"The role of Science and Technology (S&T) Policies in Natural Resources Based (NRB) Economies: The cases of Chile and Finland"

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Abstract: The study explores the role of Science and Technology (S&T) policies in NRB economies, focusing on the cases of Chile and Finland. Several authors have identified the exploitation of natural resources as a limiting-long-term factor affecting economic growth. Finland and Chile are worthy cases to study. Whereas the former was able to leave behind its Natural Resources Abundance (NRA) dependency by means of implementing policies promoting S&T as a driving economic force, the latter, albeit its successful open-market and export-led strategy, has not overcome the NRA hurdle. Using analytical tools I analyze first the S&T contribution to national income per capita over the 1981-2000 period, and second the relationship between S&T expenditures and NRA in both countries. I explain the diverging S&T performances in light of three factors: institutions, education, and decentralization.

1. Introduction

NRA has been at the center of an intensive and steady debate during the last decades. Is it a real "curse," deterring NRB countries from economic growth or a factor fueling economic growth once some conditions are fulfilled? Australia, Canada, the United States and the Scandinavian countries are successful cases of nations able of creating wealth over natural resources endowments, yet their development has not been limited by their exploitation (DeFerranti, Perry et al. 2002). On the other hand, scholars have cited the absence of sound property rights systems, high learning capacities or steady R&D investment rates as the actual reasons why NRB Latin American and African countries are not wealthier countries (Lane and Tornell 1996; Deaton 1999; Maloney 2002).

Analyzing the cases of Chile and Finland shows how diverging NRA-countries economic performances have been through the twentieth century. At the turn of the century, both countries were depending on their natural resources endowments: Chile on nitrate and copper exploitation, and Finland as an agricultural-based economy (Eyzaguirre, 2005; Blomstrom, 1991). The income per capita gap between the two countries was not significant, with Chile slightly outperforming Finland (Maddison, 1995). However, the adoption of several policies regarding trade liberalization, innovation and learning capacity boosted Finland to an in-depth national productive structure transformation becoming a competitive and knowledge-based economy (Schienstock, 2005). On the other hand, Import Substitution Industrialization (ISI) protectionism affected the dynamics of the Chilean economy by reducing the incentives to innovate and to compete. The outcome of the implementation of both strategies was an increasing income per capita gap between both countries during the second half of the century as their current income per capita performances confirm[1].

The article focuses on a comparative analysis for the cases of Chile and Finland regarding the role and effect of Science and Technology (S&T) policies on national economic growth. I devote special attention to comparing innovation performances using input and output indicators. In order to define the R&D contribution to economic growth, I use an Ordinary Least Squares (OLS) with robust standard errors covering the 1981-2000 period, expanding regular growth regression by using explanatory variables regarding NRA and R&D. I test two hypotheses. Firstly, I suggest that R&D contribution to national income per capita has been higher in the case of Chile than Finland (Hypothesis 1). Secondly, I predict that NRA has been a stronger complement of R&D in the case of Chile than Finland (Hypothesis 2). Stating both hypotheses takes into account previous work on the effect of R&D investment on economic growth suggesting that the returns to R&D in developing countries are above those of industrialized countries (Goal and Ram, 1994). Worth noting is that high and increasing levels of both S&T expenditures and human capital, solid institutions, a steady and fruitful public-private interaction, and the emergence of strong regional innovation systems are cited as key factors behind the technological Finnish success (Schienstock, 2005). The article is organize as follows: a) NRA literature review, b) Innovation Capacity measured in terms S&T Indicators in both countries, b) methodology, d) results and analysis, and e) conclusions

2. Natural Resource Abundance (NRA)

The concept of Dutch Disease has been introduced to help explain the impact of natural resources on economic growth. Coined as a term by The Economist in 1977[2] as a description of the decline of the manufacturing sector in the Netherlands after the discovery of North Sea oil in 1970, its theory states that an increase in revenues from natural resources will de-industrialize a nation's economy by raising the exchange rate making the manufacturing sector less competitive. Developed by Corden and Neary (1982) the Dutch Disease model divides the economy in three categories: a non-traded sector (services), and two traded sectors, a booming or tradable natural resources sector (oil, gas, mining, crops), and a lagging or tradable non-resource sector (manufacturing). It states that the greater the NRA, the higher the demand for non-tradable goods, shifting away labor and capital from the manufacturing sector.

Following up the Dutch Disease statement, several authors have deepened the discussion. Matsuyama (1992) has provided a formal model of the "linkage approach", exploring the role of agriculture productivity in economic development granting learning-

[1] Chile GDP per capita-2008: $13,270 (PPP)
Finland GDP per capita-2008: $35,660 (PPP)
World Development Indicators, The World Bank

[2] The Dutch Disease" (November 28, 1977). *The Economist*, pp. 82-83.

by-doing feature to the manufacturing sector. He comes to the conclusion that forces that push the labor force away from manufacturing and toward agriculture lower the growth of the economy by reducing the learning-induced growth of manufacturing. Furthermore, he points out that trade liberalization in land-abundant economies may slow growth performance by leading to resource shift from manufacturing towards agriculture.

Sachs and Warner (1995) show that economies with a high ratio of natural resource exports over GDP in 1971, have lower growth rates over the 1971-1989 period. The trend holds even after controlling for important growth variables such as initial per capita income, trade policy, government efficiency, investment rates and other variables. Mainly, they state that 1-standard-deviation increase in natural resources exports as fraction of GDP would lead to a 1 percent point per year slower rate of growth. However, it is worth noting that despite the negative relationship between NRA and economic growth the authors define as a mistake subsidizing or protecting non-resource-based sectors as a basic strategy for growth. In further studies, both scholars revisit the topic, reinforcing their prior conclusion by changing the base year to 1970 and by extending the dataset by one year to 1990 (Sachs and Warner, 1997), and by analyzing the role of geographical or climate variables and by answering whether there is a bias resulting from some other unobserved growth deterrent (Sachs and Warner, 2001).

Other studies support the Sachs and Warner NRA-negative relationship with growth performance. Gylfason et al. (1999) grants the fact that natural resource sectors create and need less human capital than other productive sectors, concluding that "an increase in either the share of the primary sector in the labor force or in the share of the primary exports on total exports from 5 to 30 percent from one country or period to another reduces per capita growth by about 0.5 per cent per year".

What kind of factors can be behind the harming-growth feature of NRA? De Long and Williamson (1994) notes that when a natural resource has high transport costs, then its physical availability within the economy is essential for the introduction of a new industry or a new technology. Lane and Tornell (1996) hold an explanation based on a "feeding frenzy" which starts with a windfall coming from either an improvement of terms of trade or the discovery of a new natural resource source which leads to a strong rent-seeking competition among power groups ending up in an inefficient exhaustion of public goods.

Stijns (2005) argues that once a natural resource boom starts out, developed countries are in better shape than Less Developed Countries (LDC) to face the challenge of NRA exploitation due to the well-defined and well-functioning property rights systems ruling the latter which contrast sharply with the weak and dysfunctional LDC economic policies. He states that in the LDC case, a natural resource boom may lead to wasteful rent seeking process and possible rising inequality. Deaton (1999) cites as the main problems in the specific case of African countries the low quality of investment, low processing level of exports, high concentrated mineral ownership, and the absence of complementary factors, particularly education.

