OECD Reviews of Innovation Policy

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Foreword

This review of Chile's innovation policy is part of a series of OECD country reviews of national innovation systems*. It was requested by the Chilean authorities, represented by the Ministry of Economy, and was carried out by the OECD Directorate for Science, Technology and Industry (DSTI) under the auspices of the Committee for Scientific and Technological Policy (CSTP).

This review draws on a background report prepared by the Chilean Ministry of Economy as well as the results of a series of interviews with major stakeholders in Chile's innovation system and a peer review meeting within the CSTP**. The review was drafted by Gernot Hutschenreiter (Country Review Unit, DSTI, OECD), Patricio Velasco (consultant to the OECD, former Director at CONICYT, Chile) and Guillermo Rozenwurcel (consultant to the OECD, Professor at UNSAM, Argentina), with contributions from and under the supervision of Jean Guinet (Head, Country Review Unit, DSTI, OECD).

This review owes a lot to Chilean government officials, in particular Marcia Varela, who helped in providing background information, arranging the interviews in Chile, and supporting the OECD team throughout the review process.

* See www.oecd.org/sti/innovation/reviews.

** During this meeting the examiners from OECD Member countries were Alpo Kuparinen (Finland) and Roger Ridley (New Zealand).

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OVERALL ASSESSMENT AND RECOMMENDATIONS

Chile, a small, open economy with traditionally strong resource-based production, has recorded an impressive economic performance over the last two decades. Growth of gross domestic product (GDP) per capita accelerated at a remarkable 5 to 6% a year in the 1990s, more than twice the long-term trend of 2.4% over the preceding 40 years. After a short-lived period of stagnation at the end of the 1990s, growth picked up again sharply in 2004 and 2005, partly owing to favourable conditions in Chile's main export markets.

As a result, Chile has significantly reduced the gap in income per capita with advanced countries, and it has been the top performer in the Latin American region over the last two decades. With GDP per capita of about USD 11 000 in purchasing power parity (PPP), Chile ranks among the high middle-income countries. The remaining income differential is to some extent due to lower utilisation of labour, but its main source by far is a productivity gap. While Chile's income gains have considerably alleviated poverty, the distribution of income has remained exceptionally unequal.

Chile's strong economic performance of the past two decades has been underpinned by its economic reforms and the building of modern and stable institutions. It has followed best international practices in the areas of macroeconomic management and development of market mechanisms. Its monetary and fiscal stability is reflected in sound public finances and in an inflation rate that is steadily declining towards the level of developed countries. Openness to international trade and foreign direct investment (FDI) has featured prominently among the factors explaining Chile's success in deriving increasing income from its comparative advantages. International openness has also contributed to the development of well-functioning markets and made possible a boom in exports by industries that exploit Chile's comparative advantages.

The emergence of dynamic, export-oriented activities revealed that the Chilean innovation support system was largely unable to deliver relevant services and knowledge. Partly as a response to new, more sophisticated demand from some firms, but also in response to other needs of the society and economy, Chile has started to build a more comprehensive innovation system, although at a slower pace than in the case of other institutional pillars of an efficient, market-oriented economy.

A growing political awareness of the importance of innovation for the country's future has resulted recently in three bold decisions which are in line with international best practices: the creation of an Innovation Council for Competitiveness, entrusted with the mission of proposing guidelines for a long-term national innovation strategy; the increase of public resources available to implement this strategy through the introduction of a specific mining tax; and the encouragement of the business sector to engage in this strategy through the introduction a R&D tax incentive. This report assesses the current status of Chile's innovation system and policies with a view to determining the areas that most require improvement in order to make the most efficient use of this additional public investment.

The Chilean innovation system: distinctive features, main weaknesses and potential

Some of the characteristics of the Chilean economy should be kept in mind when assessing the current status and envisioning Chile's future innovation system and related policies, notably:

- *Geography.* Chile is remote from major markets and knowledge centres. In addition it stretches over 4 300 km, a distance roughly the same as that from San Francisco to New York. At the same time, its width never exceeds 240 km, so that its length is more than 18 times its widest stretch. Its geographical position and its topography offer a number of challenges, especially for developing and managing the national infrastructures and for maintaining the international connectivity essential to innovation and economic growth.
- *Political centralisation.* Chile is a unitary and relatively centralised state. Local governments are heavily dependent on government transfers and have quite a weak position and little policy-making autonomy. Consequently, most have not developed the institutional capabilities and managerial skills needed to play a strong role in innovation policy. Efforts have been made to increase the participation of regional and local governments, such as through the regional agencies for economic development, but results have yet to materialise.
- *Geographical concentration of economic power and intellectual capital*, which contrasts with the dispersion of export-oriented activities. A probably excessive physical separation between knowledge producers and some users complicates the development of producer-centred regional innovation systems and innovative clusters.

- *The legacy of a "physiocratic" culture.* Chile's economy has traditionally been dependent on exports of natural resources. As a consequence, rent-seeking behaviour is pervasive throughout the economy. Technology and innovation are often seen primarily as a tool that can easily be imported to appropriate such rents. An innovation culture which views technology and knowledge as the main source of sustainable wealth creation is not yet prevalent in the business community and society in general.

The low research and development (R&D) intensity of the Chilean economy (0.67% of GDP in 2002) cannot be ascribed entirely to an income gap with developed countries and a comparative advantage in resource-based industries that reduces the scope for R&D-based innovation. It is also a reflection of the inefficiency of the national innovation system, which suffers from strong imbalances and bottlenecks; this leads to disappointing performance and low returns on investment in R&D, and slows capacity building.

A system focused on public research and poorly connected to market dynamics

- *The modest role played by the business sector* in the financing and performance of R&D is the feature that most visibly and measurably distinguishes Chile's innovation system from those of more advanced economies. This is partly due to its specialisation in non-R&D-intensive industries but also to the fact that the vast majority of small and medium-sized enterprises (SMEs) in all areas do not engage in R&D and innovation. Indeed, innovation surveys, which also capture non-R&D-based innovation, reinforce the impression that most SMEs have both a low propensity to innovate and an insufficient level of innovativeness. Only a small proportion of firms have put the development of new products and processes at the centre of their competitive strategy, and successful, export-oriented firms in resource-based clusters show innovativeness mainly in non-R&D-based product differentiation, business models and marketing. A larger share of innovative firms focus on adapting imported technologies and know-how. However, for the vast majority of Chilean companies, purchase of capital goods is the means of technology adoption. In contrast to their significant contribution to investment, employment and exports, local subsidiaries of multinational companies carry out very little R&D and innovation activities in Chile.

- *Most R&D is financed by the government and carried out in universities.* The Chilean scientific community is small but of good quality, although in some fields the lack of critical mass is clearly an issue, despite improvements brought about by measures to promote centres of excellence. Owing to the low level of R&D-based innovation activities in the business sector, scientific research has long been under less pressure to demonstrate economic relevance than in most OECD countries. The Chilean portfolio of scientific activities, shaped by the policy of a few dominant universities and opportunities for international co-operation within the academic community, has not changed significantly in response to the dynamic changes that have taken place in the Chilean economy during the last two decades.

- *Public research institutes play a questionable role in the innovation system.* These institutes, which are dependent on various ministries or private non-profit organisations, play a minor role in pre-competitive R&D. They are mainly involved in applied research and technological development, technology transfer, the supply of "technological services" and the generation of information. They did contribute positively to the technological development of the Chilean economy at some earlier point, and owing to pressures to provide more market services, they have changed in the last ten years. However, their performance remains quite uneven. A number are seen as inefficient and detached from the sectors they are meant to serve. The research they carry out is not considered of top quality and not always economically relevant. They are also perceived as being cut off from international trends.

Discrepancies in the capability building process

- *Shortage of specialised human resources.* Although the situation has improved over the last decade and current university enrolments in science and technology (S&T) and engineering studies are promising, the scarcity of human resources for science and technology (HRST) remains an important bottleneck. Advanced training, notably at the doctoral level, in science, technology and engineering is quantitatively and qualitatively insufficient, although there are uncertainties concerning the future demand for human resources specialised in science. There is in particular a deficit in training in the advanced management skills and business leadership required for incorporating innovation into firms' strategies.

- *Underdeveloped supporting financial market mechanisms.* The supply of risk and seed capital seems even smaller than the demand for specialised equity funding tools.

- *A very narrow market for knowledge.* The market-based provision of services is underdeveloped in many areas (*e.g.* IPR, innovation management, engineering), in part because of a shortage of specialists with both a solid professional or scientific background and business flair, barriers to entrepreneurship, and unwarranted competition from public technological institutes.

Bottlenecks impeding knowledge flows and co-operative undertakings

- *Insufficient networking and clustering of firms.* The majority of Chilean firms do not perceive the value of co-operation in innovation, and those that do not find institutional frameworks that facilitate market-friendly forms of collective action. While some innovative clusters have taken shape, *e.g.* in the food and beverage industries, many others are latent. For example, the mining industry could be the nexus of a broader set of diversified interrelated services and manufacturing activities.

- *Industry-science relationships (ISRs) face the same problems as in other countries,* such as a lack of demand by firms, a research culture in academia which does not emphasise economic relevance, low mobility of researchers, and competition between public research and industry for public support. However, these problems are more acute in Chile than in most OECD countries for two main reasons. First, there is an important shortage of the type of human resources necessary for vibrant ISRs. In particular, engineering disciplines are not effectively bridging science and innovation early in the education system and later in the workplace. Second, the institutional frameworks that are commonly used to promote ISRs are underdeveloped, particularly public-private partnerships for innovation and mechanisms to stimulate and organise discussion of current and prospective needs for specialised human capital between companies and educational institutions.

Potential for future development

- *Better exploitation of favourable framework conditions.* Chile is a pioneer in the field of competition law and policy among South American and developing countries and has been a leader in applying competition policy principles in infrastructure sectors. Other favourable basic framework conditions can also greatly enhance the effectiveness of innovation policy. These include: the quality and reliability of institutions and political stability; robust macroeconomic performance, including stable inflation and balanced fiscal accounts; an open trade regime and favourable legislation for foreign direct investment.

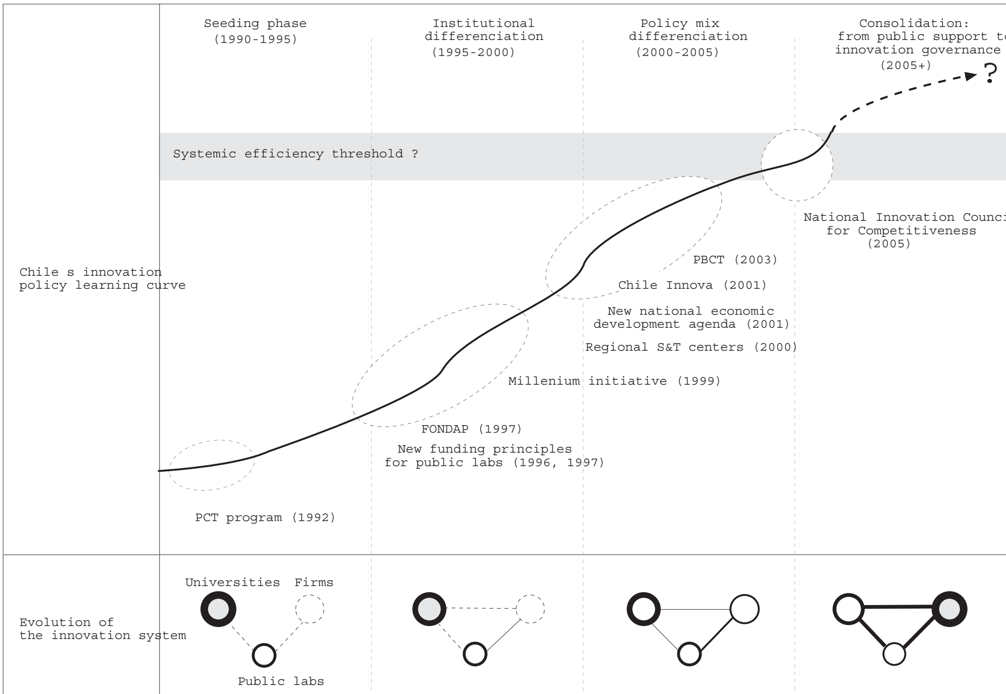
However, the share of foreign affiliates in total business R&D is currently far beyond comparable Latin American countries such as Brazil, Mexico and Argentina. If Chile strengthens its national absorptive capabilities, it can expect to benefit in the future from the increasing globalisation of R&D.

- *A core of competent actors approaching critical mass.* Chile's success in export markets would not have been possible without some form of innovation. Over the last decade, a significant core of firms and entrepreneurs has been able to marry technological and market opportunities creatively. Chile now has considerable experience in learning how to increase value added in resource-based industries through innovation, including science-based new technology, especially biotechnology. This concerns both the development of business competencies and the nurturing of supporting institutions, such as Fundación Chile, which is now widely recognised as an example of international best practice.
- *New opportunities.* Chile has a number of opportunities for dynamising its innovation system: it can exploit new knowledge to increase value added by resource-based industries; it can build on strong clusters to develop related innovative service and industrial activities; it can turn logistic constraints into innovation challenges; it can advance further as a regional leader in selected niches in the industrial and service sectors; it can exploit Chile's environmental advantages to capture a larger share of the high-end tourism market; it can derive unexpected benefits from serendipity in science and technology through sustained investment in high-quality basic research.

Government innovation policy: a learning process at a critical stage

Until the beginning of the 1990s, innovation policy tools consisted mainly of a funding agency that supported mostly academic research and financed scholarships and a set of technological institutes that performed public missions and provided some basic technological services to a limited number of firms in the industrial and agricultural sectors. In the last 15 years Chile has undergone an accelerated learning process whereby a more complete portfolio of instruments, addressing a broader set of objectives, has gradually been built (Figure 0.1). Although innovation policy is not yet well prioritised or implemented in a balanced way, it has reached a stage of maturity in terms of institutional capabilities. This makes it possible to contemplate a leap in efficiency, provided that the high-level political commitment to increase public support also stimulates reforms that would correct the most serious defects in current practices.

