulatory and anti-trust) (García 2006). In addition, a number of other policy measures were implemented such as privatizations, monetary and fiscal reforms (Corbo et al 2005).

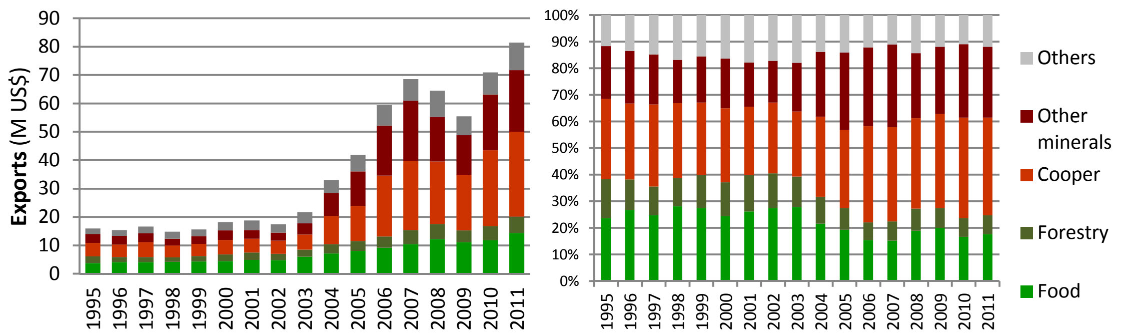
The changes defined decades ago continued during the 2000s and later, both in the economic, social and institutional fields. This new phase has tried to improve the added value of exports and to develop new products and services, objectives that have required changes in the national innovation system. In particular, innovation policy has been focused on strengthening the links between science and the private sector to agree a common research agenda to foster R&D and to increase human capital. Consequently, in 2005 the National Innovation Council (NIC) was created to define an innovation strategy that would lead competitiveness improvement because Chile showed and still shows low value-added exports as a result of the traditional low R&D investment and other innovation deficits. To finance this strategy, a royalty to the extraction of copper, the main industry in Chile, was applied along with a tax credit law launched to promote private R&D investments (García 2006; Maloney and Rodriguez-Clare 2007; CNIC 2010; Pérez 2012).

Despite the remarkable progress achieved by all these economic, political and institutional reforms, the national economy has been losing dynamism in the last decade. Some specialists insist in the relevance of those policies that based on a traditional approach emphasize investments in tangibles assets, considering technology and knowledge exogenous factors that can be obtained elsewhere in the world, keeping the role of the State reduced to solve market failures and to promote entrepreneur activities (Nelson 2007). However, these policies seem not to be sufficient to support sustainable growth in future, an aspect reflected in the poor long-run trends of the Chilean economy, as well as in the fall of total factor productivity (CNIC 2010; Pérez 2012). This fact is also confirmed by the latest competitiveness report prepared by the World Economic Forum (WEF 2013) and the Global innovation index (Dutta and Lanvin 2013), where innovation factors along with other social and economic elements and infrastructures are underlined as main limits for the progress of this country. In this regard, some scholars agree that innovation capabilities become more important than catching up, and therefore local capabilities should be developed and applied for countries' convergence toward the leaders

(Verspagen 1993). The reason is that in more advanced stages of the development' path, competitive advantages are based on innovation more than physical assets (Porter 1990) and for the future of Chile, openness and FDI, current pillars of growth, will not have the same effect on productivity growth (Álvarez and Fuentes 2006).

To understand this trajectory and the potential future advance of the country, it is important to be aware that historically Chile has been characterized by a strong presence of NR-based industries, reason why it is considered as a NR-specialized economy (Maloney 2007; CNIC 2010). Both renewable and nonrenewable resources are present, having the sectors of mining, foods (agriculture and fishery) and forestry, a special relevance and orientation toward foreign markets (Figure 2). The NR exports represent more than 80% of total exports, corresponding to mining more than 60% of them during last years, while renewable resources reached around 25%. These data comes to describe an economic structure that dominated by NR implies to consider this productive specialization in the definition of growth policies.