However, several authors have stated that NRA not necessarily is a deterrent of growth performance. The cases of Australia, Canada, USA and Scandinavian countries do not confirm the rule of the "natural resource curse". In his long-run comparison of mineral-based and non-mineral based countries performances, Davis (1995) concludes that mineral-based countries outperform non-mineral countries. De Gregorio and Bravo-

Ortega (2005) argue that high levels of human capital may outweigh the negative effect of NRA on growth. They point to the case of Scandinavia as an example of how countries that are well-endowed with human capital may reach high growth rates through a simultaneous synergetic development of a natural resource industry and a high technology sector.

Maloney (2002) identifies barriers with deep historical roots to technological adoption and innovation as the causes of Latin America's underperformance, mainly a deficient "learning capacity" which has been intensified in the postwar period by the implementation of ISI policies. He notes that strengthening local human capital, reaching high literacy rates or promoting technical education, has reinforced the developed countries capacity to learn from what was happening abroad, accessing quickly to knowledge generated abroad, and, in the long run, establishing local clusters. De Ferranti et al. (2002) reinforce the assessment of NRA role according to endogenous capabilities, promoting engendering a high level of human capital and developing capacity for national learning and innovation.

Overall complementary factors may put NRA countries out of the "curse" path. NRA countries with high level of human capital, well-defined property rights systems, stable and homogenous economical-political system, and steady R&D investment, may transform their NRA into an important booster of their growth performance.

3. Innovation Capacity

To identify the major factors that have shaped the diverging economic performances of Chile and Finland, the analysis ought to be extended beyond superficial and short-term variables focusing on deep-seeded socio-economic and political factors. Blomstrom and Meller (1991) group factors explaining divergence between Scandinavia and Latin America into six clusters: natural resources and industrialization, trade and industrial policy, socio-political aspect and the role of the state, land reform, education and foreign technology. In terms of my research question I concentrate on both countries innovation capacity. Finland is a knowledge-driven economy focusing on achieving development through higher levels of competitiveness (Schienstock, 2005). The strategy has afforded Finland to overcome the hurdle of natural resources dependency to become a high-tech-driven nation (Dahlman et al, 2005). Chile has not been able to replicate such process yet. Though indicators may put Chile on the top of the list of developing countries, its low innovation capacity is still defined as a barrier to development (The World Bank, 2003; OECD, 2005).

4.1 S&T Indicators

The comparative analysis is divided in two sections: a) input indicators, and b) output indicators. Input indicators refer to S&T expenditures and number of researchers, whereas output to number of publications and patents.

a) Input Indicators

In terms of S&T expenditures, Chile and Finland have followed both increasing trends during the last decades either on absolute or per capita terms (see Figure 1). Nevertheless, their performances differ significantly. Finland total expenditures have been at least nine-fold and 26-fold larger than Chile's for each year in absolute terms and per capita terms, respectively.

As to the share of GDP spent on S&T, the difference remains, as during the 1981-2003 period Chile spent on average 0.55 percent of its GDP on S&T, far low than Finland's 1.98 percent (see Figure 2). It is worth noting that the gap between both performances has increased since the early 1990s which coincides with Finland's formal adoption of the National System of Innovation approach, strongly promoted among OECD countries at the time.