Figure 0.1. Chile's innovation policy: the learning trajectory



Trigger	First policy push	Growth of export-oriented industries		Second policy push
Type of learning	Assisted learning from foreign practices	Accelerated own learning from best practices in advanced countries plus elements of endogenous institutional learning		Endogenous national and institutional learning, including within the OECD community
Policy focus	Horizontal promotion of R&D projects through a pure bottom-up process	Engage firms; concentrate funding of scientific research on areas of excellence	Build stronger linkages between actors in targeted areas; improve specific framework conditions	Improve overall governance, streamline and prioritise
Funding instruments	Grants to individual projects; unconditional funding of public labs	Introduction of grants to research groups; new funding mechanisms for public labs	Development of consortia, emergence of a cluster-based approach	Introduction of a R&D tax incentive

Weak overall governance and agency co-ordination

Chile does not yet have a fully developed formal mechanism for defining an explicit strategy, translating it into priorities and guiding implementation.

- Priorities have always been defined in a relatively decentralised manner by agencies such as CORFO (the Foundation for Promoting Development) in the Ministry of Economy, CONICYT (the National Commission for Scientific and Technological Research) in the Ministry of Education and the FIA (the Agrarian Innovation Fund) in the Ministry of Agriculture. Ministries such as Health and Planning have played a comparatively minor role. Some degree of co-ordination does exist at the programme level and to a lesser extent across agencies but this is not a good substitute for high-level steering of the system.

- Agency co-ordination, especially between CONICYT and CORFO, is a longstanding problem which has not so far found a satisfactory solution. As a result, the objectives, rationale and types of outcomes desired are not sufficiently differentiated in many funds and programmes. In fact each major agency has tended to develop its own responses to all problems, resulting in a poor division of labour in the public support system.

Two recent decisions of the Chilean government are therefore particularly opportune: the creation of the National Innovation Council for Competitiveness and of the National Innovation Fund for Competitiveness (FIC) which will allocate the proceeds from the recently introduced mining tax.

Unbalanced policy mix

Chile's innovation policy mix reveals quite strong disequilibria. These reflect structural features which can be changed only progressively, notably the dominant role of universities in the performance of R&D, but also policy choices regarding priority objectives and preferred instruments. For the latter, three problematic features stand out:

- First, the emphasis has been on R&D rather than on knowledge diffusion and technology-based entrepreneurship, even if Innova Chile has been much more active in these areas in the past years.

- Second, project-based schemes, as opposed to programme-based support, represent the lion's share of overall public expenditure for R&D.

- Third, compared to most OECD countries, Chile's mix of instruments to promote R&D in the business sector has so far been tilted towards direct government support. R&D spending is currently deductible against corporate income tax liabilities, as is one-half of donations to universities. The bulk of public support takes the form of competitive grants through a multiplicity of funds.

This last feature is about to be corrected with the introduction of an R&D tax incentive. However, given its design, it is unlikely to exert a strong influence on the overall balance of incentives within the innovation system.

Fragmented and unfocused instruments

Lack of critical size

- Public spending for R&D and innovation in Chile is important in relative terms, when compared to the level of private efforts, but limited in absolute terms. The multiplication of instruments unavoidably means that resources are spread too thin in all areas, but particularly in the promotion of business innovation, since a large fraction of public money for R&D is earmarked for basic research. This fragmentation has sometimes been encouraged by the introduction of measures, based on good practices in advanced countries, in a context that is not entirely prepared to cope with the ensuing accelerated institutional differentiation.

Duplication and blind spots

- Fragmentation and failed efforts at co-ordination unavoidably lead to duplication or at least to unnecessary overlaps. There are many examples, such as the pre-competitive projects promoted by the Scientific and Technological Development Promotion Fund (FONDEF) (at CONICYT) and the Development and Innovation Fund (FDI) (now absorbed by CORFO's Innova Chile), or the promotion of centres of excellence in scientific research by the Millennium Initiative and the Fund for Advanced Research in Priority Areas (FONDAP), to mention just two.

- At the same time some of the most basic needs of many economic actors have remained essentially unmet, because to satisfy them would have required actions that are: *i)* more difficult to articulate because they require inter-agency co-ordination, such as cluster-based policies; and/or *ii)* are less visible politically and less in demand by the usual "clientele" of funding agencies, such as measures to help the "silent majority" of SMEs to take the first steps towards innovation; and/or *iii)* are less easy to handle by existing public agencies given their skills and/or corporate culture, such as addressing "capability gaps" in some areas.

- One of the main problematic features of the current mix of instruments is that it offers uneven support to the different phases of innovation projects in different types of firms. The public system remains focused on the research stage of innovation in well-prepared companies. The early stage of capacity building in “could-be” innovative firms, and the obstacles encountered by “would-be” innovative firms in stages such as concept-to-prototype, industrialisation and commercialisation are not well covered. As a consequence, innovation policy does not reach the vast majority of Chilean SMEs.

Deficient articulation with sector-specific demand

- The connection between the innovation support system and the competitive development of productive sectors has been too weak for too long, even though institutions like Fundación Chile demonstrated quite early the feasibility of a cluster-based approach to the promotion of innovation and public policy has been tilting in this direction in recent years.

Recommendations

Strategic orientations

Despite Chile’s impressive economic performance over the past two decades, there is still a significant gap with the income levels of developed countries. The *overarching objective* of Chile’s economic policy is to achieve sustainable, high and equitable growth in order to close this gap while further reducing poverty and the persistent inequality in income distribution.

To achieve this goal may require a long-term shift in the sources of growth. There is an emerging consensus that factor accumulation needs to be complemented by sustained productivity growth. Innovation – underpinned by favourable framework conditions and stimulated by an explicit innovation policy – is a major route to boosting productivity growth. So far, Chile’s performance in and attention to innovation does not match its achievements in other areas. An entrepreneurial culture is not yet pervasive and innovative activity is scarce and often isolated.

Chile will need to reach a consensus regarding the important role of innovation in the further development of the economy. In the context of a strategy for innovation, the government’s role is not just to ensure adequate macroeconomic conditions for achieving high rates of investment, but also to correct market and systemic failures that prevent the country from realising its full innovative potential. Government policy can also play a significant role in facilitating and stimulating diversification which, in the longer term, will induce beneficial changes in the industrial structure of the Chilean economy.

The distance to the frontier represented by the technologically and economically most advanced countries may be turned to Chile's advantage, since it implies a significant potential for catching up. In the past, Chile has shown that it has the social capability and absorptive capacity to make good use of such potential, but to achieve this overall objective, several important tasks need to be accomplished.

Develop human resources

- Measures aimed at developing the human resource base are a cornerstone of any strategy aimed at innovation-based growth. The lack of skilled human resources is a major bottleneck for Chile's social and economic development and for upgrading its innovation capability. Developing the human resource base is therefore one of the country's most urgent tasks. Even though educational attainment has increased in recent years, quality remains inadequate. Significant measures to raise Chile's educational standards to international levels are being implemented, and new ones are on the way.

Extend the breath and depth of comparative advantages

- Despite gradual diversification through the emergence of new export-oriented industries in the agro-food sector and increasingly important exports of services, the Chilean economy is still relatively undiversified. The scope of "exportables" has remained limited. Agriculture and mining tend to be less conducive to the development of product variety than certain services and manufacturing (which has stagnated). The share of intra-industry trade, a highly dynamic segment of international trade, is very low, much lower than for comparable countries in Latin America (Brazil, Mexico, Argentina). The current specialisation pattern of the Chilean economy has some disadvantages:

  - The high risk associated with a diminishing, but still high, level of specialisation in commodities, which renders the economy vulnerable to sudden changes in international commodity prices and secular shifts in the demand for commodities.

  - A low degree of product variety and share of intra-industry trade in international trade, which could constrain Chile's long-term growth.

- A successful innovation strategy can play a major role in facilitating structural change and thus reduce the risks inherent in this specific type of specialisation.
- In the transition to more innovation-driven growth, Chile should emphasise the country's strengths and comparative advantages by building on nascent clusters, mainly based on natural resources, to develop innovation practices which can help transform the static advantages of the Chilean economy into dynamic advantages. New activities can be encouraged by adding products with high value added to the export base and by further developing specialised goods and services that were originally customised to meet the needs of natural resource-based clusters.

Guiding principles

In pursuing these tasks the government should apply the following guiding principles:

- *Timeliness*. Make use of the opportunities offered by the favourable economic context to use the country's current comparative advantages to develop new ones. The acceleration of globalisation raises new challenges and opportunities, and countries may fall behind if opportunities are not seized. In Chile, the immediate challenges are perhaps less severe than in many other countries. Chile has been a pioneer among developing countries in terms of liberal reforms and openness. Unlike other countries with a similar level of income per capita, Chile does not have a sizeable low-productivity, labour-intensive manufacturing sector that is exposed to new, vigorous competition from emerging economies. Rather, it currently benefits from rapid growth in emerging economies, in particular from the ensuing high demand for raw materials. Nevertheless, it seems prudent to take a longer-term perspective and make good use of the current window of opportunity. The Chilean government's strategy to use some of the increased revenue for forward-looking purposes is timely and well-founded.
- *Build on the sound macroeconomic framework and solid institutions.* Chile has been successful in establishing a sound macroeconomic framework and modern and solid institutions. This framework and these institutions are one of Chile's major assets. Strong macroeconomic performance and stability contribute to improved business confidence in the private sector. Stability reduces uncertainty and thus contributes to a climate conducive to investment and innovation.

- *Address both market and systemic failures.* Good framework conditions are necessary for a well-functioning innovation system. At the same time, more specific policy measures are required to address specific market or systemic failures that hamper R&D and innovation. These interventions should be based on a sound rationale. In implementing the new innovation policy, it will be important to ensure the stability of the strong institutions and policies the country has established in recent decades.

- *Broad and balanced approach to innovation.* A narrow high-technology orientation should be avoided in favour of a strategy that builds on strengths and enables change with a view to strengthening and broadening the foundations for long-term growth. A comprehensive approach to innovation includes organisational innovation, new business models as well as innovation in services sectors. A balanced approach recognises that technology diffusion is the key enabler of innovation in the majority of firms.

- *Consolidation of the public support system*. Reducing current overlaps and achieving critical size for individual instruments is a priority but should not be to the detriment of the institutional differentiation which is necessary for addressing a broad set of objectives efficiently. When different agencies/programmes have tried several approaches to resolving similar problems, resources should be concentrated on the one that has proven most effective.

- *"Clever" targeting.* In Chile the question is not whether, but how, innovation policy should target clusters of activities or firms' networks, using market-friendly focusing devices such as public-private partnerships. This does not preclude the use of horizontal policies to capitalise on serendipity, to help firms from all sectors build on externalities from dynamic cluster developments and to upgrade innovation capabilities throughout the economy.

- *Advanced governance principles.* A clear distinction should be made between policy formulation and policy implementation, and the latter should be accomplished using an effective mix of a range of proven instruments: co-ordination, competition (*e.g.* competitive funding), co-operation (*e.g.* joint research projects); performance-based steering mechanisms (*e.g.* performance contracts, funding criteria).

Specific recommendations

Overall governance

The National Innovation Council could be the catalyst of an accelerated maturation of Chile's innovation system, provided that it is properly composed, institutionally positioned and equipped. OECD countries' experience in this field suggests that:

- Its composition, in terms of numbers and institutional affiliation of members, should balance representativity and efficacy, in order to avoid capture by vested interests and ensure productive deliberations. While it should include representatives of all communities (government, industry, the financial sector, academia and technological institutes), at least one-third of the members should not have any responsibility for the management of innovation policy. Among the "independent" members, at least one should be foreign or at least a Chilean expatriate with a proven record in science, technology or innovation.
- Its institutional positioning should maximise its policy impact and guarantee its reputation as an impartial body that acts in the public interest.
- Its mandate and mode of operation should safeguard against the "talking-shop" syndrome and encourage evidence-based approaches to policy assessment and advice.
- It should be backed by a well-resourced and strong executive secretariat, steered through a reduced-scale executive board, which should have the skills and financial means to carry out or commission independent studies and evaluation, and ensure permanent monitoring.
- Provided that it meets all of the conditions for efficient operation, it might be entrusted with the task of strategically orienting the flow of new public resources for innovation through a mechanism that would translate its priorities into funding priorities for the Innovation for Competitiveness Fund (FIC).

Its role in evaluation should be two-fold: *i)* to set quality standards and a framework for the evaluation of individual institutions, programmes and measures; and *ii)* to carry out thematic evaluations from a systemic perspective. Regarding the latter, the following tasks stand out as particularly important:

- Assessing the role of the technological institutes (ITPs) in the innovation system and their steering mechanisms. These have evolved over time, at different paces and according to various motivations and guiding principles. Developing a coherent policy for the ITP sector will require an assessment of the performance and capabilities of all ITPs, from a truly systemic perspective, to reaffirm or redefine missions, operating modes, technological focus, etc., without excluding any option, reorganisation, merger, privatisation or closure.

- Assessing the combined efficiency of existing programmes and measures, including key framework conditions (*e.g.* intellectual property rights – IPRs) to promote commercialisation of university research through researcher mobility, patenting and licensing, research contracts and spin-offs.

- Assessing the impact of the newly introduced tax incentive for R&D.

- Assessing the supply of and demand for the specialised human resources needed for innovation, with a special focus on the role of engineering sciences, with a view to obtaining a good model for more fruitful public-private co-operation in this area.

- Assessing the scope for a fully fledged cluster approach to innovation policy by: evaluating the current portfolio of programmes to promote consortia and firm networking; mapping existing and latent innovative clusters; extracting lessons from successful experience in Chile and abroad; and determining how further decentralisation of innovation policy could be achieved.

- Assessing international linkages (from FDI to scholarships) with a view to finding ways of intensifying those likely to make the greatest contribution to the whole innovation system.

The FIC will be a key tool for implementing the Council’s strategy. However, this should not involve simply translating policy priorities into sizeable incremental changes in the allocation of funds among existing structures. The government should consider ways to make the FIC a focusing device and an agent of structural change which could induce deeper, dynamic structural changes and endogenous institutional learning in the innovation system. To this effect:

- One option might be for the FIC to absorb some of the public funds targeted at innovation, especially those that address multiple objectives with multiple types of beneficiaries.