Figure 2. Exports from Chile by product. 1995 – 2011



Source: data from UNCTAD 2013

After the boom and fall of the nitrate industry at the end of the XIX century and early the XX, accounting for more than 70% of total exports and over 50% of public revenues (Meller et al 1996), the copper exploitation took the leadership as result of large endowments and foreign capital and technology, being nowadays the most important economic activity and determinant of Chilean GDP. In the seventies, the State decided to nationalize the companies of the sector for achieving the complete control over this strategic production, reason why the National Copper Corporation of Chile (CODELCO) was created, and it is today the main copper producer in the world, keeping around 10% of the total world reserves of this metal (CODELCO 2013). Later, opportunities were given to private investors through mining concessions, with the objective of increasing the production. Thus, since the beginning of the nineties and thanks to favorable FDI policies, large foreign investments have been attracted, and today about two-thirds of national production is handled by private capitals, representing around 35% of total exports (Arias et al 2012). Besides, other minerals have also gained importance in the mining industry such as potassium nitrate, sodium nitrate, lithium, iodine, and molybdenum, but don't have reached the same economic relevance than copper (Wright and Czelusta 2007). Nonetheless, the discovery of new deposits and new available exploitation technologies come to offer a prosperous long-term scenario.

This industry is a net importer of knowledge and technology due to the limited capacity of suppliers and mineral companies to generate innovations and knowledge transfer, and the poor relationships within the sector where the collaborations are based on other types of services (Maloney 2007). Moreover, research centers and universities have been mainly adaptors of technologies and organizational strategies created in more developed countries, and scarcely devoted to develop new ones (Arias et al 2012).

Additionally to non-renewable NR, Chile is well known in international markets for its food and forestry production (Maloney 2007). The forestry sector, dominated by large local companies, includes both native forests and plantations with introduced species (mainly Pine and Eucalyptus), it represents around 3.1% of GDP and it accounts for 7% of total exports (CORMA 2013). The technology used by this industry originally came from abroad, but decades ago local R&D has also been carried out by public and private research centers and universities in collaboration with firms. Although local knowledge has improved in several areas, flows of complementary foreign technologies still remains.

The food sector is other example of productive specialization. Several governments' interventions began in the sixties to capture technology from abroad through the creation of State agencies to drive development strategies and improving investments in human capital and infrastructure (Pérez 2012). Then, Chile became leader in food production since the eighties, with special importance of fruits, wine, and fish products, which is a consequence of a planned process and a strong private entrepreneurship (CNIC 2010; Figueroa and Calfucura 2010).

Unlike forestry, food industry has been driven by small and medium producers distributed along the country, with the exception of salmon production where large Multinational Companies (MNC) took the control. The technologies are mainly from abroad and this has been the dominant situation of the production system until now. The suppliers have played an important role as promoters of innovation, providing new technologies and knowledge created in developed countries that have been adapted to local conditions. Complementarily, local capacities are being improved with important advances in human capital, infrastructures and R&D, as consequence of both private and public efforts, and new strategies are being implemented in order to create own technologies.

There is a broad consensus about the achievements in food, forestry and mining sectors and, particularly, about the fostering action of governments, through macroeconomic and microeconomic policies, the strengthening of adequate institutions, opening, local and foreign investments and foreign technologies, being FDI a determinant factor that provide resources from developed countries (Álvarez and Fuentes 2006; García 2006; Maloney 2007; Bas and Kunc 2009; Figueroa and Calfucura 2010; Arias et al 2012; Pérez 2012). Nonetheless, scholars also agree on the need to improve national innovation capabilities because the knowledge and technologies diffusion from abroad can be seen as a complementary source of growth but not as a sufficient condition (Verspagen 1993; Castellacci 2006).

4. Empirical analysis: Methodology and sources of information

The first step of this analysis is to identify those elements and variables that are determinant of technical efficiency improvements and significant for catching up processes. This is especially relevant for the possibilities of middle-income countries (MIC), a reason that justifies the election of Chile as target economy in this study. To answer the research question about the key dimensions of the Chilean catching up, an approach based on the knowledge-economy is follow. The results will allow us to detect the relevant fields in which policies and strategies must focus to improve growth and development in the long run, and to avoid the NR curse and the MIC trap.

To drive innovation policies, taking into account the NR specialization and built over national system of innovation (NSI) and knowledge-economy (KE) approaches, is particularly relevant to know the characteristics of the gap between Chile and leading countries, with similar economic structure, and its dynamics. We can expect that our findings provide new clues for policy makers' decisions and for the definition and implementation of more efficient policies. The general assumption is that more efforts should be done to improve local capabilities to innovate in NR sectors, creating own technologies and knowledge in order to reduce the foreign dependence and improve competitiveness and the added value of exports.