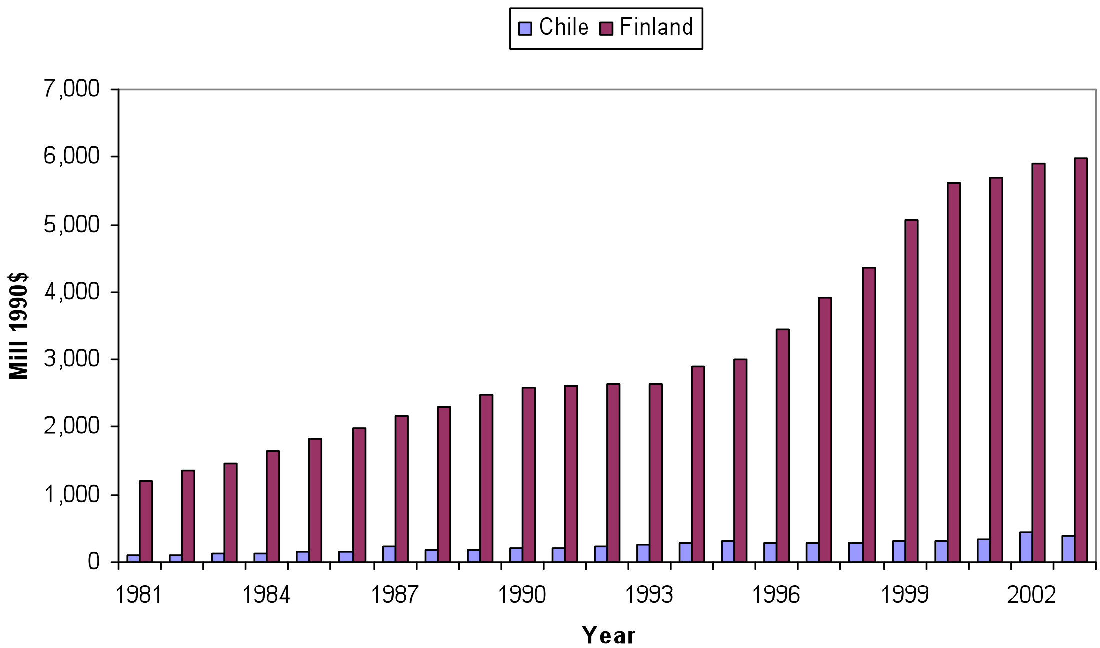

Figure 1: R&D Expenditures 1981-2003
Source: CONICYT

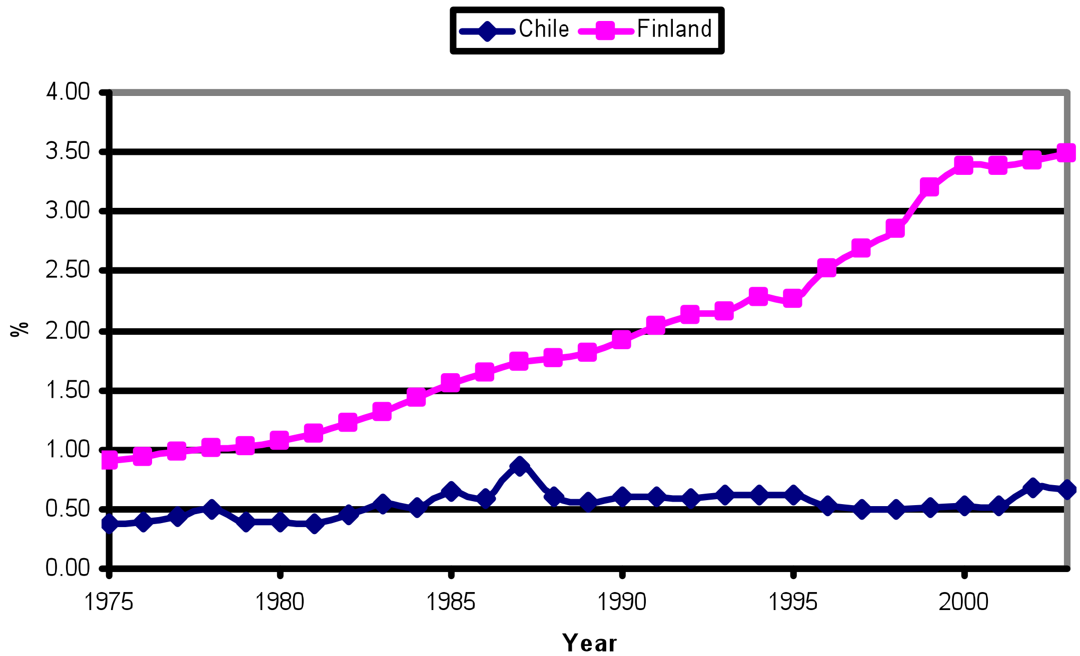

Figure 2: Share of R&D Expenditures in GDP
Source: CONICYT

With regard to S&T funding sources, 53 percent of Chile's S&T is publicly funded, whereas 37 percent is allocated by industry. Finland presents a quit different picture as 25.5 and 70.8 percent of S&T are publicly and privately funded, respectively (see Figures 3 and 4). It is worth noting that there is no sign of a changing pattern able to break the current stagnancy currently ruling the S&T funding in Chile.

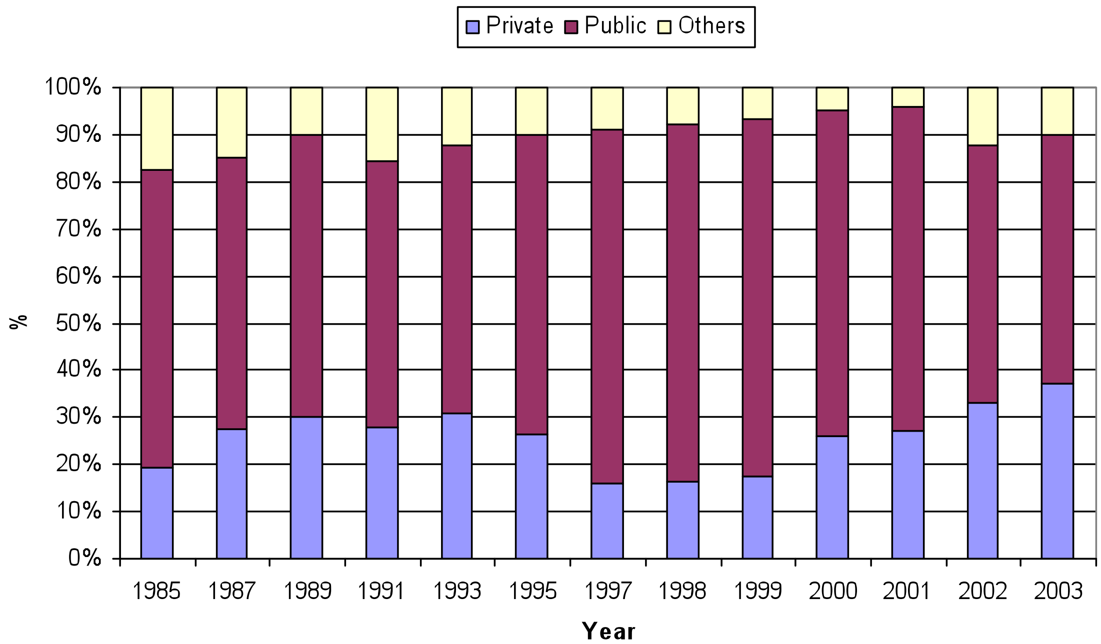

Figure 3: Chile-R&D expenditures by financing sector
Source: CONICYT

Figure 4: Finland-R&D expenditures by financing sector
Source: EUROSTAT

The trend is replicated when comparing number of researchers in each country. In the early 1980s, Finland already doubled Chile on number of researchers by having 8,837, whereas Chile had just 3,283. In the next decades the gap increased, particularly during the second half of the 1990s: whereas Chile reached 498 researchers per million inhabitants, Finland took off by peaking at 7,110 researchers per million inhabitants (see Figure 5).

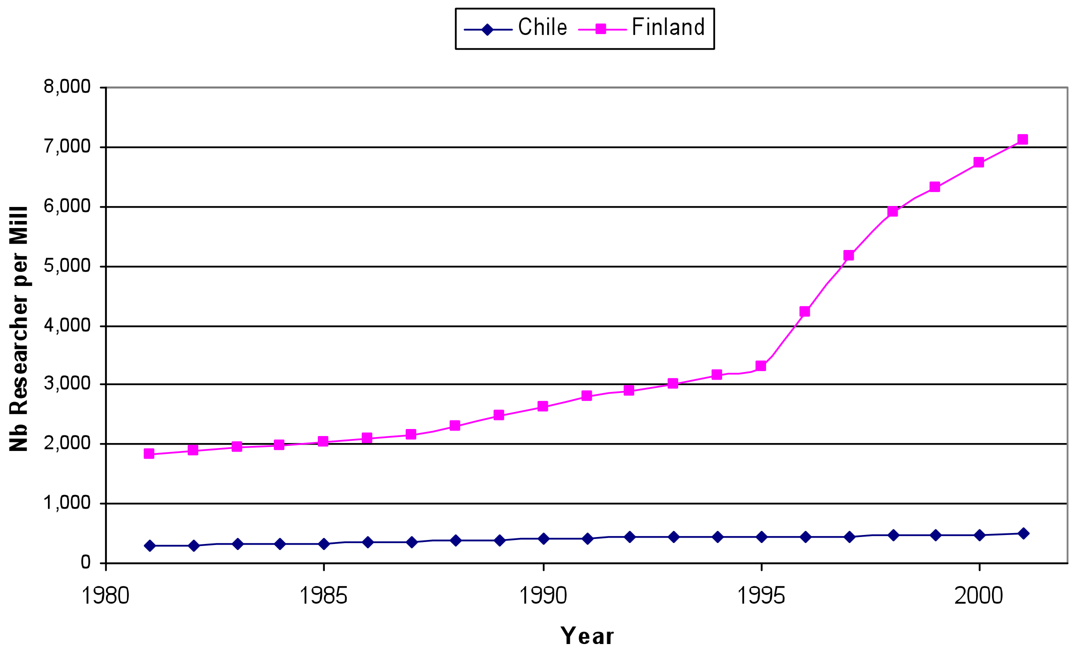

Figure 5: Number of researcher per million inhabitants
Source: RICYT, OECD Main S&T Indicators

b) Output Indicators

With regard to output indicators the Finland-outperforming-Chile trend does not change. Finland's researchers have been significantly most productive in publishing, experiencing a noticeable took off since the early 1990s. The gap among the two countries has done nothing but to increase during the last two decades being Finland publishing productivity almost ten times larger than Chile's in 2005 (see Figure 6). On the other hand, the performances are much more diverging regarding patent productivity (see Figure 7). Finland outperforms Chile, and the gap between both increases throughout the period considered. Chile patenting productivity has been stagnant not taking off during the last two decades.