- Another, which would better preserve institutional differentiation while taking advantage of the experience of existing funding agencies in dealing with stakeholders, would be to structure and manage the FIC following the venture capital industry's model of a "fund of funds", with the adaptations required to comply with public finance regulations and fulfil its public interest mission.

Local governments should become stronger players in the Chilean innovation system. Further decentralisation of policy making is needed to facilitate the development of producer-centred regional innovation systems and innovative clusters that could contribute to economic diversification around strong export industries. But changing the balance of power among different levels of government will yield these benefits only if it is accompanied by efforts to strengthen the institutional capabilities and managerial skills of sub-national levels of government.

Improved policy mix and instruments

The public support system should be less focused on the research stage of innovation in well-prepared and motivated companies. This would require, in particular:

- Giving more attention to the early stage of capacity building in the vast majority of SMEs which do not yet innovate, and to the obstacles encountered by innovative SMEs in stages such as concept-to-prototype, industrialisation, and commercialisation.
- Promoting the development of the market for knowledge, including relevant institutions such as technology brokers and other intermediaries that create a bridge between knowledge producers and end-users.
- Sharpening the division of labour between CONICYT and CORFO by better differentiating their respective funds and programmes according to clearer objectives, rationale and desired types of outcomes.
- Improving the management of project-based support by funding agencies, especially with regard to the evaluation of the financial aspects of projects, the speed for processing and selecting applications and the responsiveness to feedback from beneficiaries.
- Devoting more resources to and strengthening the governance of multi-objective and multi-actor programmes, such as research consortia.

Human resources for innovation

- Continue with efforts to raise Chile's educational standards to the level of high-performing countries. Increased investment in education should be maintained over time and accompanied by adequately monitored improvements in teaching quality.

- Stress skill formation at all levels rather than focus on the higher end of skills. An effective system of vocational training provides favourable conditions for innovative activity throughout the economy, including in the SME sector. The role of business enterprises as creators of human capital for innovation, notably through formal training, should receive close attention.
- Continue initiatives to raise digital literacy throughout society and to close the digital divide.
- Encourage entrepreneurship by teaching about starting up a new business, as a number of OECD countries have done in recent years. Improve training in advanced management skills and business leadership.
- Develop anticipatory policies to balance supply and demand for human resources for science and technology over the medium to long term. These policies should be directed towards both the supply and the demand sides. Demand for researchers by the business sector, both state-owned and private, needs to be stimulated. On the supply side, HRST policy should anticipate increased demand from the business sector. Mechanisms for public-private dialogue in defining educational priorities over the medium to long term should be strengthened.
- Improve the PhD-Master's programme mix, to focus on some strategic areas and concentrate scarce resources on them, and develop incentives to achieve more co-operation among institutions in the design and implementation of joint programmes.
- Develop more active policies for "brain gain" which address both expatriates and foreign talent. More generally, improve the level of internationalisation of the education system. In particular, take measures to increase the number of foreign students received in Chile and the number of Chilean students studying abroad. Consider taking a more strategic approach to the use of scholarships as a tool for internationalisation to better align human resource development policies with long-term economic development goals.

Summary table

The Chilean national innovation system: Strengths, weaknesses, opportunities and threats

Strengths	Opportunities
• Stable macroeconomic framework and well-functioning product markets • International openness • Reliable regulatory and legal frameworks • Political commitment to increased support to innovation • Trustful relationship between government, public servants and the private sector • Strong export-oriented and resource-based industries • A significant core of dynamic firms and entrepreneurs with innovative business models • Accumulated learning and a proven model for upgrading resource-based industries through knowledge and technology • Pockets of excellence in scientific research	• Greater exploitation of value-added innovation in the resource-based industries • Build innovative clusters around existing dynamic export-oriented industries • Important potential of the service sector, from low-skilled jobs to knowledge-intensive business services • Exploitation of Chile's environmental advantages to capture a larger share of the high-end tourism market • Turn logistic constraints into innovation challenges • Advance as a regional leader in selected niches in the industrial and services sectors • Derive unexpected benefits from serendipity in science and technology through sustained investment in quality basic research
Weaknesses	**Threats**
• Rents from the exploitation of natural resources exceed those that can be expected from most innovations • Logistic challenges due to geography • Basic research-centred innovation system • Very low level of business R&D and innovation, including in foreign-owned firms • Weak innovation governance, with a lack of a high-level overall strategy, and weak regional actors • Fragmented, R&D-centred, project-based public support system with duplication of effort and blind spots • A very narrow market for knowledge • Underdeveloped and partly outdated infrastructure for technology diffusion • Low supply of seed and risk capital • Severe bottlenecks in the supply and mobility of HRST	• Long-term trends in long-distance transport costs of low-value-added exports • International specialisation lock-in in products with low income elasticity in world demand • Marginalisation as a source and destination of international flows of high skilled human capital • Increasing regional disparities • Shortage of specialised human resources needed for innovation • Loss of human and social capital if the current level of inequalities is not reduced • Deterioration of misused capabilities, notably in engineering sciences

ÉVALUATION D'ENSEMBLE ET RECOMMANDATIONS

Le Chili, petite économie ouverte dont la production repose traditionnellement sur l'exploitation des ressources naturelles, enregistre depuis vingt ans des résultats économiques remarquables. Le pays est parvenu à obtenir une forte « accélération de la croissance », avec un PIB par habitant en hausse de 5 à 6 % par an dans les années 90, c'est-à-dire plus de deux fois les 2.4 % généralement atteints tout au long des quatre décennies précédentes. Après une courte période de stagnation à la fin des années 90, la croissance est nettement repartie à la hausse en 2004 et 2005, en partie grâce à des conditions favorables sur les principaux marchés d'exportation du pays.

Le Chili est ainsi parvenu à réduire sensiblement l'écart avec les pays avancés en termes de revenu par habitant. De ce point de vue, il a surpassé tous les autres pays d'Amérique latine sur les vingt dernières années. Avec un PIB par habitant d'environ 11 000 USD (PPA), le Chili figure désormais parmi les premiers pays à revenu intermédiaire. L'écart de revenu restant est dû en partie à une utilisation moindre de la main-d'œuvre, mais elle s'explique surtout par un retard de productivité. Si le Chili a su utiliser ses gains de revenu pour réduire considérablement la pauvreté, la répartition des revenus est demeurée exceptionnellement inégale.

Les bons résultats économiques du Chili sur les deux dernières décennies ont récompensé les efforts déployés par le pays pour réformer son économie et bâtir des institutions modernes et stables, en s'inspirant des meilleures pratiques internationales de gestion macro-économique et de développement des mécanismes de marché. Le Chili a pu établir une stabilité monétaire et fiscale qui s'est traduite par une diminution régulière du taux d'inflation jusqu'au niveau des pays développés, ainsi que par des finances publiques saines. L'ouverture au commerce international et à l'investissement direct étranger explique en grande partie que le pays ait réussi à tirer des revenus accrus de ses avantages comparatifs. L'ouverture internationale a également contribué à l'instauration de marchés efficaces et a permis une forte hausse des exportations des industries exploitant les avantages comparatifs du Chili.

L'émergence d'activités à vocation exportatrice dynamiques a mis à l'épreuve la capacité du système d'innovation du Chili de leur fournir tous les services et connaissances pertinents. Face à des demandes nouvelles et plus pointues exprimées par certaines entreprises, mais aussi en réponse à d'autres besoins de la société et de l'économie, le Chili a accéléré la construction d'un système d'innovation plus complet, bien qu'à un rythme moins soutenu qu'il ne l'a fait pour les autres piliers institutionnels d'une économie de marché efficiente.

Prenant de plus en plus conscience de l'importance de l'innovation pour l'avenir du pays, les autorités ont récemment pris trois décisions ambitieuses, conformes dans leur principe aux mesures exemplaires observées dans certains pays de l'OCDE : la création d'un Conseil de l'innovation pour la compétitivité chargé de proposer des lignes directrices pour une stratégie nationale à long terme dans ce domaine ; l'accroissement sensible des ressources disponibles pour mettre en œuvre cette stratégie, grâce à l'introduction d'un impôt sur la production minière ; et l'encouragement donné au secteur privé, sous la forme d'une incitation fiscale à la R-D, à s'inscrire dans cette stratégie. Ce rapport présente une évaluation de l'état actuel du système et de la politique de l'innovation du Chili en vue de déterminer là où il y a lieu de l'améliorer en priorité pour tirer le meilleur parti possible de ces investissements publics supplémentaires.

Le système d'innovation chilien : caractéristiques, principales faiblesses et potentiel

Il convient de garder à l'esprit certaines des caractéristiques de l'économie chilienne lorsque l'on évalue l'état actuel du système et de la politique d'innovation du pays et que l'on imagine quelle pourrait être leur évolution à l'avenir, en particulier :

- *La géographie*. Le Chili est éloigné des grands marchés et centres de connaissances. En outre, son territoire s'étire sur 4300 km, soit environ la même distance qu'entre San Francisco et New York, sur une largeur qui ne dépasse jamais 240 km, sa longueur étant ainsi dix-huit fois supérieure à sa plus grande largeur. Cette configuration géographique et topographique particulière pose un certain nombre de problèmes, notamment pour le développement et la gestion des infrastructures nationales et des liens physiques avec l'étranger, qui sont essentiels pour l'innovation et la croissance économique.

- *La centralisation politique*. Le Chili est un État unitaire et relativement centralisé. Les autorités locales sont encore dans une position de relative faiblesse. Elles ont un pouvoir de décision limité et restent largement tributaires des transferts financiers en provenance du gouvernement central. La plupart d'entre elles n'ont donc pas développé les capacités institutionnelles et les compétences de gestion nécessaires pour jouer un rôle plus important dans la politique de l'innovation. Des efforts ont été consentis pour renforcer la participation des autorités régionales et locales, notamment par l'intermédiaire des Agences régionales pour le développement économique, mais les résultats se font encore attendre.

- *La concentration géographique de la puissance économique et du capital intellectuel,* contrastant avec la dispersion des activités axées sur l'exportation. Un éloignement « physique » probablement excessif entre les producteurs de savoir et certains utilisateurs n'est pas favorable à l'épanouissement de systèmes d'innovation régionaux et de grappes innovantes *(« innovative clusters »)* centrés sur les producteurs.
- *L'héritage d'une culture physiocratique*. L'économie chilienne reposant depuis toujours sur l'exportation des ressources naturelles, la recherche de rente imprègne les mentalités dans la sphère économique. Les technologies et l'innovation sont considérées avant tout comme des outils pouvant être facilement importés pour s'approprier ces rentes. Peu sont ceux, au sein des entreprises comme dans la société en général, à avoir vraiment adopté une « culture de l'innovation » qui amène à considérer les technologies et les connaissances comme les sources principales d'une croissance durable.

Le faible niveau d'intensité de R-D de l'économie nationale (0.67 % du PIB en 2002) ne peut s'expliquer entièrement par l'écart de revenu avec les pays développés, auquel s'ajouterait un avantage comparatif dans des industries fondées sur l'exploitation des ressources naturelles qui a pour conséquence de réduire le champ des innovations issues de la R-D. Il traduit également le manque d'efficience du système d'innovation national, qui souffre de déséquilibres et de blocages importants et produit donc des résultats décevants et de faibles retours sur les investissements en R-D, ce qui ralentit le renforcement des capacités des acteurs.

Un système centré sur la recherche publique ayant trop peu de liens avec la dynamique du marché

- *Le rôle modeste du secteur privé* dans le financement et les résultats de la R-D représente le trait distinctif le plus visible et le plus facilement mesurable du système d'innovation chilien lorsqu'on le compare à ceux de pays plus avancés. Cela est dû en partie à la spécialisation du pays dans des activités à faible intensité de R-D, mais aussi au fait que la grande majorité des PME, quel que soit leur domaine d'activité, ne s'investit pas dans la R-D et l'innovation. Il semble en effet, d'après des enquêtes d'innovation, qui portent également sur l'innovation non issue de la R-D, que non seulement la plupart des PME ont une faible propension à innover, mais que celles qui innovent le font à un niveau modeste. Seul un petit nombre d'entreprises ont vraiment placé l'élaboration de produits et procédés nouveaux au cœur de leur stratégie de compétitivité et les sociétés à vocation exportatrice prospères au sein de grappes industrielles axés sur l'exploitation des ressources naturelles font montre d'innovation essentiellement pour la différenciation de produits non fondés sur la R-D, pour leurs modèles d'entreprise et pour la commercialisation. La plupart des entreprises chiliennes innovantes se contentent d'adapter des technologies et des savoir-faire importés, mais pour la très grande majorité des sociétés chiliennes, l'achat de biens de production constitue le seul vecteur d'introduction des technologies nouvelles. Si elles contribuent largement aux investissements, à l'emploi et aux exportations, les filiales locales d'entreprises multinationales poursuivent très peu activités de R-D et d'innovation au Chili.

- *La plus grande part des activités de R-D sont financées par l'État et menées à l'université*. Le milieu scientifique chilien est peu nombreux mais de bon niveau, même si dans certaines disciplines, l'insuffisance des effectifs pose clairement problème, malgré les améliorations apportées par les mesures en faveur des centres d'excellence. En raison du faible niveau des activités d'innovation fondées sur la R-D dans le secteur privé, les chercheurs ont pendant longtemps subi moins de pression que dans la plupart des pays de l'OCDE pour justifier la pertinence économique de leurs travaux. La gamme des activités scientifiques, qui a été façonnée par la politique de quelques grandes universités et par les possibilités de coopération internationale au sein du milieu scientifique, n'a pas beaucoup changé au regard des évolutions dynamiques que l'économie chilienne a connues en l'espace de vingt ans.