According to the KE framework, knowledge and technology are crucial factors to support growth, reason why research in the area devotes great efforts to evaluate and to understand countries' technology gap and then to assist more precisely development strategies. Studies in this tradition have used different methodologies to identify the distance between the leader and countries applying catching-up and benchmarking strategies. It is frequent to measure the gap as the relative distance to leading economies, discussing the reasons explaining the value of this ratio and the need of adequate policies to converge. Thereby, to detect the determinant factors of the gap, we estimate an applied growth model rooted on the KE framework and the evolutionary theory using a sample of countries identified by cluster technique. This sample is made up by economies characterized for a NR specialized economic structure, being high or medium-high income according to the WB classification, and that have shown high rates of growth between 1990 and 2008. The solution of the cluster analysis is one group of countries (called SELECTED) made up by Argentina, Australia, Canada, Chile, Colombia, Kazakhstan, Mexico, Peru, Russia, and South Africa, which is consistent with other studies that analyze NR specialization and successful cases of development (Ferranti et al 2002; Castellacci 2006; Gylfason and Zoega 2006; Gimenez and Sanau 2007; Maloney and Rodriguez-Clare 2007; Smith 2007; CNIC 2010; Silva and Teixeira 2011; Ville and Wicken 2012).

Previously, we use the metafrontier methodology to determine and to compare Technical Efficiency (TE) and Technological Gap Ratio (TGR) of SELECTED countries. In order to identify the opportunities derived from improved production efficiency or technological catching up, stochastic metafrontier methodology has become popular in the literature because it identifies the optimal production function of the firms within an industry and the distance of each individual to frontier. According to O'Donell et al (2008), this econometric tool can also be applied to evaluate countries as units of analysis. The stochastic frontier production function postulates the existence of technical inefficiencies of production, based on the concept of a production meta-function and assuming that all individuals have access to the same technology (Battese and Rao 2002). However, it is well known that technology is not a public good because there are several factors that limit cost-free technology transfer and diffusion processes. The meta-frontier production function proposed by Battese et al. (2004) is a frontier function that envelops all frontiers of individual regions or groups, and permits to deal with the technology heterogeneity and to distinguish from technical inefficiency (Battese and Rao 2002; Villano et al 2010). Therefore, it is possible to estimate technology gap assuming different technologies relative to the frontier. This model includes an error term that comprises a symmetric random error and a technical inefficiency term (Battase and Coelli 1995; Battese and Rao 2002). Thus, two main components relative to efficiency can be determined: a component that measures the distance to the group frontier (commonly defined as Technical Efficiency), and a second element that measures the distance between the group frontier and the metafrontier, from which the Technological Gap Ratio can be identified (O'Donell et al 2008).

A second and complementary econometric analysis was conducted to identify the determinant factors of the technology gap in NR-based economies. We estimate the models by using panel data regression, considering both fixed and random individual effects. The variables were selected according to the literature review and taking into account the restrictions of the analytical method. We followed the conventional approach used in other applied growth models, taking labor and capital (investments) as the main traditional production factors (Romer 1990; Aghion and Howitt 1992). Physical investment was used as indicator of capital in a similar way as Stijins (2005) and Castellacci (2008). For the analysis of the effect of NR, an index of specialization was calculated as the ratio between natural resources exports and total exports. According to evolutionary framework, we also include indicators that reflex innovation capabilities – patents - and absorptive capacity – schooling - (Castellacci 2007). Moreover, an indicator of institutions has also been introduced: the Institutions index elaborated according to WB methodology (Kaufmann et al 2003). Finally, the openness and foreign direct investment (inward FDI stock) were selected to proxy international influences. Table 1 shows the definition and sources of all the variables used in our empirical analysis, whose general specification would adopt the following form:

$$\textbf{GDP GAP}_{it} = \beta 0 + \beta 1K_{it} + \beta 2L_{it} + \beta 3NR_{it} + \beta 4Pat_{it} + \beta 5FDIIS_{it} + \beta 6Op_{it} + \beta 7Sch_{it} + \beta 8Ins_{it} + \eta_i + \gamma_t + \varepsilon_{it} \quad (1)$$

Where:

GDP GAP: ln GDP GAP; GDP: Gross Domestic Product (GDP) per capita; K: ln Capital, investment; L: ln Labor; NR: ln natural resources, specialization; Pat: ln Patents; FDIIS: ln FDI, inwards; Op: ln Openness; Sch: ln Schooling; Ins: Institution index. The subscript *it* refers to the country *i* in period *t*, η_i and γ_t represent individual and time effects, respectively; ε_{it} is a random error term.