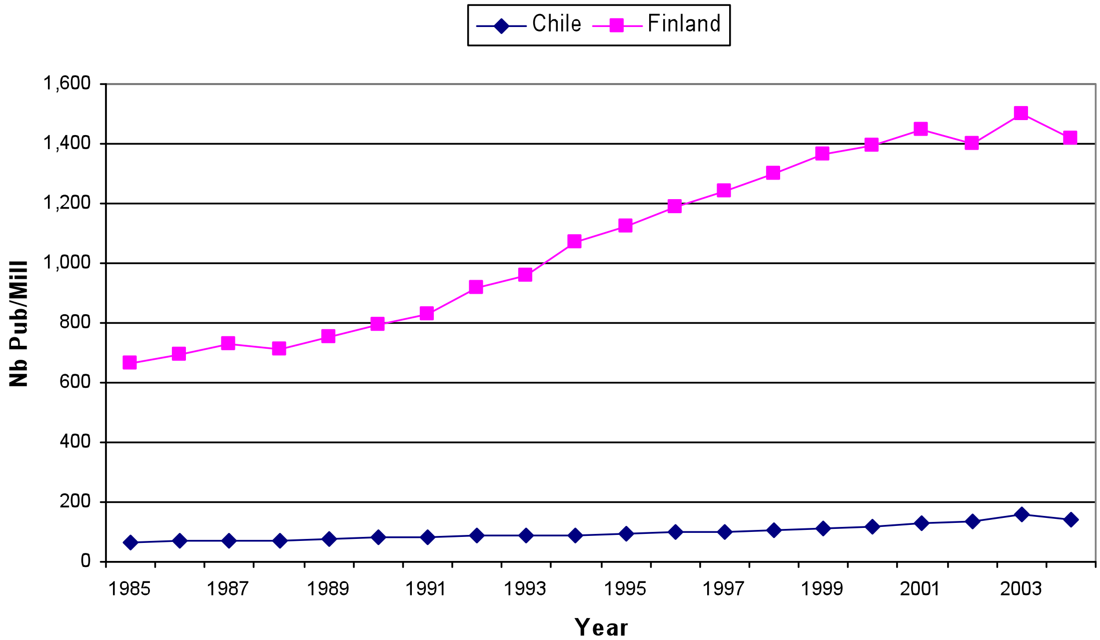

Figure 6: Number of publications per million inhabitants
Source: CONICYT, NSF

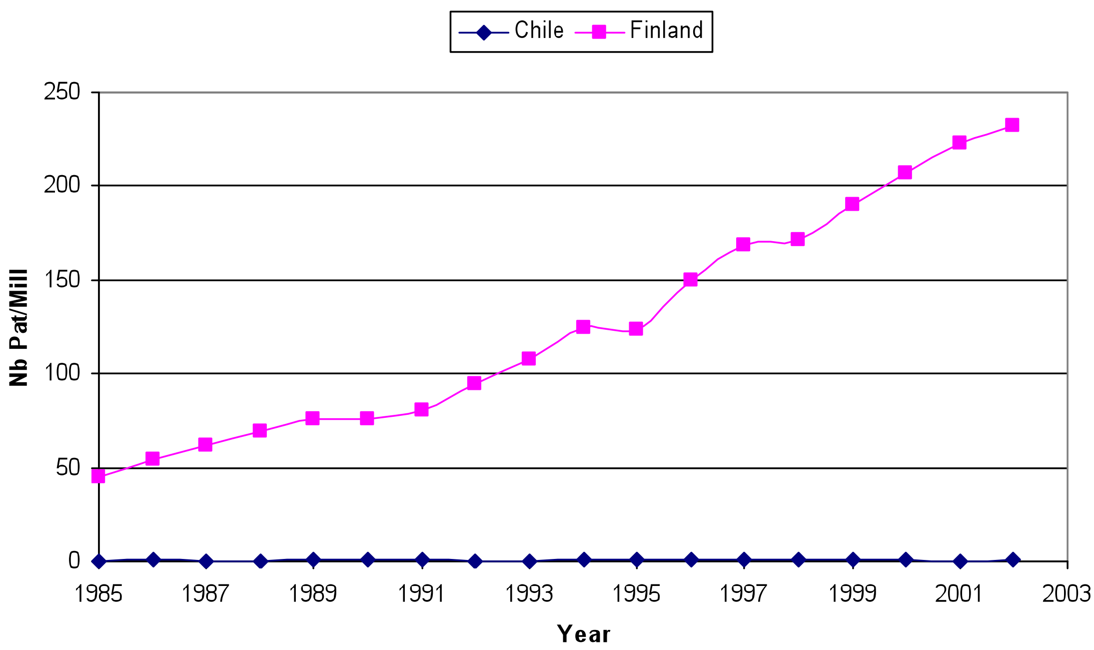

Figure 7: Number of patents per million inhabitants
Source: USPTO

5. Methodology

In order to test the role of S&T in both NRB economies, I draw upon prior economic growth theory (Solow, 1956; Arrow, 1962; Uzawa, 1965; Lucas, 1988; Romer 1986, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992; Barro and Sala-i-Martin, 1992; Mankiw et al, 1992; Helpman, 2004; Lederman and Saenz, 2005) to set two hypotheses:

Hypothesis 1: Chile's R&D contribution to national income per capita has been higher than Finland's over the period 1981-2000.

Hypothesis 2: NRA has been a better complement of R&D in the case of Chile than Finland over the period 1981-2000.

The log of GDP per capita over the 1981-2000 period is defined as the dependent variable, whereas four independent variables are considered: investment as a fraction of GDP (I); labor growth measured as yearly growth rate of the economic active population (L); the share of S&T expenditures in GDP (ST); and the share of natural resources exports in total exports (NR)[3]. Lags are likely to be occurred between S&T expenditures and economic growth (Rouvinen, 2002). Goal and Ram (1994) cite three types: a) lag between S&T spending and completion of projects; b) lag between project completion and the increase on productivity that may lead to economic growth; and c) a bell-shaped pattern in the time path of increase in productivity. The US Bureau of Labor Statistics proposes a 2-years-lag for applied research and 5-years-lag for basic research; CNIC-B (2006) identifies 4-years-lag as a lagging average, with variation across industries going from 2 years for telecommunication and electronic equipment to 5 years for pharmaceutical industry. In terms of my research question, in light of Chile's basic funding during the period covered I favor a 5-years-lag.