- *Les instituts de recherche publics jouent un rôle discutable dans le système d'innovation*. Ces instituts, qui dépendent de plusieurs ministères ou d'organismes privés à but non lucratif, sont peu actifs dans le domaine de la R-D préconcurrentielle et se consacrent essentiellement à la recherche appliquée et au développement technologique, au transfert de technologies, à la prestation de « services technologiques » et à la génération d'informations. Ils ont effectivement contribué au développement technologique de l'économie chilienne à certaines époques. Face à la nécessité de fournir plus de services aux acteurs du marché, ils ont évolué au cours des dix dernières années, avec des résultats toutefois assez inégaux. Certains sont globalement considérés comme inefficaces et détachés des secteurs pour lesquels ils sont censés œuvrer. Les travaux de recherche qu'ils poursuivent ne sont pas jugés d'un très haut niveau de qualité et ne sont pas toujours pertinents d'un point de vue économique. Ils semblent être également insuffisamment intégrés aux réseaux internationaux de recherche et d'innovation.

Des faiblesses dans le processus de renforcement des capacités

- *Une pénurie de ressources humaines spécialisées*. Si la situation s'est améliorée au cours de la dernière décennie et si les inscriptions en université dans les filières scientifiques, technologiques et d'ingénierie sont encourageantes, la rareté des ressources humaines en science et technologie (RHST) reste un goulet d'étranglement important. Les formations de haut niveau, notamment les doctorats, en science, technologie et ingénierie sont quantitativement et qualitativement insuffisantes, même en tenant compte des incertitudes quant à la demande future de scientifiques. En particulier, les compétences de haut niveau en matière de gestion et dans le domaine de la direction d'entreprise, nécessaires pour incorporer l'innovation dans les stratégies des sociétés, ne sont pas suffisamment enseignées.

- *Des mécanismes de soutien du marché financier insuffisants*. L'offre de capital-risque et de capital de départ semble même inférieure à la pourtant déjà faible demande d'instruments spécialisés de dotation en capital.

- *Un marché de la connaissance très étroit*. La prestation de services par le marché est peu développée dans de nombreux domaines (par exemple, les DPI, la gestion de l'innovation, l'ingénierie, etc.), en partie à cause du manque de spécialistes ayant à la fois un solide bagage professionnel ou scientifique et une culture entrepreneuriale, mais également à cause d'obstacles à la création d'entreprise et d'une concurrence infondée de la part des instituts publics de technologie.

Des obstacles à la circulation des connaissances et à la collaboration

- *Des réseaux et grappes d'entreprises insuffisamment développés.* La majorité des entreprises chiliennes ne voient pas l'intérêt de coopérer dans le cadre des activités d'innovation, et celles qui le souhaitent ne trouvent souvent pas les cadres institutionnels appropriés qui facilitent des formes d'action collective en harmonie avec le marché. Si certaines grappes d'entreprises innovantes ont vu le jour, par exemple dans l'industrie alimentaire et des boissons, de nombreuses autres ne sont encore que dans les limbes, par exemple dans le secteur minier, qui pourrait être au cœur d'un ensemble plus vaste et d'activités de fabrication et de services interdépendantes et diversifiées.

- *Les relations entre le secteur privé et le milieu scientifique sont entravées* par les mêmes facteurs que dans les autres pays : la faiblesse de la demande des entreprises, une culture scientifique à l'université qui ne met pas l'accent sur la pertinence économique des travaux, une faible mobilité des chercheurs et la concurrence entre la recherche publique et les entreprises pour les aides publiques. Toutefois, ces problèmes sont plus aigus au Chili que dans la plupart des pays de l'OCDE, et ce, pour deux raisons principales. Premièrement, il existe une pénurie importante du type de ressources humaines qui serait nécessaire pour établir des relations dynamiques entre secteur privé et milieu scientifique. En particulier, les sciences de l'ingénieur ne jouent pas bien leur rôle de passerelle entre recherche et innovation au sein du système éducatif puis plus tard sur le lieu de travail. Deuxièmement, les cadres institutionnels généralement utilisés pour promouvoir les relations entre les entreprises et le milieu scientifique ne sont pas assez développés. Cela est particulièrement vrai des partenariats public/privé pour l'innovation et des mécanismes visant à encourager et à organiser le dialogue entre les entreprises et les établissements d'enseignement sur les besoins actuels et à venir en capital humain spécialisé.

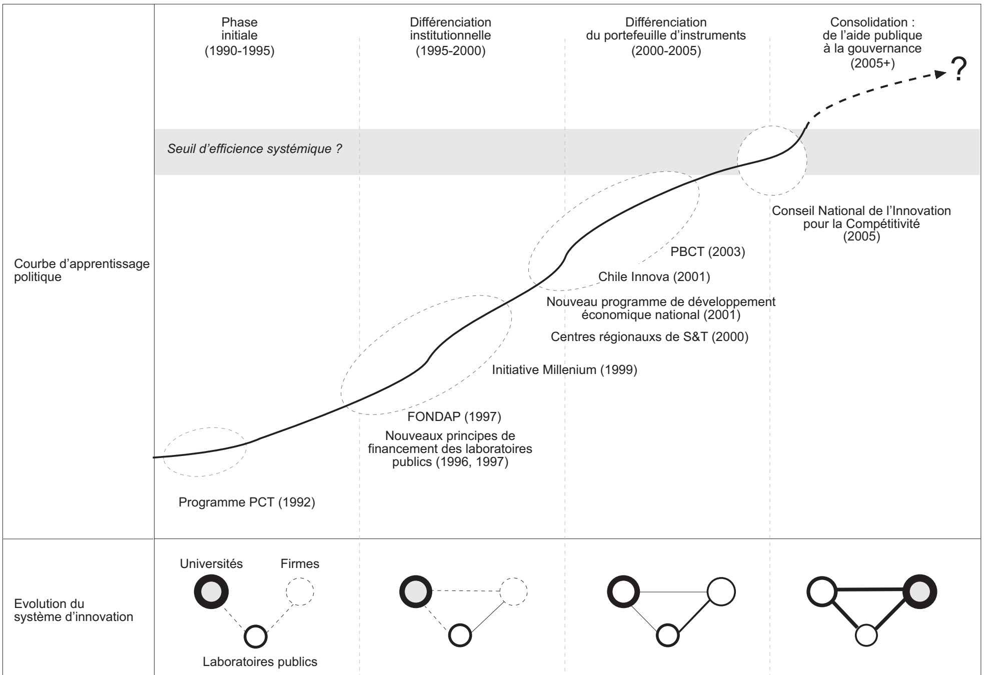
Les possibilités de développement futur

- *Mieux exploiter des conditions générales favorables*. Le Chili est un précurseur dans le domaine de la législation et de la politique de la concurrence en Amérique latine et parmi les pays en développement ; il a notamment fait figure de pionnier dans l'application des principes de la concurrence dans le secteur des infrastructures. Mais le Chili bénéficie également d'autres conditions générales favorables qui peuvent largement renforcer l'efficacité de la politique de l'innovation. Les principaux atouts du Chili en matière de conditions cadres pour l'innovation sont les suivants : la qualité et la fiabilité des institutions et la stabilité politique ; des résultats macroéconomiques solides, notamment une inflation stable et des comptes budgétaires équilibrés ; un régime de libre-échange et une législation favorable à l'investissement direct étranger. Cependant, la part actuelle des filiales de sociétés étrangères dans l'ensemble des activités de R-D des entreprises est bien inférieure à celle de pays latino-américains comparables tels que le Brésil, le Mexique et l'Argentine. A l'avenir, le Chili peut espérer tirer parti de la mondialisation croissante des activités de R-D s'il parvient à renforcer ses capacités d'absorption nationales.

- *Un noyau dur d'acteurs compétents approchant de la masse critique*. La réussite du Chili sur les marchés d'exportation n'aurait pas été possible sans certaines formes d'innovation. En l'espace de dix ans est apparu un ensemble important d'entreprises et d'entrepreneurs capables de conjuguer de manière originale possibilités technologiques et commerciales. Le Chili a maintenant acquis une expérience considérable dans la manière d'accroître la valeur ajoutée dans les industries exploitant les ressources naturelles, à travers l'innovation, y compris les nouvelles technologies fondées directement sur la science telles les biotechnologies. Cela concerne tant le développement des compétences commerciales que des structures de soutien, telles que la Fundación Chile, qui est aujourd'hui mondialement reconnue pour ses pratiques exemplaires.

- *De nouvelles opportunités*. Plusieurs opportunités s'offrent au pays pour dynamiser son système d'innovation, par exemple : mettre encore davantage à profit l'expérience acquise dans la manière d'accroître la valeur ajoutée dans les industries exploitant les ressources naturelles ; s'appuyer sur les grappes d'entreprises solides existantes afin de développer des activités tertiaires et industrielles innovantes dans les secteurs concernés ; transformer les contraintes logistiques en défis pour l'innovation : progresser en tant que leader régional dans certains créneaux de l'industrie et des services ; exploiter les atouts du pays en matière d'environnement pour capter une plus grande part du tourisme haut de gamme ; tirer des avantages inattendus des découvertes scientifiques et technologiques fortuites grâce à des investissements soutenus dans une recherche fondamentale de qualité.

Graphique 0.1. La politique de l'innovation au Chili : courbe d'apprentissage



Force motrice	Première initiative politique	Croissance des industries d'exportation		Seconde initiative politique
Type d'apprentissage	Apprentissage assisté des pratiques étrangères	Apprentissage autonome et accéléré des meilleurs pratiques des pays avancés et apparition des premiers éléments d'un apprentissage institutionel endogène		Apprentissage institutionnel endogène, y compris au sein de la communauté OCDE
Objectif politique	Promotion horizontale de projets de R-D suivant une approche purement ascendante	Mobiliser les firmes ; concentrer le financement de la recherche scientifique dans des domaines d'excellence	Renforcer les liens entre acteurs dans des domaines prioritaires ; améliorer certaines des conditions-cadre	Améliorer la governance d'ensemble ; rationaliser les modalités d'intervention et affuter les prioriotés
Instruments de financement	Subventions en faveur de projets individuels ; financement institutionnel des laboratoires publics	Introduction de subventions en faveur de groupes de recherche ; réforme du financement des laboratoires publics	Développement de consortia, émergence d'une politique de promotion des "grappes" d'entreprises innovantes	Introduction d'une aide fiscale à la R-D

Politique publique de l'innovation : un stade décisif dans la courbe d'apprentissage

Jusqu'au début des années 90, les instruments de la politique de l'innovation se composaient essentiellement d'un organisme de financement qui soutenait principalement la recherche universitaire et finançait des bourses ainsi qu'un ensemble d'instituts technologiques qui effectuaient des missions de service public et fournissaient certains services technologiques de base auprès d'un nombre limité d'entreprises dans l'industrie et l'agriculture. Au cours des quinze dernières années, le Chili a connu un processus d'apprentissage accéléré grâce auquel une gamme d'instruments plus étoffée, répondant à un ensemble plus large d'objectifs, a été progressivement élaborée (voir le graphique 0.1). Toutefois, si la politique de l'innovation ne bénéficie pas encore d'une priorité suffisamment claire et d'une mise en œuvre totalement équilibrée, elle a atteint un certain niveau de maturité, en termes de capacités institutionnelles, ce qui augure d'une nette amélioration de son efficience, à condition que l'engagement politique de haut niveau en faveur de l'accroissement du soutien public se traduise également par des réformes visant à corriger les principaux défauts des pratiques actuelles, qui sont les suivants :

La faiblesse de la gouvernance globale et de la coordination entre les organismes

Le Chili ne disposait pas jusqu'à présent d'un mécanisme formel complètement développé lui permettant d'élaborer une stratégie explicite en matière de politique d'innovation, et ainsi de dégager des priorités et d'orienter la mise en œuvre.

- Les priorités ont toujours été définies de manière plus ou moins décentralisée par des organismes tels que la CORFO au Ministère de l'économie, la CONICYT au Ministère de l'éducation et la FIA au Ministère de l'agriculture. D'autres ministères, comme ceux de la santé et de la planification, jouent un rôle comparativement mineur. Une certaine forme de coordination existe bien au niveau des programmes et, dans une moindre mesure, entre les organismes, mais cela ne suffit pas à compenser la faiblesse du pilotage central du système.
- La coordination entre les organismes, en particulier entre la CONICYT et la CORFO, est un problème déjà ancien qui n'a pas encore trouvé de solution satisfaisante. C'est pourquoi de nombreux fonds et programmes ne sont pas suffisamment différenciés en termes d'objectifs, de raison d'être et de types de résultats attendus. De fait, chaque organisme a

tendance à apporter ses propres réponses à l'ensemble des problèmes, ce qui conduit à une mauvaise répartition des tâches au sein du système de soutien public.

Dans ce contexte, deux décisions récentes du gouvernement chilien semblent particulièrement opportunes : la création du Conseil national de l'innovation pour la compétitivité (CNIC) et la constitution du Fonds de l'innovation pour la compétitivité (FIC), dont la tâche principale sera d'affecter les recettes issues du nouvel impôt sur la production minière.

Un portefeuille de mesures déséquilibré

L'ensemble des mesures prises par le Chili dans le domaine de l'innovation souffre de déséquilibres importants, qui reflètent des caractéristiques structurelles qui ne peuvent être modifiées que progressivement, en particulier le rôle dominant des universités dans la R-D, mais également des choix stratégiques concernant les objectifs prioritaires et les instruments à utiliser. Sur ce dernier point, trois problèmes ressortent.

- Premièrement, l'accent a été mis sur la R-D plutôt que sur la diffusion des connaissances et l'entrepreneuriat axé sur les technologies, même si Innova Chile est depuis ces dernières années de plus en plus actif dans ces domaines.
- Deuxièmement, les mesures de soutien à des projets individuels, par opposition à celles prises dans le cadre de programmes, représentent la plus grande part des dépenses publiques de R-D.
- Troisièmement, à l'inverse de la plupart des pays de l'OCDE, la panoplie des mesures prises par les autorités chiliennes pour promouvoir la R-D dans les entreprises a jusqu'à présent privilégié des aides publiques directes. Actuellement, les dépenses de R-D sont déductibles de l'impôt sur les sociétés, tout comme la moitié des dons versés aux universités. La majorité du soutien public prend la forme de subventions accordées sur une base concurrentielle par l'intermédiaire de multiples fonds.

Ce dernier problème est sur le point d'être corrigé avec l'introduction d'une incitation fiscale en faveur de la R-D. Toutefois, cette mesure est conçue de telle sorte qu'elle a peu de chances d'exercer une grande influence sur l'équilibre général des incitations au sein du système d'innovation.