Table 1. Definition of variables, indicators and data sources

Variable	Definition	Source
GDP	Per capita GDP, PPP, at 2005 constant prices	CANA from Penn World Table
Labor	Labor force, total	WDI
Capital	(%) Investment. Share of per capita GDP at constant prices 2005 PPP converted	Penn World Table
Patents	US Patents granted per Country of Origin. Number of utility patents granted by the USPTO by year and Inventor's Country of Residence per inhabitant	CANA from USPTO
Schooling	Mean years of schooling. Average number of years if school completed in population over 14.	CANA from Barro & Lee; WB
Inward FDI	FDI Inward Stock (%GDP)	UNCTAD
Openness	Openness Indicator: (Import+ Export)/GDP. PPP	CANA from UNCTAD
Institutions	Index made up: Rule of law, Corruption control, Voice and Accountability, Political stability and Absence of violence/terrorism, Government effectiveness, and Regulatory quality.	World Bank
NR specialization	NR exports as share of total exports	UNCTAD (exports)

Source: authors' elaboration

To asses in depth the convergence of each gap component of Chilean economy and the evolution of them, a distance or convergence analysis was driven following Li and Liu (2005), and Sala-i-Marti (2000) to evaluate the gap dynamic or convergence (β convergence). The distance was calculated according to the next specification:

$$\textbf{GAP}_{it} = (\textbf{A}\text{max} - \textbf{A}_{it}) / \textbf{A}_{it}$$

Where:

GAP: is the GAP between the leader and the economy analyzed i in the time t; A_{max}: data from leader economy; A_{it}: data from economy analyzed (i) in the time t

Among SELECTED countries, Australia and Canada show the highest GDP and Technical Efficiency, and the smallest technology gap; but Australia has a more specialized economic structure, thus this country has been considered as leader. In addition, the Chilean data were also compared with USA because this economy is one of the most developed and it is usually used as reference in the gap analysis.

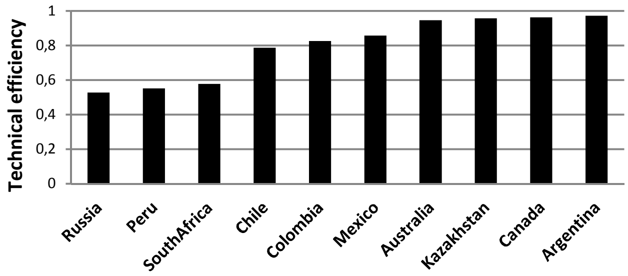
Finally, an analysis of the dynamic evolution of Chile's GDP is discussed following Faberberg et al (2007) classification of countries, which identify and classify the economies into four categories: Catching up, Losing momentum, Moving ahead, and Falling behind. Unlike the work conducted by Faberberg, we take several periods of a same individual – Chile - to try to understand the evolution of growth.

5. Discussion of results

5.1. Technical Efficiency and Technical Gap Ratio

The analysis of Technical Efficiency allows us to know efficiency level of a country to employ its resources (tangible and intangibles), being management capabilities crucial to understand potential improvements (Battase and Coelli 1995; Battese and Rao 2002; O'Donnell et al 2008; Villano et al 2010). The results show that Russia, Peru, and South Africa have the lowest TE, with values under 60% (Figure 3). This would indicate that these economies can achieve higher performance with the stock of available resources (technologies, NR, capital and intangibles assets) and then their growth opportunities could be defined through resources' management. Moreover, although Chile, Colombia, and México have also the opportunity to growth faster by improving their internal processes and use of resources, their gap is narrower and hence they have lesser options via management. On the other hand, Argentina, Canada, Kazakhstan, and Australia are the countries with highest TE, thus growth can be improved from development of new technologies, innovations, or the incorporation of new advances from areas different than the reorganizations of available resources. For the specific case of Chile, the opportunities to improve TE by benchmarking or the incorporation of best practices from the leaders are limited because these have similar TE and the threshold is small; thus it is more suitable to orient efforts to develop its own knowledge, technology and innovations.

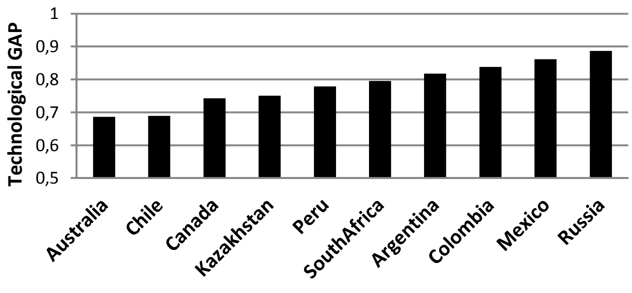
Figure 3. Technical efficiency (TE) taking into account country effects