The data sources drawn upon are: a) the World Development Indicators dataset, b) International Labor Organization (ILO), c) Chilean National Commission of Science and Technology (CONICYT), d) Statistics Finland, and e) the COMTRADE database. I run an OLS regression with robust standard errors to prevent heteroskedasticity for each country case:

$$\text{Log GDPpc}_i = \alpha 0 + \alpha 1 * I_i + \alpha 2 * L_i + \alpha 3 * ST_i + E_i \quad [1]$$

Next, I add the NR variable and an interaction term (ST*NR) in order to analyze the NRA effect and the relationship between NRA and S&T expenditure.

$$\text{Log GDPpc}_i = \alpha 0 + \alpha 1 * I_i + \alpha 2 * L_i + \alpha 3 * ST_i + \alpha 4 * NR_i + \alpha 5\ ST * NR + E_i \quad [2]$$

6. Results

The results are presented in Table 2. In regard to Hypothesis 1, in both country cases the share of S&T expenditures in GDP is positively correlated with income per

[3] As natural resources endowment is measured in value terms it captures not only supply effects but also impact on current account and/or in exchange rate of higher prices of some commodities

capita. For the case of Chile, an increase of 1 percentual point in the ratio of S&T expenditures to GDP has increased by 29.215 percent GDP per capita. For Finland, an increase of 1 percentual point in the ratio of R&D expenditures to GDP has increased by 27.89 percent GDP per capita. In both cases the variable is significant at the 1 percent level. Hypothesis 1 is accepted.

In regard to Hypothesis 2, the interaction term ST*NR is positively correlated with income per capita in the Chile's case, whereas it is negatively correlated in the Finland's case. That would mean that in the case of Chile higher S&T expenditures would decrease the negative effect of NRA on income per capita, and that in the case of Finland a higher level of NRA decreases the positive effect of R&D expenditures. The variable is significant at the 5 percent and at the 1 percent level in Chile's and Finland's cases respectively. Hypothesis 2 is accepted.

TABLE 2 Results

	EQUATION 1		**EQUATION 2**	
	CHILE	**FINLAND**	**CHILE**	**FINLAND**
Investment/GDP	0.216626***	0.188143***	0.0164888***	0.0168206***
Labor Growth	-0.524572***	0.573885***	-0.4584461***	0.2665227
R&D/GDP	0.291519***	0.278951***	-3.819181*	0.47787***
Natural Resources			-.037045***	0.0107955*
R&D/GDP*NR			.0455671**	-0.0182648***
Constant	9.558367	8.939639	12.8033***	8.986311***
R2	0.9809	0.8717	0.9903	0.9131
Observations	20	20	20	20

*** significant at 1%
** significant at 5%
* significant at 10%

7. Analysis

7.1 Hypothesis 1

Before discussing Hypothesis 1 results, I stop on the analysis of two variables considered in Equation 1: Investment Rate and Labor Growth. It is worth noting that in both cases, the return to R&D is higher than the return to physical. Regarding labor growth, in the case of Chile the variable is negatively correlated with income per capita, whereas in the case of Finland the correlationship is positive. In both cases, the variable is significant at the 1 percent level. At first sight, we may be leaned to conclude that as Finland has a high-quality education system, with high enrollment rates and high average years of schooling, an increase in the labor force may lead to an increase in the availability of high skill workers, having the economy to its disposal a better trained manpower. Following that rational, the negative correlationship of the Chilean case may be explained by the lower quality of its educational system, which would generate on average workers with lower skill than Finnish workers. Nevertheless, other factors have to be taken into account. Economic Active Population (EAP) may vary according to economy's fluctuations. As economies jump into recession times EAP may increase or decrease, since either more people starts looking for job or people get discouraged. In recovery periods, EAP may either grow pushed by an increasing amount of people looking forward getting a new job as the odds of achieving one increase or decrease as the so called "secondary" labor force returns to home. It is worth to note that in the long run EAP and economy growth may vary following the same direction but in the short term such pattern may be different. During the considered period (1981-2000), Chile and Finland went trough pervasive economical crisis, therefore EAP effect might be pushed by endogenous short-term factors, which have to be considered on the analysis of the EAP effect on economic growth.

Back to Hypothesis 1, Barro (1991) points out that an S&T dollar buys greater increases in productivity for Less Developed Counties (LDC) than for innovating countries. Goel and Ram (1994) estimate an R&D return rate of 19.6 percent for a sample of 52 nations including innovating countries and LDCs. They replicate the model by limiting the sample to 18 LDCs, estimating an R&D return rate of 41.5 percent. Therefore, the results obtained are in accordance with previous research and particularly with the central statement that an S&T dollar has a higher return in LDCs than in industrialized or innovating countries. In my model, Finland's wealthier innovation-driven economy would be the reason of Chile's S&T return better performance. However, we must have in mind that in order to reach its current economical and technological level Finland started out decades ago a comprehensive process involving socio, economic, and political issues leading to an increasing stock of knowledge. At this point, it is worth to bring up Helpman (2004) who notes that the transformation of Western countries into modern economies would have not been possible without the formation of institutions that encouraged the creation and accumulation of knowledge and its application to new technologies. What has been the Finland's case? According to Lemola (2003) a systemic upgrading of public policies, institutions and instruments are the seed of the R&D Finland's success. Public policies were designed aiming to meet the dynamics of not only the local but also the global industry innovation demand. In addition, Dahlman et al (2005) cite education as a second pillar of Finland's success by defining it as "the key to both the supply and demand of innovation". They state that in absence of a sufficiently trained workforce new technologies hardly would be adopted or created: human capital complements technological advances. Another interesting feature of Finland's economical transformation is that becoming an innovating country was complemented by geographical-homogenous development. In general, high rates of economical and population concentration may become significant barriers to development, particularly for innovation nodes emergence (Castells and Hall, 1994). Finnish authorities achieved regional development by implementing strategies based on using higher education and S&T as engines of regional economic growth (Castells and Himanen, 2001).

I state an analysis of the evolution of S&T public policies in both countries aimed to identify the S&T-factors that led Finland to leave behind its natural resources dependency transforming it in an innovation-driven economy. Such pool is part of the set of causes explaining its current wealth and which would justify the return to S&T the model estimates. I focus on three categories: a) Institutions, regarding the evolution of institutions and public policies related with S&T, b) Education, regarding the human capital policies and their influence in S&T developments, and c) Decentralization, regarding the role of regional development in knowledge generation.

7.1.1 Institutions

Castells and Himanen (2001) point out that it would be wrong to claim that "the rise of information technology was just a result of the recession, and even more wrong to think that Finnish information-societies strategies written since 1994 have been its source". In the early 1960s, Finland's industry was mainly concentrated on natural resources exploitation and characterized by a low level of technology deterring it from having a competitive position at international markets. Therefore, catching up with more competitive economies was the main shaping force setting the S&T national system. Such task was carried out taking into account the example of more developed countries and the trade liberalization dominant trend at the time.

Lemola (2003) breaks down the S&T public policies development in three eras: a) R&D policy, b) Technology policy, and c) Innovation policy. The also called "Era of R&D Policy" covering the 1960s and the 1970s was characterized by the setting up of some of the main Finnish S&T organizations regarding planning, funding, and coordination tasks. The Science Policy Council (SPC), a ministerial committee, was created in 1963 aimed to coordinate R&D actions. In 1961, the older research councils were gathered under a central body, the Academy of Finland assuming the research funding task. The Finnish National Fund for Research and Development (SITRA) was established in 1967 to support industrial R&D. Once the laying of S&T system foundations occurred, a singular discussion on how to carry out the development Finland S&T started. Partisans of science-oriented strategy promoted strengthening the role of the Ministry of Education and its operational agencies as coordinators and funding agents, and to concentrate science development on university research. On the other hand, interested groups promoted a technology-oriented strategy highlighting the role of the Ministry of Trade and Industry. At the beginning the science-oriented trend dominated the scene; however, at the turn of the 1970s, the technology partisans gained room in the discussion leading technology to become the center concept of future S&T strategies.