Un éparpillement des aides et des instruments mal ciblés

Le manque de taille critique

- Les dépenses publiques dans les domaines de la R-D et de l'innovation au Chili sont importantes en valeur relative, si on les compare au niveau des dépenses du secteur privé, mais elles sont limitées en valeur absolue. La multiplication des instruments d'attribution de ces fonds crée inévitablement un éparpillement des aides dans tous les domaines, mais particulièrement dans la promotion de l'innovation en entreprise, étant donné qu'une large part des fonds publics consacrés à la R-D est réservée à la recherche fondamentale. Ce morcellement a parfois été favorisé par l'introduction hâtive de mesures ayant fait leur preuve dans les pays avancés, dans un contexte qui se prêtait mal à une gestion politique efficace de la différenciation institutionnelle requise.

Recoupements et angles morts

- La fragmentation du système de soutien et l'échec relatif des tentatives de coordination entraînent invariablement des doublons ou du moins des chevauchements inutiles. Il y a de nombreux exemples, parmi lesquels les projets préconcurrentiels encouragés par le FONDEF (CONICYT) et le FDI (aujourd'hui absorbé par Innova Chile, de la CORFO), ou l'Initiative Millenium et le FONDAP pour la promotion des centres d'excellence en recherche scientifique, pour n'en citer que deux.

- Dans le même temps, certains des besoins fondamentaux de nombreux acteurs économiques n'ont quasiment pas été pris en compte, car pour y répondre, il aurait fallu mettre en place des actions : *i)* plus difficiles à harmoniser parce que demandant une coordination entre les organismes, par exemple des mesures de promotion des grappes innovantes; et/ou *ii)* politiquement moins visibles et moins demandées par la « clientèle » habituelle des organismes de financement, par exemple des mesures pour inciter la « majorité silencieuse » des PME à « faire le premier pas » vers l'innovation ; et/ou *iii)* plus difficiles à manier par les organismes publics existants compte tenu de leurs compétences et/ou de leur « culture d'entreprise », par exemple des mesures visant à remédier à l'insuffisance des capacités dans certains domaines.

- L'une des caractéristiques les plus problématiques de la palette actuelle des instruments de la politique d'innovation chilienne est qu'elle offre un soutien inégal aux diverses phases des projets d'innovation de différents types d'entreprises. Le système de soutien public reste focalisé sur l'étape de recherche du processus d'innovation au sein d'entreprises bien préparées. La phase initiale de renforcement des capacités des firmes qui ne sont pas encore innovantes et l'abaissement des obstacles qui empêchent les firmes déjà innovantes de l'être davantage, lors d'étapes telles que le passage de l'idée au prototype, l'industrialisation et la commercialisation, ne sont pas correctement couverts. En conséquence, la politique de l'innovation n'atteint pas la vaste majorité des PME du pays.

Une mauvaise articulation avec la demande sectorielle

- L'articulation entre le système de soutien à l'innovation et la dynamique concurrentielle des secteurs productifs a été trop faible pendant trop longtemps, même si certaines institutions telles que la Fundación Chile ont démontré très tôt la faisabilité d'une approche fondée sur les grappes d'entreprises pour encourager l'innovation, et bien que l'action des pouvoirs publics penche dans cette direction depuis quelques années.

Recommandations

Les orientations stratégiques

Malgré les résultats économiques remarquables enregistrés par le Chili depuis vingt ans, il existe toujours un écart appréciable avec les niveaux de revenu des pays développés. La politique économique du Chili a donc pour *objectif primordial* de parvenir à une croissance durable, soutenue et équitable afin de combler cet écart tout en réduisant encore la pauvreté ainsi que l'inégalité persistante dans la répartition des revenus.

Il sera difficile d'atteindre cet objectif sans une modification, sur le long terme, des sources de la croissance. Nul ne doute que, de ce point de vue, l'accumulation des facteurs de production doit s'accompagner d'une hausse constante de la productivité. L'innovation – soutenue par des conditions cadres favorables et stimulée par une politique dédiée explicite – représente l'un des moyens les plus efficaces d'accroître la productivité. Jusqu'à présent, les performances et les efforts déployés dans le domaine de l'innovation ne sont pas à la hauteur des résultats obtenus par le Chili dans d'autres secteurs. La culture d'entreprise ne s'est pas encore pleinement répandue dans le pays et les activités innovantes sont toujours rares et souvent isolées.

Il faudra parvenir à un consensus plus ferme sur le rôle clé que l'innovation aura à jouer dans le développement futur de l'économie chilienne. Dans le contexte d'une stratégie pour l'innovation, le rôle du gouvernement ne se résume pas seulement à établir des conditions macro-économiques propices à des niveaux élevés d'investissement, il doit également corriger les défaillances du marché et du système qui empêchent le pays d'exploiter pleinement son potentiel d'innovation. L'action des pouvoirs publics peut aussi contribuer largement à faciliter et à stimuler la diversification qui, à terme, entraînera des changements bénéfiques dans la structure industrielle de l'économie chilienne.

La distance que le Chili doit encore parcourir jusqu'aux pays les plus avancés d'un point de vue technologique et économique peut être mise à profit pour doper la croissance puisqu'elle suppose un potentiel de rattrapage important. Le Chili a déjà montré dans le passé un degré élevé de capacités sociales et de capacité d'absorption pour faire bon usage de ce potentiel.

Les principales tâches à accomplir pour parvenir à l'objectif primordial sont les suivantes.

Développer les ressources humaines

- Les mesures visant à développer la base des ressources humaines au Chili constituent la pierre angulaire de toute stratégie en faveur d'une croissance reposant davantage sur l'innovation. Les ressources humaines qualifiées représentent un facteur de blocage majeur pour le développement économique et social du Chili ainsi que pour renforcer ses capacités d'innovation. L'une des tâches les plus urgentes consiste donc à développer la base des ressources humaines du pays. Même si les niveaux de formation ont augmenté dernièrement, la qualité est toujours insuffisante. Il est donc encourageant de constater que des mesures significatives pour élever la qualité de l'enseignement aux niveaux internationaux sont en cours d'application, et que de nouvelles initiatives dans le même sens sont prévues.

Étendre la portée et l'ampleur des avantages comparatifs

- Malgré une diversification progressive, grâce à l'apparition de nouveaux secteurs à vocation exportatrice dans le domaine agroalimentaire et à la hausse des exportations de services, l'économie chilienne est toujours relativement peu diversifiée. La gamme des produits exportables est demeurée limitée. L'agriculture et l'exploitation minière sont généralement moins propices à la diversification des produits que certains services et industries manufacturières (lesquelles stagnent). La part des échanges intra-sectoriels – un segment extrêmement dynamique du commerce international – est très faible, bien inférieure à celle de pays comparables en Amérique latine (Brésil, Mexique, Argentine). Le modèle de spécialisation actuel de l'économie chilienne comporte certains inconvénients, notamment :

- Un risque élevé associé à une spécialisation en recul mais toujours forte dans les produits de base, ce qui rend l'économie vulnérable à de brusques variations des prix internationaux des produits de base et à des déplacements à long terme de la demande concernant ces produits.
- Le faible degré de diversité des produits et la modeste part des échanges intra-sectoriels dans le commerce extérieur pourraient peser sur la croissance à long terme du pays.

- Une stratégie réussie en matière d'innovation peut être déterminante pour faciliter les changements structurels de nature à réduire les risques inhérents à ce type particulier de spécialisation.
- Au cours de la transition vers une croissance reposant davantage sur l'innovation, le Chili devrait mettre encore mieux en valeur ses atouts et ses avantages comparatifs en s'appuyant sur les grappes d'entreprises naissantes, centrées principalement pour l'heure sur l'exploitation des ressources naturelles, pour promouvoir des pratiques plus innovantes qui permettront de transformer les avantages statiques de l'économie chilienne en avantages dynamiques. L'essor de nouvelles activités peut être encouragé en élargissant la gamme des produits à haute valeur ajoutée exportés et en étoffant l'offre de produits et services spécialisés qui, à l'origine, s'est développée pour répondre aux besoins spécifiques des grappes d'entreprises exploitant les ressources naturelles.

Principes directeurs

Pour atteindre ces objectifs, les pouvoirs publics devraient appliquer les principes directeurs suivants :

- *Exploiter la présente fenêtre d'opportunité*. Il convient de tirer parti des possibilités qu'offre une conjoncture actuellement favorable à l'économie chilienne pour mettre à profit les avantages comparatifs existants afin d'en générer de nouveaux. L'accélération du processus de mondialisation entraîne de nouvelles opportunités mais aussi le risque de se laisser distancer dans si ces opportunités ne sont pas saisies. Dans le cas du Chili, les problèmes immédiats sont peut-être moins épineux que pour nombre d'autres pays. Le Chili a été l'un des premiers pays en développement à engager des réformes libérales et à privilégier l'ouverture. A l'inverse d'autres pays ayant un revenu par habitant similaire, il n'y a pas au Chili de très grand secteur manufacturier à faible productivité, utilisant beaucoup de main-d'œuvre et désormais exposé à une vive concurrence de la part d'économies émergentes. Au contraire, le pays bénéficie largement à l'heure actuelle de la croissance rapide des principales économies émergentes, en particulier de la demande accrue de matières premières qui en résulte. Néanmoins, il semble prudent d'exploiter la situation présente en adoptant une perspective à long terme. De ce point de vue, la stratégie du gouvernement chilien, qui utilise une partie des recettes supplémentaires pour investir au service de besoins futurs, se révèle opportune et sage.

- *S'appuyer sur un cadre macroéconomique et des institutions solides*. Le Chili est parvenu à établir un cadre macroéconomique efficace et des institutions modernes et solides qui constituent l'un de ses principaux atouts. La stabilité et de bonnes performances macroéconomiques contribuent à améliorer la confiance des entreprises et induisent donc un climat propice à l'investissement et à l'innovation.

- *S'attaquer aux défaillances du marché et du système*. De bonnes conditions cadres sont nécessaires à un système d'innovation efficace mais elles ne sont pas suffisantes. Il faut aussi entreprendre des actions plus spécifiques afin de corriger des défaillances du marché ou du système qui nuisent à la R-D et à l'innovation, en les soumettant aux principes rigoureux justifiant l'intervention publique. En mettant en œuvre des mesures ambitieuses en faveur de l'innovation, il faudra préserver la stabilité des institutions et du cadre politique, qui constituent des atouts majeurs du pays.

- *Adopter une approche ouverte et équilibrée de l'innovation*. Éviter de se focaliser sur les hautes technologies pour privilégier une stratégie plus ouverte du changement s'appuyant sur les points forts en vue de renforcer et d'élargir les fondements d'une croissance à long terme. Une approche ouverte de l'innovation prend en compte l'innovation organisationnelle, les nouveaux modèles d'entreprise ainsi que l'innovation dans les services. Une approche équilibrée reconnaît que la diffusion technologique est le principal vecteur de l'innovation dans la majorité des entreprises.

- *Consolider le système de soutien public*. Il est nécessaire de réduire les chevauchements existants et d'obtenir une taille critique pour chaque instrument, mais cela ne doit pas se faire au détriment de la différenciation institutionnelle, qui est nécessaire pour pouvoir poursuivre de manière efficiente un vaste ensemble d'objectifs. Toutefois, lorsque plusieurs solutions à des problèmes analogues ont été expérimentées par différents organismes/programmes, il faut concentrer les ressources sur la méthode qui s'est révélée la plus efficace.

- *Effectuer un ciblage « intelligent ».* Au Chili, la question n'est pas de savoir si, mais de quelle manière efficace une partie de la politique de l'innovation devrait viser certaines catégories d'activités ou certains réseaux d'entreprises, à l'aide d'« instruments de ciblage » compatibles avec les lois du marché, tels que les partenariats public/privé. Un ciblage « intelligent » ne rend pas moins nécessaire des politiques horizontales pour augmenter la probabilité de percées technologiques inattendues, pour aider les firmes de tous les secteurs à tirer avantage des retombées du développement des grappes industrielles les plus dynamiques et pour élever les capacités d'innovation dans l'ensemble de l'économie.

- *Respecter des principes de gouvernance avancés*. Une distinction claire devrait être établie entre la formulation des politiques et leur mise en œuvre, celle-ci devant reposer sur une combinaison efficace d'instruments éprouvés : coordination, concurrence (financement sur appel d'offres, par exemple), coopération (projets de recherche communs, etc.), mécanismes de gestion fondés sur les résultats (contrats d'objectifs, critères de financement, etc.).

Recommandations spécifiques

La gouvernance globale

Le Conseil national de l'innovation pourrait être le catalyseur d'une maturation accélérée du système d'innovation chilien, à condition que sa composition, son positionnement institutionnel et les moyens dont il dispose soient appropriés. Si l'on en croit l'expérience acquise par les pays de l'OCDE dans ce domaine, il convient de prendre en compte les éléments suivants :

- Sa composition, en termes d'effectifs et d'appartenance institutionnelle des membres, doit conjuguer représentativité et efficacité, afin d'éviter toute récupération par des intérêts particuliers et assurer des délibérations productives. S'il doit comprendre des représentants de tous les « milieux » (pouvoirs publics, entreprises, secteur financier, universités et instituts technologiques), au moins un tiers de ses membres ne devrait pas exercer de responsabilités dans la gestion actuelle du système. Parmi les membres « indépendants », au moins un devrait être étranger ou Chilien expatrié et posséder une expérience avérée en science, en technologie ou dans le domaine de l'innovation.

- Son positionnement institutionnel doit permettre d'optimiser son impact et de préserver sa réputation en tant qu'organisme impartial au service de l'intérêt général.

- Son mandat et son mode de fonctionnement doivent garantir son utilité pratique et encourager son recours à des méthodes d'évaluation et de conseil reposant sur des données objectives.
- Il doit donc s'appuyer sur un secrétariat exécutif solide et doté des ressources adéquates, dirigé par un comité exécutif restreint, qui doit réunir les compétences et disposer des moyens financiers nécessaires pour mener ou commander des études et évaluations indépendantes et mettre en place un système de suivi en continu.
- A condition qu'il réponde à toutes les conditions énoncées ci-dessus pour un fonctionnement efficace, il pourrait se voir confier la mission d'établir l'orientation stratégique des nouvelles ressources publiques destinées à l'innovation, en utilisant un mécanisme permettant de traduire ses priorités politiques en priorités de financement pour le Fonds de l'innovation pour la compétitivité (FIC).