Source: authors' elaboration

Taking into account that the Technological Gap Ratio reflects the available technologies in one country, technological gap is equivalent to 1-TGR and this indicates catching up opportunities (Figure 4). Accordingly, Chile, Canada, and Australia show the lower gap; however, an important distance still persists, reason why these countries can achieve income improvement using technology available abroad. From the Chilean perspective, both Australia and Canada may serve as leaders for the gap analysis and benchmarking strategies, but the former has a more similar economic structure to Chile and hence a more comparable development path. Thus, it can be said that Chile could increase its economic performance both from foreign technologies, using catching up processes beyond NR industries, and improving strategies of resource management. However, these options are not unlimited and local innovations (technological and no-technological) should be encouraged to advance because total convergence doesn't reached by catching up alone and even more, leaders are pressed to innovate in order to expand production and technological frontier to follow their growth trajectory (Porter 1990; Verspagen, 1993).

Figure 4. Technological gap considering country effects



Source: authors' elaboration

5.2. GAP analysis: GAP model and Catch up convergence

Considering Australia as leader of NR-specialized economies and high performance, the next convergence analysis tries to identify the key determinants to build a sustainable development strategy. This study focused on Chile, although policy implications derived from our findings can be generalized to other specialized nations. Additionally, USA and Canada were also alternatively used for convergence analysis. In any case, the variables that define the gap between Chile and USA, Canada or Australia, follow a similar pattern. This would indicate that there is a similar growth trajectory between these countries, confirming both the adequate selection of leaders in the analysis and the possibility for considering our findings to discuss policy implications for NR-based economies.

As the results show, the income gap of economies dominated by NR is explained not only by the traditional production factors but also by other elements postulated by the NSI and KE approaches, having a strong relevance the international dimension (Table 2). The results come to indicate that the reduction of the gap in these countries can be done by an increase in capital investment, in accordance with the nature of this economic activity, as well as by the development of innovation capabilities, being also significant trade openness and FDI attraction. This combination of factors is coincident with the assumption that NR can lead development when intangible assets are also incorporated into the strategy. In fact, NR specialization positively affect the gap narrowing, a finding that find support in the related literature and evidence that point out that NR may successfully contribute to growth when natural and other traditional factors (capital and labor) are properly combined with strategic intangible assets, such as human capital, good institutions, and openness policies (Bravo-Ortega and De Gregorio 2005; Manzano 2006; Gimenez and Sanau 2007; Iizuka and Soete 2011).

The internationalization of these economies is also revealed as a significant factor that affects convergence in accordance with the importance that in the literature has the international dimension as main source of technology, capital and demand. When the model is estimated without considering the global dimension, the NR exploitation has not impact on the income gap; although, when openness and FDI are incorporated into the model, NR positively affect growth, reducing the gap. This result remarks this aspect for specialized economies, being economic takeoff inconceivable for a closed NR-producer country. In addition, a more open economy implies that the workforce can move to other productive activities generating the opportunity to develop complementary knowledge intensive goods and services, and even promoting new sectors.

Table 2. Gap model (per capita GDP). Static Panel Data

	Model A		Model B		Model C	
	coef	se	coef	se	coef	se
Labor	0.014***	0.003	0.018***	0.003	0.020***	0.003
NR	-0.003	0.002	-0.004**	0.002	-0.003**	0.002
Investment	-0.007***	0.002	-0.006***	0.001	-0.007***	0.001
Patent	-0.001*	0.000	-0.001*	0.000	-0.001*	0.000
Schooling	-0.005	0.005	-0.004	0.005	-0.004	0.005
Openness			-0.003**	0.001	-0.002**	0.001
FDIIS					-0.001**	0.000
Institution	0.000	0.001	-0.001	0.001	-0.001	0.001
cons	-0.205***	0.052	-0.268***	0.041	-0.299***	0.036
Hausman test (chi-sq)	45.31		63.04		122.36	
Num. of obs.	128		128		128	
R-sq: within	0.5196		0.5547		0.588	
R-sq: between	0.0490		0.0648		0.0496	
R-sq: overall	0.0590		0.0740		0.0580	

Source: authors' elaboration. *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors, fixed effects

The positive relationship between labor and the GDP gap (see Table 2) can be explained attending to the fact that NR activities are nowadays capital and scale economies intensive, requiring less amount of labor to increase or maintain the production level (Álvarez and Fuentes 2006; Arias et al 2012). Thus, low-skilled workforce or with limited education can be qualified increasing the level of human capital and then be employed in activities related to NR but being more knowledge-intensive, such as the creation of new technologies or knowledge services. In this regard, Manzano (2006) argues that for upgrading their productive structures, these economies need better human capital, along with R&D infrastructure and appropriate institutions, highlighting the importance of skilled workers to face more complex activities in order to add value to exports by creating and incorporating innovations.