During the 1980s, Finland left behind science-oriented positions promoting technology as the core of its goals. Technology was perceived as an instrument able to raise economic growth through the emergence of the new business areas. The "Era of Technology Policy" started out characterized by an increasing government role regarding industrial innovation promotion. As an outcome of such strategy, the government decided to raise the S&T expenditures from 1.2 percent of GDP in 1982 to 2.2 percent by 1992 (Castells and Himanen, 2001). In order to meet the new-strategy goals, two key organizations were created: the National Technology Agency (TEKES) in 1983 and the Science and Technology Policy (STPC) in 1987, based on the former SPC. In addition, the decade was well-known by the creation of several technology transfer, diffusion and commercialization organizations stemming the emergence at a steady pace of spin offs and technology parks. The last phase, “The Era of Innovation Policy”, started at the early 1990s. The assimilation of the concepts of National Innovation System and OECD-Knowledge-based Society was the main driven of growth. Finland integrated the NIS systemic approach of innovation and in order to adapt the OECD premise created the conditions for knowledge-intensive growth by implementing measures relating to R&D, education, competitive conditions, intellectual property, national and international networks, and technology transfer and exploitation (Lemola, 2003).

Comparing the Finland S&T development with Chile’s, several differences can be highlighted. Firstly, since the late 1960s Finland has had a central public organization in charge of governing and planning the S&T national system: STPC. Organized directly under the Prime Minister’s authority, STPC states the major goals and tasks regarding S&T, using a top down approach to spread its decisions (Castells and Himanen, 2001). Chile has lacked such type of formal organization. Each public agency sets its own planning regardless external activities. Even more, despite the inclusion in its title of the “National Commission” concept, CONICYT has not been a planning discussion organization. Its role has been restricted mainly to funding tasks. It is worth to note that as an outcome of the discussion on the allocation of funds coming to S&T tasks from a new mining tax, a National Innovation Council for Competitiveness (CNIC) integrated by public, private and academic agents has been recently created. It would be advisable that CNIC assumes an STPC role alike; otherwise current problems such as duality in funding and task allocation, and lack of homogeneity in the decision-making research area process will not be completely overcome.

Secondly, in general, the S&T public supporting structure has been set up much earlier in Finland than Chile. Organizations such as SPC, Academy of Finland and SITRA were established in the 1960s. In the case of Chile, only CONICYT was created at that time, and its first significant fund, FONDECYT, was established in 1981, and aimed to fund basic research activities. In regard to technology institutionalization, despite its main boost started in the late 1970s, especially with the creation of Tekes, several prior policies had defined it as one of the main public agencies targets. In the case of Chile, the advent of democratic government in the early 1990s was the main technology-policy driven. The launch of several technology-oriented-publicly-funded programs was accompanied by a reorientation of CORFO’s goal. Since the early 1990s CORFO has been the main promoter of technological development at the firm level in Chile, leaving behind its prior industrialization promoter role. Comparing only the setting dates of the public organizations involved in NIS, including the reorientation of preexisting agencies, there is a significant delay in the Chilean case regarding Finland.

Thirdly, Chile lacks significant private investment in innovation. Only a 33.2 percent is funded by the private sector, contrasting with the 70.8 percent of Finland, and the OECD average of 65 percent. According to CNIC-C (2006), such performance is an outcome of the scarce relevance attributed to innovation within the firms’ strategy, and to the innovation absence in their productive routines. Such rational is in part related with the commodities-intensive productive structure dominant in Chile, which deters the country from added-value-chains. Even though Chilean firms well-perform regarding “soft” innovation related with management tasks, “hard” innovation has not been a common target in Chilean firm practices. Such premise has led to lack of innovation culture which is reinforced by several factors at the firm level: low availability of venture capital; scarce presence of individuals with technological innovation management capacity; insufficient information regarding public innovation supports; and the weak firm interaction at cluster level (CNIC-C, 2006). Such situation diverges from Finnish policy of incentives. Tekes has fully assumed its funding research task for which it has been recognized at the international level (Castells and Himanen, 2001). According to Schienstock (2005) one of the most effective ways to improve the quality of research in Finland has been increasing the share of competitive funds. Besides, SITRA has evolved from a funded technology research task to a venture capitalist role aimed to finance the beginning and expansion of start-up companies that have already received research funds from Tekes.

7.1.2 Education

According to Maloney (2002), learning capacity is built over national human capital performance and the networks of institutions that facilitate the adoption and creation of new technologies. I focus my analysis on variables regarding human capital capacity by breaking down the analysis into three categories: literacy, primary and secondary enrollment, and tertiary enrollment.

Since the nineteenth century, Scandinavian countries have followed a tradition of high literacy rate. Finland has not been the exception: almost 89 percent was literate in 1890 (O'Rourke and Williamson, 1995). In contrast, Chile inherited from its Spanish colonizers, a low-entrepreneurial mentality which led to both a high concentration of wealthy individuals and high rates of marginalization affecting the access to education: Chilean literacy rate was barely 30.3 percent in 1890 (Engerman et al, 1997). Despite its significant increase over the years, the earlier low Chile's literacy performance represented a serious disadvantage.

With regard to primary and secondary enrollment rate, both countries have reached high levels during the last decades. Firstly, both countries have attained gross enrollment rates of primary education above 100 percent in 2004: 101 percent in Finland and 104 percent in Chile. Worth to highlight is Chile's behavior regarding gross enrollment rate of secondary education, jumping from 53 percent in 1980 to 89 percent in 2004. Such increase was based on strong coverage policies undertaken during the 1990s. However, despite of such progress, Chile's educational system still presents several quality disadvantages regarding Finland's. Chile's performance in the Third International Mathematics and Science Study (TIMSS) of students was poor ranking 35th among 38 countries in both categories math and science, whereas Finland ranks at 14th and 10th positions respectively (TIMSS, 1999).

The tertiary education enrollment presents the most significant difference. At the early 1980s, Finland had a gross tertiary enrollment of 32 percent which increased up to 90 percent in 2004. During the same period, Chile started at a low 12 percent, attaining in 2006 a 43 percent rate, mainly boosted by the emergence of private-funded universities. Among tertiary students the Science and Engineering (S&E) enrollment rates score at similar levels: 31.4 percent for Chile, and 38.2 percent for Finland. I highlight such statistic due to the S&T input category of S&E graduates. Most of them will work on either technological development issue or knowledge creation, and some of them will be part of the S&T national community. In that sense, the number of researchers in both countries has increased during the last decades but at different pace. The number of researchers in Finland has seen an increase of almost threefold during the 1983-2001 period whereas in the case of Chile, the increase was by 52 percent[4]. Furthermore, Finnish researchers have a major likelihood to work in the private sector than their Chilean colleagues: 30 percent of them jump into local firms whereas just 6 percent do it in Chile (Tokman and Zahler, 2004).