Sa fonction d'évaluation devrait être double : i) établir des normes de qualité et un cadre pour l'évaluation de chaque établissement de recherche public, programme et mesure ; et ii) mener lui-même des évaluations thématiques à l'échelle du système. Sur ce dernier point, les tâches suivantes seraient particulièrement importantes :

- Évaluer le rôle des instituts technologiques dans le système d'innovation ainsi que leurs mécanismes de pilotage. Ces derniers ont évolué au fil du temps, à des rythmes différents et au gré de motivations et de principes divers. Élaborer une politique cohérente pour les instituts technologiques nécessiterait une évaluation des résultats et des capacités de tous ces instituts, sous un angle réellement systémique, et avec pour objectif de réaffirmer ou de redéfinir les missions, les modes de fonctionnement, l'orientation technologique, etc. sans exclure aucune option, réorganisation, fusion, privatisation ou fermeture.
- Évaluer l'efficience combinée des programmes et mesures existants, y compris les conditions cadres les plus importantes (les DPI, par exemple), qui visent à promouvoir la commercialisation des résultats de la recherche universitaire à travers la mobilité des chercheurs, les brevets et licences, les contrats de recherche et les « rejetons technologiques ».
- Évaluer l'impact de la nouvelle incitation fiscale en faveur de la R-D.
- Évaluer l'offre et la demande des ressources humaines spécialisées nécessaires pour l'innovation, en mettant particulièrement l'accent sur le rôle des sciences de l'ingénieur, notamment afin de déterminer ce que

pourrait être dans ce domaine un modèle efficace de coopération public/privé.

- Déterminer le bien-fondé et la faisabilité d'adopter une approche fondée plus systématiquement sur le concept de grappe d'entreprise dans la définition de la politique de l'innovation, en évaluant la gamme actuelle des programmes visant à encourager les consortiums et la constitution de réseaux d'entreprises, en cartographiant les grappes innovantes existantes et latentes, en tirant des leçons d'expériences réussies au Chili et ailleurs et en déterminant la meilleure manière de poursuivre la décentralisation de la politique de l'innovation.

- Évaluer les liens internationaux (de l'IDE jusqu'aux bourses étudiantes) afin de déterminer comment intensifier ceux susceptibles d'apporter la plus forte contribution à l'augmentation de l'efficience du système national d'innovation.

Le Fonds de l'innovation pour la compétitivité (FIC) sera essentiel pour mettre en œuvre la stratégie du Conseil, mais il ne s'agira pas simplement de traduire les priorités d'action en modifications significatives mais marginales de la répartition des financements publics entre les organismes/fonds existants. Les pouvoirs publics devraient envisager de faire de ce Fonds un « instrument de ciblage » ainsi qu'un « agent d'évolution structurelle » qui pourrait induire des changements plus profonds et alimenter le processus d'apprentissage endogène des institutions au sein du système d'innovation. A cet effet :

- Une solution pourrait être que le FIC absorbe certains des fonds publics destinés à l'innovation, en particulier ceux finançant des programmes aux objectifs multiples et concernant une grande variété de types de bénéficiaires.

- Une autre option, qui préserverait davantage la différenciation institutionnelle tout en tirant profit de l'expérience acquise par les organismes de financement existants au contact de certaines parties prenantes, serait de structurer et de gérer le FIC en suivant le modèle d'un « fonds de fonds » tel qu'il en existe dans le secteur du capital-risque, en y apportant bien sûr les adaptations nécessaires pour se conformer aux règles des finances publiques et respecter sa mission d'intérêt général.

Les gouvernements locaux devraient devenir des acteurs plus actifs de la politique d'innovation du Chili. Une poursuite des efforts de décentralisation serait salutaire car elle faciliterait le développement de véritables systèmes régionaux d'innovation et de grappes innovantes qui contribuera à la diversification économique autour des pôles puissants d'exportation. Mais la modification de l'équilibre des pouvoirs entre les différents niveaux de gouvernement ne sera bénéfique que si elle s'accompagne d'efforts pour renforcer les capacités institutionnelles et les compétences managériales des gouvernements régionaux et locaux.

Un portefeuille de mesures amélioré

Le système de soutien public devrait se focaliser moins sur l'étape recherche du processus d'innovation au bénéfice trop exclusif des entreprises les mieux préparées et motivées pour en tirer parti. Ceci suppose en particulier :

- Accorder plus d'attention à la phase initiale de renforcement des capacités des firmes qui ne sont pas encore innovantes et aux obstacles qui gênent les firmes innovantes lors d'étapes telles que le passage de l'idée au prototype, l'industrialisation et la commercialisation.
- Promouvoir le développement du marché de la connaissance, y compris les institutions pertinentes telles que les courtiers en technologie et les autres intermédiaires qui établissent un pont entre producteurs et utilisateurs finaux de la connaissance.
- Affûter la division du travail entre la CONICYT et la CORFO en différenciant mieux les tâches de leurs fonds et programmes respectifs en fonction de critères plus rigoureux ayant trait à la raison d'être de l'intervention gouvernementale, son objectif et la nature des résultats attendus.
- Améliorer la gestion par les organismes de financement de l'aide aux projets individuels, particulièrement en ce qui concerne l'évaluation des aspects financiers de ces projets, la rapidité de l'instruction et de la sélection des dossiers de candidature et la réactivité face au retour d'expérience des bénéficiaires.
- Allouer plus de ressources aux programmes ayant une pluralité d'objectifs et de participants, tels les consortiums de recherche, tout en renforçant leur gouvernance.

Des ressources humaines pour l'innovation

- Poursuivre les efforts déployés pour élever la qualité de l'enseignement au Chili au niveau des pays performants. Les investissements accrus dans l'éducation doivent s'inscrire dans la durée et s'accompagner d'améliorations de la qualité de l'enseignement dispensé qui doivent faire l'objet d'un suivi approprié.

- Mettre l'accent sur l'acquisition de compétences à tous les niveaux. Ne pas se focaliser exclusivement sur les niveaux supérieurs. Un système de formation professionnelle performant offre des conditions propices aux activités innovantes dans l'ensemble de l'économie, notamment dans les PME. Il convient d'accorder beaucoup d'attention au rôle des entreprises en tant que créateurs de capital humain pour l'innovation, notamment à travers la formation structurée.

- Poursuivre les initiatives visant à accroître le niveau de « culture numérique » dans l'ensemble de la société et à réduire la fracture numérique.

- Encourager et renforcer l'entrepreneuriat en améliorant les formations portant sur la création d'entreprise, comme plusieurs pays de l'OCDE l'ont fait ces dernières années. Améliorer l'enseignement des compétences de haut niveau en matière de gestion et dans le domaine de la direction d'entreprise.

- Élaborer des mesures anticipatives permettant d'équilibrer l'offre et la demande de ressources humaines en science et technologie (RHST) à moyen et long terme. Ces mesures devraient porter tant sur l'offre que sur la demande. Il est nécessaire de stimuler la demande de chercheurs par les entreprises, publiques comme privées. Du côté de l'offre, la politique relative aux RHST devrait anticiper une hausse de la demande de la part des entreprises. Les mécanismes structurant le dialogue entre secteurs public et privé pour définir les priorités de formation à moyen et long terme devraient être renforcés.

- Améliorer la gamme des programmes de doctorat-maîtrise, en mettant davantage l'accent, par la concentration des moyens, sur certains domaines stratégiques, et encourager la coopération entre institutions dans la définition et la mise en oeuvre de programmes conjoints.

- Concevoir des mesures plus actives en direction des expatriés comme des étrangers pour attirer au Chili les compétences. Plus généralement, améliorer le niveau de l'internationalisation du système d'enseignement. En particulier, prendre des mesures visant à accroître le nombre d'étudiants étrangers au Chili et d'étudiants chiliens à l'étranger. Envisager d'adopter une approche plus stratégique concernant le système des bourses, qui pourrait être employé comme un outil de cette internationalisation, afin d'harmoniser les mesures de renforcement des ressources humaines avec les objectifs de développement économique à long terme.

Tableau récapitulatif – Système national d'innovation au Chili : atouts, faiblesses, opportunités et menaces

Atouts	Opportunités
• Un cadre macroéconomique stable et des marchés de produits performants • L'ouverture internationale • Des cadres réglementaire et juridique fiables • L'engagement politique en faveur d'un soutien accru à l'innovation. Des relations de confiance entre les autorités, les fonctionnaires et le secteur privé • La solidité des industries exploitant les ressources naturelles à vocation exportatrice • Un noyau dur conséquent de firmes et d'entrepreneurs dynamiques mettant en oeuvre des modèles d'entreprise novateurs • Une grande expérience et un modèle avéré en ce qui concerne la modernisation des industries exploitant les ressources naturelles par le recours aux connaissances et technologies • Des poches d'excellence dans la recherche scientifique	• Développement supplémentaire des activités d'innovation à forte valeur ajoutée dans les industries exploitant les ressources naturelles • Construire des grappes innovantes autour des industries dynamiques existantes tournées vers l'exportation • Important potentiel du secteur des services, depuis les emplois peu qualifiés jusqu'aux services aux entreprises à forte intensité de qualifications • Exploitation des avantages du Chili en matière d'environnement afin d'obtenir une part plus importante du tourisme haut de gamme • Transformer les contraintes logistiques en défis pour l'innovation • Progresser en tant que leader régional dans certains créneaux de l'industrie et des services • Tirer des avantages inattendus des découvertes scientifiques et technologiques fortuites grâce à des investissements accrus dans une recherche fondamentale de qualité
Faiblesses	**Menaces**
• Les rentes issues de l'exploitation des ressources naturelles excèdent celles qui peuvent être attendues de la plupart des innovations • Des difficultés logistiques dues aux contraintes géographiques • Un système d'innovation centré sur la recherche fondamentale • Un niveau très faible de R-D et d'innovation dans les entreprises, notamment dans les sociétés sous contrôle étranger • Faiblesse des structures de gouvernance du système d'innovation, avec un manque de clarté de la stratégie globale au plus haut niveau politique et des acteurs régionaux au rôle marginal • Un système de soutien public fragmenté, centré sur la R-D et privilégiant l'aide aux projets individuels, avec un recoupement des activités et des angles morts • Un marché de la connaissance très étroit • Une infrastructure de diffusion des technologies insuffisante et en partie obsolète • Une offre insuffisante de capital de départ et de capital-risque • Des facteurs de blocage importants au niveau de l'offre et de la mobilité des RHST	• Des tendances lourdes en matière de coûts de transport longue distance pour des exportations à faible valeur ajoutée • Une spécialisation internationale figée sur des produits caractérisés par une faible élasticité de la demande mondiale par rapport au revenu • Marginalisation en tant que source et destination des flux internationaux de capital humain hautement qualifié • Creusement des disparités régionales • Pénurie des ressources humaines spécialisées nécessaires pour l'innovation • Perte de capital humain et social si le niveau actuel des inégalités n'est pas réduit • Détérioration de capacités mal employées, notamment dans les sciences de l'ingénieur

Chapter 1

TOWARDS MORE INNOVATION-DRIVEN GROWTH

1.1. Macroeconomic performance and institutional build-up

1.1.1. Economic performance

The economic performance of Chile, a small, open economy with a traditionally strong base in the production of commodities linked to natural resources, has been impressive over the last two decades. Between 1988 and 1997, it was particularly strong, with real GDP growing at an average annual rate of 7.9%. During this period, Chile's "growth acceleration" (Hausmann *et al*., 2004) was spectacular. From 1984 to 1997 GDP per capita grew by 5-6% a year, more than twice the long-term trend of 2.4% of the preceding 40 years (OECD, 2003). As a result, Chile not only stood out in the Latin American region but was one of the world's best-performing economies. High growth was associated with a significant rise in total factor productivity (TFP).

Chile's sound public finances and monetary and fiscal stability are reflected in a rate of inflation that has declined steadily towards the level in developed countries (Corbo, 2007). A prudent fiscal stance – supported since 2001 by a fiscal rule requiring a structural fiscal surplus equivalent to 1% of GDP (OECD, 2003) – has maintained public debt at low levels.

During the period of strong economic performance, Chile reduced the gap in per capita income with developed countries. Today, with GDP per capita of USD 10 874 in purchasing power parity (PPP) (2004), Chile ranks among the high middle-income countries. The differential in (PPP-based) GDP per capita with high-income countries, specifically the United States, is to some extent accounted for by a comparatively lower utilisation of labour, but the main source is a gap in labour productivity as measured by GDP per hour worked (OECD, 2005a, p. 25). There are substantial productivity differentials across industries, however.[1] Moreover, labour productivity in

1 Anecdotal evidence indicates that labour productivity in mining and some parts of agri-business has approached the levels of the best-performing countries but lags in sectors such as financial services and network industries (OECD, 2005a, p. 22).

manufacturing has not kept pace with the OECD average over the past two decades. The OECD Economic Survey of Chile concludes that more will need to be done to ensure sustained convergence with high-income countries over the longer term (OECD, 2007a).

Following the very strong growth between 1988 and 1997, growth slowed in 1998 (3.2%), and in 1999 the economy contracted (-0.8%). From 2000 to 2003, growth rebounded but remained more varied than in the decade to 1997. Then, in 2004 and 2005, real GDP rose sharply to 6.2 and 6.3%, respectively. International conditions were favourable for the Chilean economy in 2005: rapid growth of the world economy, the high price of copper and favourable external financial conditions. All sectors of the economy, except fisheries, contributed to growth; trade, manufacturing and the construction industry were the most significant sectors. Domestic expenditure was driven by private-sector and government consumption and also to a great extent by gross fixed capital formation. Real available gross national income grew by 9.1% as a result of the terms of trade, with price increases in mining products more than compensating for rises in oil prices. Total savings reached 23.0% of GDP (Banco Central de Chile, 2006).