The results of convergence analysis show the successful path of Chile closing the income gap with leaders (Australia, Canada and USA), but its per capita GDP is still about half of the most advanced countries. Several authors, such as Álvarez and Fuentes (2006), García (2006), Figueroa and Calfucura (2010), Pérez (2012) have noted that Chile has achieved a high economic standard in recent decades, but this progress has not yet been sufficient to complete income convergence.

Some of the causes for this convergence are found among the government's reforms and the policies implemented decades ago, oriented to opening the country and attracting FDI as a source of capital and technology (Meller et al 1996; Lefotrt 1997; García 2006; Bas and Kunc 2009; Arias et al 2012; Pérez 2012). However, if we analyze different determinant factors of the gap, important differences arise because Chilean policies have been more oriented to opening and catching up than to building local capabilities (Table 3).

Table 3. Convergence coefficients (β) between Chile and leaders

			Intragroup leader	
	β (AUS)	β (USA)	Country	β (leader)
Per capita GDP	-0.035***	-0.080***	CAN	-0.053***
Investment	0.010**	0.0000	AUS	0.010**
Patent	0.919	-9.645	CAN	-2.372
Schooling	-0.014***	-0.013***	AUS	-0.014***
Openness	-0.006**	-0.002	CAN	-0.008
FDIIS	0.000	0.008**	CHL	---
Institutions	-0.002	-0.011***	CAN	-0.006***
Scientific articles	-0.209***	-0.346***	CAN	-0.360***
Royalties	-0.105***	-0.008	CAN	-0.161***
GINI	-0.019***	0.003	CAN	0.002**
R&D	-0.008	-0.017	CAN	0.037***
Infrastructure	-0.075***	-0.083***	KAZ	-0.044***

Source: authors' elaboration. Negative β means convergence. Robust standard errors

In general, differences in convergence with Australia, USA and Canada are slight and can be explained by the diversity of industrial structures and growth strategies. The empirical results indicate a robust convergence in schooling, scientific articles and infrastructure, confirming the effort carried out for the government to improve productive infrastructures and facilitating the population access to education, at least to primary and secondary levels. Nevertheless, several authors, based on international evaluations of the education system, indicate that education quality is still deficient, and this represents one of most relevant bottlenecks to cross the development threshold.

The convergence values of the institutions' indicator differ depending on the chosen leader. According to WB data, the negative shift of this index in Chile is linked to lower government effectiveness and the loss of government ability to define and implement policies to promote private business, while Australia exhibits a strengthening in these parameters. This context clearly shows the need to enhance the institutional environmental in Chile in order to avoid potential social conflicts, provide more stability to investments, and contribute to strengthen the international relationships, because they are the pillars of economic progress (Nelson 2007).

As the NR industries are capital-intensive and require important investments in physical assets, a gap reduction in this production factor is determinant to profitably exploit these endowments. Despite the fact that investment gap has increased during the entire period, Chile has narrowed it in the nineties, this confirming the successful policies applied to promote investments in NR sectors and related activities during the last decade of XXI century. This is the result of external inflows of capital through FDI and other foreign investments, mainly as a consequence of public service privatizations, and also due to the reinvestment of NR revenue (Álvarez and Fuentes 2006; García 2006; Arias et al 2012; Pérez 2012). However, in an extended analysis from 1996 to 2008, signs of broadening the gap are found at the end of the period, although the gap values are around zero. Therefore, it is interesting to pay more attention to this variable in the analysis of the causes of the reduction in Chile's attractiveness as a destination for local and foreign investors. In this sense, related explanations point out that the causes are the raise of labor costs, environmental policies and the perception of higher risks, which could be offset if Chile makes more efforts on other factors of production, as it is proposed by the KE.

As already said, other assets along with physical investment are also required to exploit successfully NR, mainly knowledge and technology (Verspagen 1993; Ferranti et al 2002; Giménez and Sanau 2007; Silva and Teixeira 2012; Ville and Wicken 2012). The reason is that countries can improve the production of goods and services with higher value added, to create new ones, or to reduce the costs through innovation, and the NR industries are not an exception. Thus, innovation becomes a key factor for getting competitive advantages that guarantee sustainable growth and development, and the ability of countries is directly conditioned by the characteristics of the NSI (Schumpeter 1947; Nelson and Winter 1982; Lundvall 2007; Fagerberg and Srholec 2008; Porter 1990).