In 1981, the OECD made a review of Finnish educational policy recommending carrying out a thorough polytechnic reform, which was rejected by the Finnish authorities at the time arguing that such proposal was out of the national targets therefore an allocation of resources was not feasible (MINEDU, 2004). However, later on MINEDU restudied the OECD proposal, and decided to launch a Vocational Education and Training (VET) reform which would include not only the establishment of polytechnics but also a strong cooperation between upper secondary schools and post-comprehensive vocational schools (MINEDU, 2004).

In 1991, the Finnish Parliament enacted the beginning of the VET reform. Following this legislation, 22 polytechnics were set up across the country, merging the 250 VET's schools existing at the time according to disciplinary and regional criteria (MINEDU, 2004). The new polytechnics have undergone rapid growth. Between 1992 and 1999 the number of applicants and the number of first-year student rose fourfold and fivefold respectively. It is worth to note that 89,700 people applied for 24,040 places in 2000. However, the most impressive increase regards the total number of polytechnic students, which have risen twentyfold since the early 1990s (Kekkonen, 2005).

7.1.3 Decentralization

According to Kautonen et al (2005), Finnish regional innovation systems successfully implemented have afforded GDPs 20 percent higher than the national performance for those regions over the 1995-1999 period. However such success has been paved over two main development factors: human capital and institutions. Regarding human capital, the National Government aimed to prevent a high concentrated supply of high skill workers by implementing, from the 1960s onwards a network of regional universities with emphasis on engineering and technology. Before that, only Helsinki and Turku had full universities. Castells and Himanen (2001) cites several Finnish regions as examples of regional development regarding the technological university settlement: Tampere, where two universities played a major role in the implementation of the Tampere's information cluster; Oulu, nowadays an ICT pole which has transformed the region in the fourth major metropolitan node in Finland; Rovaniemi, where setting up a new technology-oriented university was the key for the revival of high value-added industries, and Lappeenranta, where the process of growth was clearly associated with the presence of a new technology-oriented university. The polytechnic reform started in the early 1990s, with a clear homogenous-development criterion, has been the "second wave" of this technology-regional-oriented educational reform by covering the demand of high skill workers able to participate of high tech production process. Regarding institutions, the national government undertook important reforms. First, a reduction of the number of administrative districts was implemented looking for a lower bureaucracy and higher capacity to shape more fitted regional innovation policies

[4] CONICYT Indicators, www.conicyt.cl

(Schienstock, 2005). The Center of Expertise Program (CEP) was launched in 1994 aimed to improve knowledge base by focusing on regional strengths and by promoting joint-multidisciplinary project. In addition, Ministry of Trade and Industry, Ministry of Labour and Ministry of Agriculture jointly combined their regional efforts in the Employment and Economic Development Centers (EEDC) at the regional level. Fifteen centers countrywide have been settled providing a comprehensive range of advisory and development services for businesses, entrepreneurs, and private individuals. Both types of factors have contributed to the emergence of technology parks throughout Finland taking advantage of public incentives and well-trained manpower.

With regard of the Chilean case, I organize the analysis in two points. Firstly, Chile historically has been a concentrated country in terms of population and political and economical power. Nowadays, forty percent of the population lives in Santiago[5], the national capital, whereas just 18 percent of Finnish population lives in Helsinki[6]. Despite some governmental initiatives and the Regional Reform launched in 1992, Chilean political and economical powers are mainly concentrated in Santiago. Secondly, regarding innovation activity, the centralization persists: 50 percent of the Chilean researchers work at the capital and 60 percent of the FONDECYT, FONDEF and Technological Development National Fund (FONTEC) budgets have been allocated to projects presented in the Metropolitan Region during the 1990s (Academia Chilena de Ciencias, 2006). In addition, despite the successful examples of the fruit, salmon and wine industries (Giulani, 2004), the concept of technological cluster has not reach its maximum potential (World Bank, 2003). In the emergence of the Chilean clusters already mentioned, there was an active participation of public agents, and technology transfer institutions such as Fundación Chile as support organizations. However, before both the CORFO's initiative of the upper 1990s and CONICYT's regional knowledge programs launched in 2001, Chile has not promoted or implemented a steady regional knowledge generation policy such as Finland did which would lead to a more homogenous development through the emergence of development poles along the country.

7.2 Hypothesis 2

In order to analyze Hypothesis 2, it is worth to bring up De Gregorio and Bravo-Ortega (2005) who point out that economies with rich endowments of human capital and close linkages between natural resources and industrial activities can formalize "the idea of the joint development of an industrial or high-technology sector simultaneously with natural resources". They highlight the case of the forestry industry in Scandinavia where the development of natural resources was accompanied by the growth of an industrial base linked to the forestry sector. So, one way to offset any possible negative effect coming from a natural resources dependency may be the emergence of new technology-based industries whose emergence would be conditioned by both having high-skill manpower and high rate of R&D investment. Such phenomenon would afford not only a reinforcement of natural resource industries but also the establishment of new industries that may lead in the long term to significant modifications of the current productive structure. According to Dahlman et al (2005), the diversification of export portfolio has been mandatory to the improvement of Finnish economy stemming from a steady

[5] Instituto Nacional de Estadisticas, Chile, www.ine.cl
[6] Statistics Finland, www.stat.fi

promotion of higher education, linkages and spillovers among industries, and the spawn and spread of new knowledge-based industries. Dahlman et al (2005) traced back into Finnish knowledge-based economy evolution by establishing its roots into user-producer linkages between forestry-based firms as user of high technology, and the emerging engineering, electronic and ICT industries in the 1960s. They analyzed the economic development of Finland by breaking it down in three chronological phases and by identifying their major features regarding technology-behavior and product-type (see Figure 1). Chile's case is different. The consolidation of Chilean natural resources industries has not been accompanied by the emergence of knowledge-based industries capable to supply them with intermediate or input products. The human capital richness and high R&D budget conditions are not fulfilled in the Chilean case, therefore natural resources-based industries are still constraint to low added-value products. Such situation contrasts drastically with Finland's industrial evolution where natural resources based industry were not only complemented by high tech industry but also were part of the market forces pushing for the latter's spawn and boo