Real GDP growth slowed to slightly above 4% in 2006. The slowdown, despite record highs in copper prices, appears to have been due to a temporary lull in the investment boom and some special factors: adverse weather conditions, stagnation in copper output due, among other things, to a strike in a major mine, and a cut in Argentina's natural gas exports to Chile. Forecasts for 2007 and 2008 continue to put Chile's real growth at about 5% or slightly above (International Monetary Fund, 2006; World Bank, 2007).

Over the past 20 years, Chile has closed much of the gap with advanced countries in income per capita. However, while it stands out among Latin American countries, it has not achieved the dynamism of the most successful Asian economies. Important challenges remain, including the high degree of inequality and challenges related to the management and performance of the country's educational system.

1.1.2. Economic reform and institutional build-up

Chile's strong economic performance of the past two decades, which has contrasted with other developments in the region, was underpinned by its efforts at economic reform and institution building. Macroeconomic and structural reform and a prudent and predictable monetary and fiscal policy stance have contributed to Chile's success in achieving sound macro-economic fundamentals, and the creation of sound modern institutions has contributed to sustained high growth. This has helped to create an environment that is conducive to entrepreneurship and innovation.

Chile's success in recent decades has been based on an increasingly outward-oriented model of development. In the 1970s under the military regime, Chile underwent a first wave of economic reform, with a shift from import substitution to export orientation. Trade reform opened the economy, reorienting incentives towards the production of tradables. Increased openness was accompanied by privatisation of state-owned enterprises and market deregulation. In 1982-83, an external shock triggered a deep economic and financial crisis, which highlighted a number of shortcomings in the regulatory regime. This eventually led to further institutional reforms in the second half of the 1980s (including the change in the status of the now fully autonomous Central Bank of Chile).

With the transition to democracy, which started in 1989, the market-oriented economic model has been maintained and in fact strengthened. Economic reforms continued throughout the 1990s and into the new century. They include private-sector involvement in infrastructure development, the introduction of competition in telecommunications, further trade reform through unilateral tariff reductions and a series of foreign trade agreements, anti-trust rules, monetary policy, abolition of the exchange rate band, adoption of a structural fiscal surplus of 1% of GDP as a fiscal rule, lifting of all capital controls, capital market reform and the creation of competition tribunals (Corbo, 2007). Today Chile is the most open country in Latin America, and the modern and stable institutions created over the past decades are an asset for high and sustainable economic growth. Since the transition to democracy, social policies aimed at fostering social cohesion and poverty alleviation have received more attention from government.

1.1.3. Sources of economic growth

Sustaining high growth is a major goal of Chile's economic policy. In this context it is important to understand the patterns of growth and its main proximate sources. A significant body of empirical studies addresses this issue, a number of which are based on growth accounting. Growth accounting studies are used to quantify, under certain assumptions, the proximate causes of economic growth, in particular the relative contribution of the factors of production – capital and labour – and of total factor productivity, which measures, broadly speaking, changes in the efficiency of the use of factor inputs.

A number of studies have analysed the contribution of TFP to Chile's economic growth in different periods (*e.g.* Beyer and Vergara, 2002; Fuentes *et al.*, 2004; Alvarez and Fuentes, 2004; Vergara and Rivero, 2005).

They reveal that a significant shift occurred in the 1990s in the relative contribution of the proximate sources of growth. For a survey of various growth accounting studies for Chile, see OECD (2005a).

It should be borne in mind, however, that the results of growth accounting exercises differ, depending notably on the methodology chosen and the period of observation. Since TFP is estimated as a residual it is also affected by mismeasurement of factors of production, omitted factors, etc. Moreover TFP is pro-cyclical since factors of productions tend to be underutilised in the downturn of the cycle.

While factor accumulation continues to be recognised as an important source of economic growth, there is an emerging consensus that improved TFP, which may be the more relevant source in the long term, require increased attention. While the empirical evidence indicates that a significant increase in the contribution of TFP to Chile's economic growth has taken place – especially during the high-growth phase of the 1990s – there appears to be a risk of stagnation, which is attributed to the tailing off of the impact of the structural reforms of the 1980s and early 1990s. It is thought that, to return to growth rates in the range of 7%, reforms will be needed that have the potential to boost productivity growth. These include progress in the area of education, further reforms of the public sector and measures designed to increasing private-sector innovation activity.

Beyer and Vergara (2002) consider that the lacklustre growth of the Chilean economy after the onset of the economic downturn in 1997 was due in part to unfavourable external conditions, but they emphasise that boosting TFP can dynamise growth. This might best be accomplished by a new wave of reforms aimed at the fundamentals of economic growth, at increased efficiency in the use of the economy's resources, at health, education and labour, as well as by stimulation of innovative activity. To achieve another decade of high growth it is also necessary to improve Chile's institutional structure, which is generally favourable, but has room for improvements that could stimulate growth. For a framework that links consecutive waves of reform to growth, see OECD (2003).

Table 1.1 shows the evolution of TFP and its contribution to Chile's economic growth. In the second half of the 1970s, a productivity boom coincided with the first wave of structural reforms. This phase ended with the debt and banking crisis of the early 1980s. It was followed by a recovery and the onset of a second productivity boom in the latter half of the decade which coincided with a second wave of reforms. In the second half of the 1990s, productivity growth slowed progressively, and eventually turned negative between 1998 and 2001.

Table 1.1. Contributions to GDP growth, in %

	GDP growth	Contribution to growth		
		Labour	Capital	TFP
1976-1980	6.8	2.3	0.8	3.7
1981-1985	-0.1	1.2	0.9	-2.2
1986-1990	6.8	2.5	2.0	2.3
1991-1996	8.7	1.5	3.5	3.7
1996-2000	4.1	0.5	3.6	0.1
1998-2001	2.4	0.1	2.8	-0.6

Source: Beyer and Vergara (2002).

Fuentes *et al.* (2004) break down economic growth from 1960 to 2003 into the contribution of capital and labour and of TFP. In addition, they study the determinants of TFP over the period. Using alternative measures of capital and labour, a breakdown of Chile's economic growth gives rise to various measures of residual series of TFP.[2] The results indicate that Chile's GDP grew by 3.8% a year on average over the period and that most of the growth, viewed over the entire period, is accounted for by the accumulation of factors of production, with efficiency gains playing only a secondary role. However, there are noticeable differences between sub-periods.

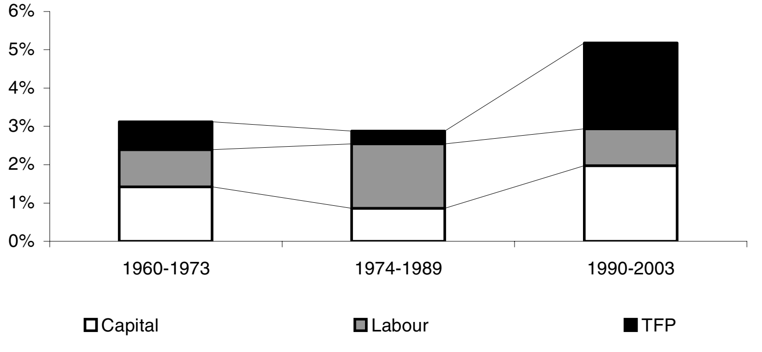
Between 1960 and 1973, a period of modest economic growth, capital accumulation made the most significant contribution to growth (Figure 1.1), while between 1974 and 1989, when economic growth was even slower, the most significant contribution was that of increased labour input. However, from 1990 to 2003, when the Chilean economy expanded rapidly, TFP made the most significant contribution. A further breakdown of the last period indicates that the contribution of TFP was particularly prominent in the period of high growth from 1990 to 1997. This buoyant phase was followed by a downturn and a period of moderate growth (1998-2003) characterised by a low contribution of TFP (Figure 1.2). This reflects strong cyclical influences but may also have had more profound causes.

The evidence concerning the determinants of TFP growth indicates that, apart from cyclical effects (proxied through terms of trade), it is influenced by macroeconomic stability (measured by low inflation) and microeconomic reform. The interaction of macroeconomic and microeconomic factors is

2. See Fuentes *et al.* (2004) on alternative measures for measuring capital and labour. In the following, the traditional measure – capital as stock of physical capital and labour as the number of workers – will be used.

very important. Under conditions of high/low macroeconomic instability the impact of microeconomic reforms is lower/higher. Fuentes *et al.* conclude that, as Chile has achieved a high level of economic stability, it will need to undertake further microeconomic reforms to achieve higher growth rates of GDP and TFP on a more permanent basis.

Figure 1.1. Sources of GDP growth in Chile, various periods



Source: Fuentes *et al.* (2004).

Figure 1.2. Breakdown of capital, labour and TFP, 1990-97 and 1998-2003

Source: Fuentes *et al.* (2004).

Box 1.1. Growth at the sectoral level

Vergara and Rivero (2005) calculate the contributions of labour, capital and TFP to growth of sectoral output between 1986 and 2001 for six sectors of the Chilean economy (manufacturing; electricity, gas and water; construction; wholesale and retail trade, restaurants and hotels; transport and communication; and financial services),* and for the sub-period 1996-2001 (also covering agriculture, mining and community services).

Over the longer period, the wholesale and retail trade sector, which uses information technology intensively, recorded the highest productivity improvements, both in absolute terms (2.7 points of the sector's annual growth are due to TFP growth) and in relative terms (36% of the growth is due to improved TFP). This is consistent with findings that the sectors with the highest TFP growth in other countries are those that use information technology. In the United States, productivity growth in the second half of the 1990s was largely due to increased productivity in the retail sector. In Chile, the sector with the second highest productivity growth rate over the long period is financial and business services, which is also an intensive user of information technology and is found to be among the sectors with the highest TFP growth in various international studies.

TFP growth, 1986-2001

		Contribution to growth		
	GDP growth	Labour	Capital	TFP
Manufacturing	4.77	0.89	4.33	-0.45
Electricity, gas and water	5.03	0.08	4.28	0.67
Construction	5.87	2.02	2.90	0.95
Trade, restaurants and hotels	7.39	1.92	2.82	2.65
Transport and communication	9.02	2.99	4.80	1.23
Financial and business services	7.26	3.90	1.98	1.38

TFP growth, 1996-2001

		Contribution to growth		
	GDP growth	Labour	Capital	TFP
Agriculture	4.12	-2.76	0.95	5.92
Mining	8.09	-1.45	3.20	6.34
Manufacturing	1.51	-1.66	3.43	-0.26
Electricity, gas and water	3.58	-1.79	4.194	1.18
Construction	-0.10	-1.64	2.98	-1.44
Trade, restaurants and hotels	2.54	0.38	2.50	-0.34
Transport and communication	6.78	2.10	5.22	-0.54
Financial and business services	4.13	1.88	3.74	-1.49
Community services	3.59	-0.37	1.51	2.45

Source: Vergara and Rivero (2005).

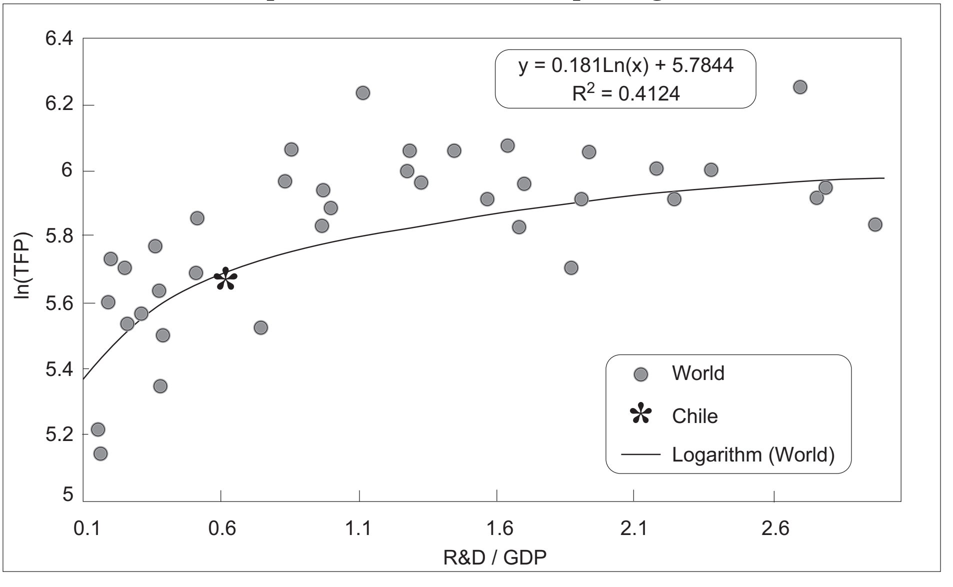
* Note: Agriculture, mining and community services are not included since the data on capital stock are highly volatile, raising doubts concerning their reliability. It should be noted that the sectors covered by this analysis represents just about one-third of the capital stock of the economy, and thus do not allow drawing conclusions on aggregate productivity.

Box 1.2. The current and prospective contribution of R&D to Chile's economic growth

Very little is known so far about the actual or potential impact of R&D on Chile's economic growth, and evidence on the impact of technological innovation is also scarce. Studies that analyse this relationship mainly consider national R&D expenditure the main variable associated with technological innovation. The results suggest that a country's economic growth is affected by its own as well as foreign R&D spending, even though the time lag involved may be significant.

Based on TFP data, calculated by De Gregorio (2004), and country-level R&D statistics, constructed by Lederman and Sáenz (2003), Benavente (2005) found a positive relationship between the two variables averaged for long periods (a simple correlation analysis yields a statistically significant value of nearly 0.6). For Chile, small increases in the innovation effort, as measured by R&D expenditure, are expected to generate significant increases in economic growth, owing to the great potential return of this type of activities to countries situated behind the global knowledge frontier.

Relationship between TFP and R&D spending (1985-2000)



Source: Benavente (2005).

In the evaluation of the impact of the Technological Development Programme in Priority Areas, Crespi and Rau (2004) studied the impact on GDP of the stimulus to TFP induced by the programme. This stimulus is related to the positive social returns estimated for the projects funded through the programme, and to increased private spending on R&D under the assumption that the private sector contributes by financing the chosen projects (the innovation support instruments are designed as a co-financing scheme). The study finds that this may lead to a stimulus in TFP of between 0.11% and 0.18% which was estimated to generate a temporary acceleration of GDP growth of between 0.4% and 0.7%.