In this sense, both technological and absorption capabilities are fundamental to developing countries, such as Chile, for catching up and for the creation of new knowledge in order to improve the performance of traditional sectors (Verspagen 1993; Castellacci and Álvarez 2006; Castellacci 2008; Castellacci and Natera 2013). Therefore, now we move to focus the analysis to patents, as a proxy of innovation capability, while schooling is taken as an indicator of absorption capacity. Chile does not show a reduction in the gap of patents, and this can be seen as a serious barrier for development. In fact, there is evidence in the literature on the weakness that Chile presents in terms of innovation capability or innovation shortfall, regarding R&D investment, human capital, and scientific facilities (Benavente 2002; Maloney and Rodriguez-Clare 2007; CNIC 2010; Arias et al 2012; Pérez 2012). On the other hand, the indicator of schooling reveals a reduction of this gap by two-thirds compared to the existing in the late eighties, reflecting the advance of absorption capabilities; this is likely the consequence of national policies and the largest education expenditures in the country during recent decades. Nonetheless, there is still the need to improve quality (García 2006) to impact positively on the innovation performance, since innovation and human capital is strongly related. According to the literature, the improvement of absorptive capabilities is crucial in the development strategy to support the generation of innovations and to provide the required skills to select, adapt and apply knowledge developed in other latitudes.

The important structural reforms established by Chilean governments in the seventies and eighties were orient to improve the macroeconomic behavior, the control of inflation, and to promote international trade and foreign capital inflows and technology (Paunovic 2000). The opening process turned Chile into one of the leaders of international trade, showing a higher openness level than NR leaders (i.e. Canada or Australia), and even leading economies around the World. Chile is one of the most attractive countries to invest in the world, and not only in NR industries but also in service and infrastructures (Bas and Kunc 2009; Pérez 2012). Scholars agree on the crucial role that the international dimension acquired in the development path of the country, being considered one of the growth engines that has been possible thanks to the economic and sociopolitical stability, which offer suitable incentives to foreign investments and the production of tradable goods (Álvarez and Fuentes 2006; García 2006). Thus, this is a key aspect to explain the Chilean economic success that has also been supported by policies that have taken advantage of catching up possibilities in the global market.

However, since capital and technology are not enough to achieve a permanent successful result of NR exploitation, because the problems of deindustrialization, depletion, corruption, and social conflicts, it is grounded in the related literature on NR that institutions are an essential factor to avoid NR curse and turn it into a blessing (Sachs and Warner 1999; Ferranti et al 2002; Manzano 2006; Figueroa and Calfucura 2010; Frankel 2010; Sæther et al 2011; Van der Ploeg 2011). The institution's index of Chile presents a lower value (weaker institutions) than leader, but the difference between Australia and Chile is only around 10% with a decreasing trend, while with Canada or USA is significant lower. Then, adequate institutions (comparatively to other NR-based countries) have also been a determinant factor of Chilean growth (García 2006; Álvarez and Calfucura 2010). This nation has been successful implementing deep reforms on governance, transparency, and corruption control, without falling into pressures resulting from NR windfall, but the indictors still have space to improve. In particular, challenges are related to the improvement of institutions quality to maintain the development path. According to García (2006), the main weakness of Chile are related to democratic governance and income distribution, while Figueroa and Calfucura (2010) also suggest that environmental policies should be urgently improved in order to avoid depletion and pollution.

Other key component of the social dimension is the income distribution in which Chile also shows a deficit. The gap with the USA and Canada has not been closed and the Gini index is still high, an aspect that can affect negatively growth due to the relation of this aspect with the stability and persistence of productivity dynamics in the long run (Castellacci and Álvarez 2006). As Morawetz (1977, p.41) point out "*it is not possible to grow first and redistribute later*," because progress is defining the pattern of distribution; indeed, multiples social protests and strikes in productive sectors have occurred in recent years, affecting social harmony and production as well.

Following the literature on NIS, there is a wide amount of variables that can be used to its analysis, including those related to inputs, outputs and processes. The production of scientific articles shows a clear convergence, but the distance to leaders is still large, being is indicator eight to nine times less than Australia, which is also consistent with the low technological capabilities. The combined gap of patents and scientific articles denotes lack of local capacities to generate new knowledge and technologies, which negatively affect growth. Even more and according to Bas and Kunc (2009) and Arias et al (2012), the patent production of Chile in the mining sector is principally done by non-resident inventors remarking this domestic default and confirming that international technology inflows remain being the cornerstone of Chilean growth. The statistics on royalties (payments) also show convergence, which is an example of catching up phase, but this is not sufficient condition for convergence since local innovation and R&D are development pillars of advanced economies when they are near the frontier (Porter 1990; Verspagen 1993).