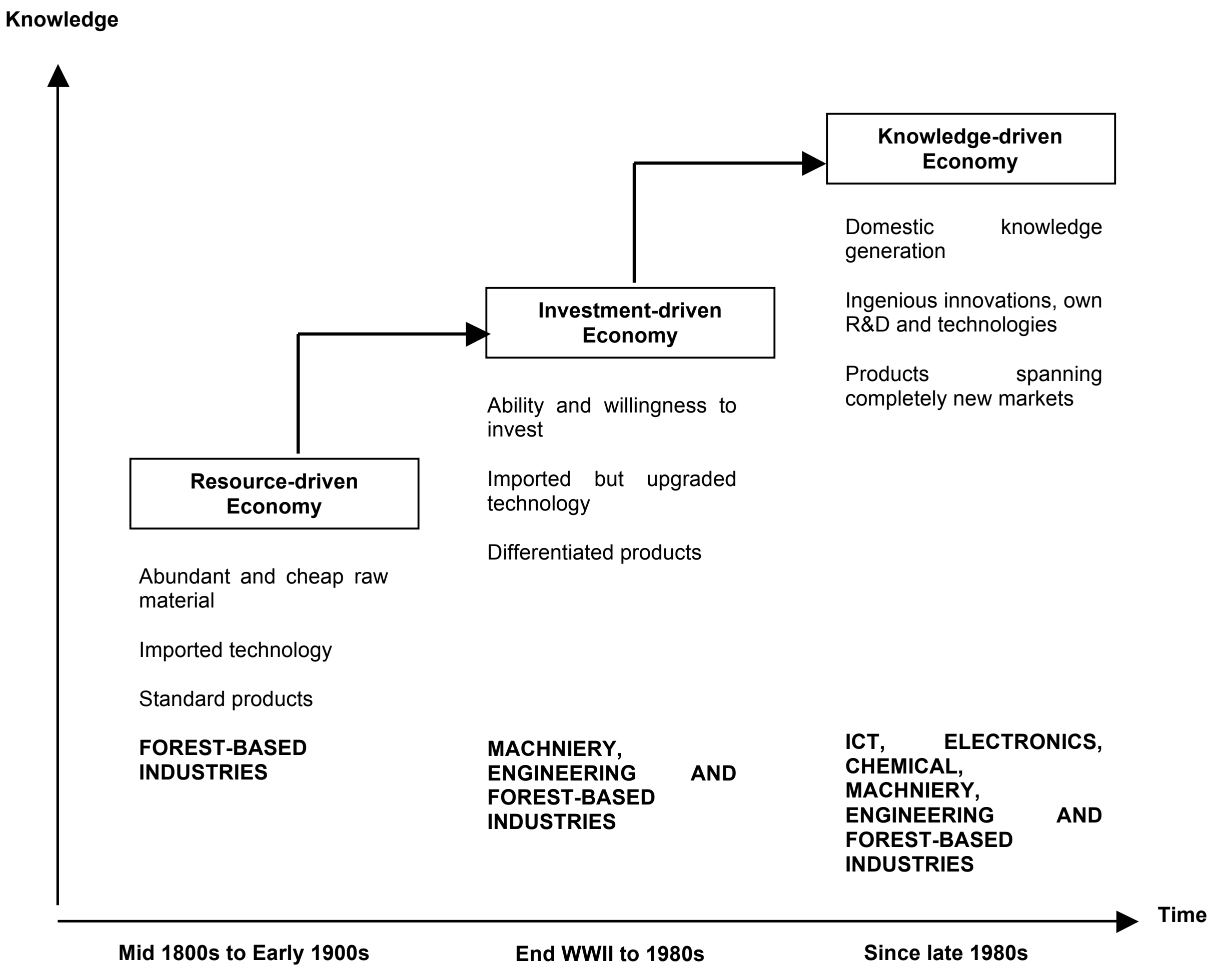

Figure 1 Finland's Stages Industrial-Economic Development
Source: Dahlman et al (2005)

Back to Hypothesis [2], an increase of 1 percentual point in the share of natural resources exports in total exports has increased by 1.07 percent Finland's income per capita. The Finland's higher and positive return to NRA is justified by its high R&D and education performances. As Finland opened its economy during the Post WWII period, its exports started to be subject to higher quality standard requirement. The challenge was addressed promoting technology creation and diffusion at the production level. In addition, by means of delivering better educational training, Finland's workforce became a high skill one, able to participate in the industrial challenges of the knowledge economy. Finland's natural resources endowment has not been a barrier to development; quite the contrary, it has been an important catalyst, not only regarding its own activity, but also pushing the emergence of new high-tech sectors. In the case of Chile, an increase of 1 percentual point in the share of natural resources exports in total exports has decreased by 3.70 percent Chile's income per capita. Therefore, Chile's return to NRA is not only smaller than Finland's but also negative. As I mentioned before, having low human capital performances and a low innovation capacity has deterred Chile from jumping into the knowledge economy postponing a high-tech industry spread. The strong natural resources dependency has not been left behind, and the establishment of "lateral" industries able to supply them with high-tech inputs has not accompanied its consolidation. Therefore, for Chile's case NRA has had a negative effect on economic growth but it has to be highlighted that NRA has not put Chile away of a steady growth path particularly during the last two decades.

Analyzing the interaction term coefficient gives us interesting insights on the evolution between R&D and NRA. Return to NRA has increased with R&D by 4.5 percent and has decreased by 1.8 percent in Chile and Finland respectively. The fact that Chile's coefficient is greater than Finland's may be contradicting the previous analysis on NRA effect on development. However, the explanation may be on the differing S&T capacity. As Chile S&T capacity is low and its dependency on natural resources high, an increase on S&T investment decreases the negative NRA influence, or in other words the returns to NRA rise with S&T. S&T offsets the NRA's negative effect on economic growth. Those results are in accordance with those of De Gregorio and Bravo Ortega (2005). The same effect is not only smaller on Finland, but even negative. The negative performance on the interaction term means that as NRA increases the positive return to S&T decreases. The explanation may be on the high S&T capacity and on the lower NRA dependency. Finland's economy is nowadays moving towards a much higher high-tech exports share becoming a much more knowledge-intensive economy. Such process has afforded a much higher economic productivity and a much higher S&T concentration on high-tech industry[7]. So, as NRA-dependency has been left behind, turning back to it would decrease the return to S&T since the economy would have been more concentrated in other areas with much higher S&T return. Overall, the pattern of the S&T and development relationship may be partly replicate with S&T and NRA: a dollar invested in S&T in a NRA-country closer to the technological frontier would have a smaller effect than in NRA-countries with low innovative capacity on decreasing the plausible NRA negative effect on economic growth since innovating countries must invent the new technologies that push the frontier forward. On the other hand, NRA-countries with low

[7] Nokia's R&D investment represents 30 percent of national R&D investment (Blomstrom et al, 2002)

R&D capacity would be able to decrease the NRA negative effect by catching up to the technological frontier.

8. Conclusions

Finland's success draws upon the conjunction and steady upgrade of a set of factors: institutions, human resources, and decentralization. At the mid-twentieth century, Finland opened its economy, putting national production under the requirement for high standard products. To address such demand, Finland reformulated its development strategy affording not only improvements of then-produced NRB goods and services, but also the emergence of a new high tech industry. On the other hand, however Chile's trade liberalization and highly recognized economic and institutional regime, the country remains as a low-added-value-good producer not able to become yet a knowledge-driven economy. Nevertheless, Chile is working on bridging the gap. Several publicly funded S&T initiatives have been launched, aimed to increase public and private S&T expenditures, to establish technological clusters, and to improve and increase human capital stock. Furthermore, a major discussion regarding S&T public governance is leading to the proposition of a new institutional framework. In general, despite the cross-country differences, *Chile is following today a relatively similar S&T path that Finland started decades ago*, and as Chile's former Minister of Economy has pointed out "…Chile has already consolidated trade liberalization, where competitiveness is essential…".[8]

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[8] Chile's Minister of Economy, Alejandro Ferreiro, El Mercurio March 10th, 2007

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