There is also convergence in physical assets, such as infrastructures, a result that is consequence of the successful reforms applied in the past that lead the increase of foreign and local investments in road, telecommunications, ports, airports and other strategic facilities and public services, all of this with effects in international trade of NR and the country's competitiveness (Porter 1990).

Following the taxonomy described by Fagerberg et al (2007), during the eighties the Chilean economy was in a *catching up* stage, while in the nineties it moved toward *losing momentum* where it was during the 2000s. At the end of the period new signs of dynamism are observed, probably because of a high commodity prices (mainly cooper), rather than a real improvement of competitiveness, internal capacities or structural changes. This is also apparent in the competitiveness data reported by WEF (2013), indicating a worrying drop in this index.

Thus, intellectual capital doesn't seem to be enough to advance and support sustainable growth and incorporate to Chile within the developed economies group. The stock of Chile's innovation capability remains below advanced economies and far from the level of developed countries with similar industrial structures. Therefore, to achieve the goal of become a developed nation, Chile should invest more in intangibles assets.

6. Conclusions and policy implications

The contribution of this paper focuses on the identification of the key determinants of national strategies in developing countries based on NR in order to improve growth in the long run, avoiding NR curse and the MIC trap. Main attention is paid to the case of Chile, a developing country based on NR that is taken as example to illustrate the development path and to detect the factors that have contributed to reduce the gap. The findings can contribute to get implications for the definition and implementation of policies and they may also serve to other catching up specialized economies as well.

The empirical evidence and findings of this paper confirm that economies based on NR-industries can successfully face the potential negative effects and pressures of resource-exploitation by means of strategies that combine traditional economic principles with the knowledge-economy perspective, which considers intangible assets as a core part of development. For these economies, openness, inward FDI, institutions, technology, and capital investments are key aspects of the development process that permits the reduction of the income gap. In particular, the promotion of more physical investment, openness, inward FDI and technology capabilities is crucial for the definition of policy actions, from an integrative approach that combines tangible assets with other factors of the national system of innovation.

The data show that Chilean per capita GDP has converged to NR-specialized leaders, as well as the USA. The same trend shows education and openness dimensions, being Chile leader in inward FDI among the countries analyzed, a result related to both macro and micro economic reforms implemented since the seventies. Additional factors related to national system of innovation, such as scientific articles, royalties and infrastructures also present convergence with developed economies, confirming that Chile has based its growth mainly on physical assets and foreign technology, along with the development of absorptive capacities. However, there are still some aspects to reinforce the Chilean development strategy such as the improvement of technological capabilities, one of the main weaknesses observed in this study. It includes the development of scientific capacities, the increase of R&D

investment and activities, and the reorientation of education to innovation, through long-term policies that attend to the cumulative nature of these dimensions.

In the light of this analysis, the main bottlenecks of the Chilean development trajectory identified through a knowledge base approach allow us to derive some policy implications. Unlike the past, to conduct the progress toward a sustainable path in Chile, technical efficiency of this country is close to frontier reason why the opportunities of the implementation of best practices from other economies are scarce and the targets should be technology and social innovations more than management improvement. Moreover, foreign knowledge and technologies flow easily into the country, but could emerge new barriers and affect seriously the economic progress, if complementary measures do not enter into scene. Therefore, the task is to improve innovation (input, process and output), and to place it at the core of development policies, maintaining NR-specialized industries but adding value to exports and diversifying them. Thus, innovation capabilities become a long-term key policy, combined with foreign knowledge and tangible assets, aspects in which Chile has made significant progress. Accordingly, it can be affirmed that policies oriented to enhance the successful internationalization process are adequate, but now should be combined with initiatives to build local capacity. In addition, the analysis shows some weaknesses in the social context and particularly regarding inequality and institutions, aspects in which governments should pay more attention.

Further research will be devoted to analysis firm and sector levels, in order to provide more key aspects to policy makers, managers and entrepreneurs, as well as science actors, being aware of the fact that development requires balanced and integrative actions between all the components of the national innovation system. In addition, analysis with micro-data would allow us to include directly innovation variables from surveys. Finally, some limitations of this study that are common in economic research respond to the use of several proxies for the study of technological and intangible factors, and also development, although all the indicators are fully justified and the results show the same tendency.

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