Source: Benavente, 2005.

There have been few attempts to break growth down at the sectoral level. A recent attempt in this direction is described in Box 1.1 and tentative insights into the current and prospective contribution of R&D to Chile's economic growth are found in Box 1.2.

1.2. International trade and foreign direct investment

At the beginning of the 1970s Chile was far from an open economy. Since then it has made very significant progress in opening up to international trade and – with some caution – to capital flows, and is today an open, market-oriented economy. Increasing openness has shifted incentives, contributed to the diversification of the economy, to technology diffusion and thus to efficiency gains and favourable overall growth of the economy.

International linkages through international trade and foreign direct investment (FDI) are also of great importance for a country's innovation performance. They are channels of knowledge flows both directly, through the transfer of knowledge, through the diffusion of know-how, and through management practices, etc., and, more indirectly, through knowledge embodied in imported capital and intermediary goods.

1.2.1. International trade

The military regime came to power in 1973 and immediately embarked on a radical trade reform, abolishing government controls on imports and exports. All international trade restrictions other than tariffs were removed in 1973, and tariffs were reduced from an average of 94% to a uniform rate of 10% between 1973 and 1979. After a temporary reversal in response to the 1982-84 debt and banking crisis, tariffs were again gradually reduced to 15% by the end of military rule in 1989. Since the return of democracy, the policy has been to increase international openness through unilateral, bilateral and multilateral trade policy. Tariffs were lowered to 6% in 2003. Chile has negotiated bilaterally with most of its major trading partners and has pursued the fine tuning of existing agreements. Chile's low and uniform applied tariff has been fundamental in enabling it to negotiate bilaterally without the risk of incoherence among the various agreements.

Over the last 15 years, Chile has negotiated new trade agreements or strengthened existing agreements throughout Latin America. It also negotiated free trade agreements with some of its main trading partners outside the region: Canada (1996), the European Union (2002), the European Free Trade Association (EFTA) (2003), the United States (2003), Korea (2003), China (2005), the P4 Trans-Pacific Economic Partnership Agreement between Brunei Darussalam, Chile, New Zealand and Singapore

(2005), and a Partial Scope Agreement with India (2006). Negotiations with Japan for an Economic Partnership Agreement were completed in November 2006. Negotiations with Australia and Malaysia are about to begin, while with Vietnam a joint study on the feasibility of a free trade agreement will also start soon. In the near future, when the agreements with Japan and India enter into force, around 90% of foreign trade will be conducted under free trade agreements, Co-operation in innovation has been included in all agreements since the negotiation of the P4 agreement; the agreement with the EU for 2007-13 includes significant funds for projects related to innovation and competitiveness.

There has thus been a profound shift in policy from import substitution towards a pronounced export orientation. As a consequence of trade reform and incentives in favour of the production of tradables, the ratio of trade (exports plus imports) to GDP has risen from 45.7% in 1976-84 to 60.3% in 1995-2002, with a ratio of exports to GDP of 30.2%.

The opening of the Chilean economy – as well as microeconomic and structural reform – provided the basis for the rise of new industries, in particular an export-oriented, more diversified agro-food sector. The fresh fruit, wine and salmon industries are well-known "success stories" and account for about half of Chile's agro-food exports. Chile has become the largest exporter of fresh grapes and the world's top exporter of farmed salmon and is among the world's leading wine exporters (Andersson *et al.*, 2005; Brooks and Lucatelli, 2004). Although copper remains its main export product, Chile's exports have thus become more diversified and less dependent on primary commodities. Other significant exports include forestry products, chemical products and cellulose.

Non-ferrous metals accounted for 41% of exports in the period 1976-84 and constituted the second most important export commodity, and metalliferous ores had a share of about 22%. Both have lost shares over the long term, and over 1995-2003 their combined share was less than 42% on average. In contrast, vegetables and fruits, fish and a range of forestry-based products such as cork and wood, pulp and waste paper, and paper and related products have gained in importance, along with beverages (Andersson *et al.*, 2005). Service exports are also increasingly important, particularly in transport and tourism.

In spite of Chile's gradual diversification – and the obvious and indeed impressive success stories that have underpinned this development – the economy can still be said to be relatively undiversified. To assess in qualitative terms the structural change that has taken place in Chile's international trade requires a closer examination of the specific patterns of change.

From 1970 to 2001, Chile's revealed comparative advantages (RCAs) remain highest in non-ferrous metals and ores, although the corresponding index[3] has dropped considerably (OECD, 2003). Remarkable shifts have occurred in a range of agricultural products; comparative advantages have emerged since the 1970s, and are strong for some products. The concentration of RCAs, as measured by a Herfindahl index, has decreased significantly over the three decades from 1970, from 49.2% to 12.2% (OECD, 2003, p. 148). This concentration is still high compared to Argentina (5.6%), Brazil (3.1), Mexico (2.5), the United States (1.9%) and the EU (1.4%).

An aspect of the changing pattern of exports is that despite the introduction of major innovations that have led to substantial revenue streams from new, mainly agro-food-based, export industries, the scope of "exportables" has remained limited. Chile's industry has stagnated, and while a relative decline of manufacturing can be considered a normal feature of the economic development process, it may have declined prematurely in some respects. This is of relevance for Chile's innovative capabilities as it has been observed that agriculture and mining may be less conducive to the development of new products than manufacturing and certain services (OECD, 2003, p. 150).

As a consequence of Chile's initial conditions and its specific pattern of structural change, the level of inter-industry trade – a highly dynamic segment of international trade – is very low, much lower than in Brazil, Mexico and Argentina (Oliveira-Martins and Price, 2004).

There are obvious disadvantages to the specialisation pattern of the Chilean economy. One is the high risk associated with a still high specialisation in commodities, as this creates an increased potential vulnerability to external shocks. These may be due to swings in international commodity prices, but also, more profoundly, to secular shifts or even collapse in the demand for a given commodity (sometimes owing to innovation). Another major disadvantage relates to the somewhat limited development of product variety. Intra-firm and intra-industry trade has been expanding rapidly in OECD countries, and the small share of intra-industry trade in Chile's international trade may act as a constraint on its long-term growth. Chile's export basket is not very well tuned to some dynamic segments of international demand (OECD, 2003).

The acceleration of globalisation raises new challenges as well as opportunities, with a risk of falling behind if opportunities are not seized.

3. The index of revealed comparative advantage (RCA) is defined as $(X_i/\Sigma X_i) - (M_i/\Sigma M_i)$, where X_i stands for exports of product i and M_i for imports of product i.

The immediate challenges are perhaps less severe than in other countries. Chile has been a pioneer among developing countries in terms of liberal reform and openness. Moreover, unlike other countries with similar income per capita Chile does not have sizeable low-productivity, labour-intensive manufacturing industries that may be exposed to vigorous competition from emerging economies. Instead, it now largely benefits from fast growth in emerging economies and their high demand for raw materials. Nevertheless it is prudent to take a longer-term perspective, and the Chilean government's strategy to use some of the increased revenue for forward-looking purposes is well-founded.

1.2.2. Foreign direct investment

Chile completely liberalised its FDI regime in 1974, and foreign investment started to play a role in the development of various industries (including the fresh fruit industry and agro-industry at large). In the 1990s, in response to volatility in the exchange rate and the stock market – the government briefly implemented short-term capital controls (an unremunerated reserve requirement for credits of less than one year; portfolio investment from abroad). The institutional framework today includes a well-developed legal framework and well-established institutions that reassure investors.

Financial openness (measured as the sum of the stocks of external assets and liabilities of FDI and portfolio investment as a percentage of GDP) has increased continuously. Since the 1990s, it has surged, making Chile akin to developed countries in this respect, with levels of openness far above those of comparable Latin American economies and other emerging economies around the globe.

When liberalisation and privatisation opened markets in a number of in Latin American countries in the 1990s, multinational enterprises (MNEs) from outside the region seized the opportunity to establish a presence in the region (UNCTAD, 2006, p. 73). More recently, there has been a certain reversal, with some Latin American firms adopting an expansionary strategy, including acquisitions. Companies such as the Chilean retailers Falabella and Farmacias Adhumadas have recently become new regional MNEs.

Foreign direct investment may serve a variety of purposes in the economic development process. In particular, it may have a significant impact on the performance of national innovation systems. Inward FDI can play a role as a channel of knowledge flows, and local networks can arise around or involve foreign companies. Outward FDI can also play an important role in linking companies to international networks and knowledge centres abroad.

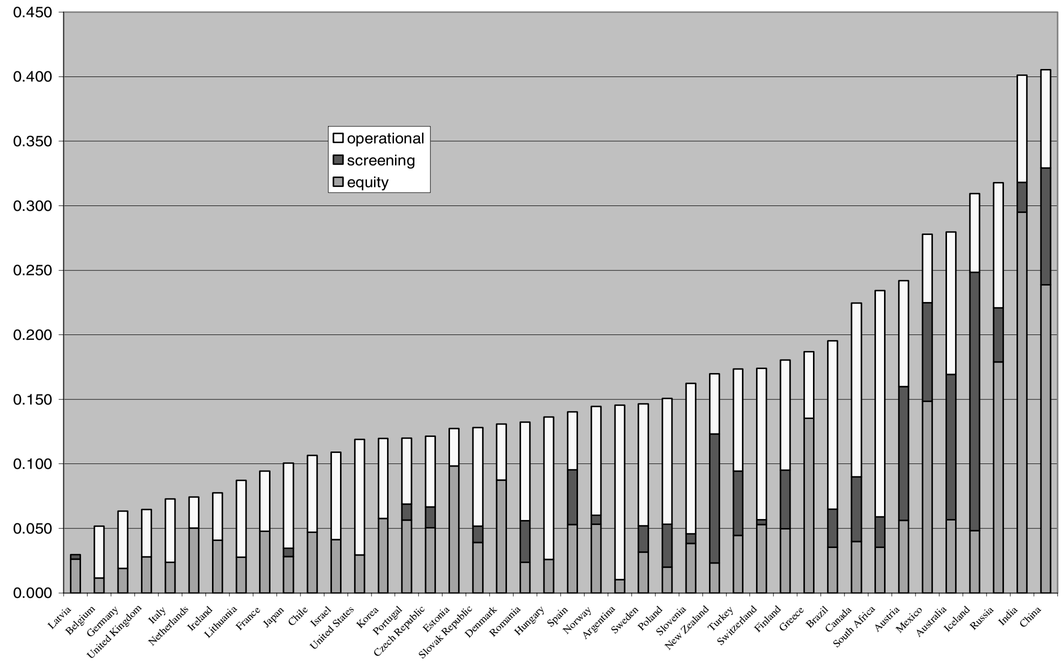
Chile's inward FDI stock as a percentage of GDP has increased steadily since the mid-1990s and stood at 64.6% in 2005 (UNCTAD, 2006). This is more than twice the South American average of 30.3%, with Argentina recording 30.4% and Brazil 25.4%. The corresponding OECD average was 20.3% (2003). In 2005, Chile's volume of inward FDI stocks was second to that of Brazil in South America. FDI stocks in Chile come largely from the United States, followed by Canada and the United Kingdom.

From 1990 to 2000, inward FDI flows accounted for 22.7% of gross fixed capital formation (15.2% for Argentina and 9.6% for Brazil). From 2003 to 2005 they accounted for around 30%, with Chile second only to Brazil in South America. FDI inflows peaked in 1999 owing to major acquisitions in the services sector. In sharp contrast to the geographical origin of inward FDI stocks, FDI inflows between 1992 and 2002 came predominantly from western Europe. Since 1990, FDI inflows have gone primarily to the tertiary sector, specifically electricity, banking and communications. The mining industry was especially attractive to foreign investors in 2002; manufacturing remained a minor recipient of FDI. Minmetals of China has recently established a joint venture in co-operation with the Chilean copper mining company Codelco.

The largest affiliates of foreign-based MNEs are in the services sector, with firms such as BBVA Banco BHIV, Scotiabank Sud Americano and Banco del Desarrollo in the financial sector; Enersis in electricity, gas and water; Getronics Chile in computer and related activities; and Telefónica CTC Chile in telecommunications (as of 2002). In the industrial sector, Noranda Chile (metals), Minera Escondida (mining) and Laboratorio Chile (pharmaceuticals) were the major foreign affiliates.

At 18.7% of GDP in 2005, Chile's outward FDI stocks are much smaller than inward stocks of FDI but are quite high compared to those of other countries in the region (12.5% for Argentina and 9.0% for Brazil). Chile's outward FDI stocks approached those of Argentina. Chile is, after Brazil, the major source of outward FDI flows among South American countries. Argentina is by far the most important location of Chilean outward FDI stocks abroad. According to UNCTAD's inward FDI performance index, based on countries' shares in global FDI and GDP, Chile ranks 25th (2005). In terms of this measure, Chile retains a strong position in the region but has lost some ground over time. Chile also has quite a high potential for inward FDI, as measured by an index based on 12 economic and policy variables.

Figure 1.3. FDI regulatory restrictiveness by type of restriction,* nine sectors



* This aggregated index covers the following sectors and sub-sectors: Business (legal, accounting, architectural, and engineering services), Telecommunications (fixed line telephony and mobile telephony), Construction, Distribution, Finance (insurance and banking), Tourism, Transport (air transport, maritime transport and road transport), Electricity and Manufacturing. *Source:* Koyama and Golub (2006).

According to an indicator-based international comparison of OECD and selected non-OECD countries (Koyama and Golub, 2006) covering business services, telecommunications, construction, distribution, hotels and restaurants, transport, electricity, and manufacturing, Chile's overall measure of FDI regulatory restrictiveness is relatively low (Figure 1.3). While regulatory restrictiveness is below the OECD average in all other sectors it is relatively high in the transport sector.

Very little R&D is performed by multinationals in Chile. In spite of a relatively large stock of inward FDI, the share of foreign affiliates in total business R&D was just 3.6% in 2002 (UNCTAD, 2005, p. 127), *i.e.* significantly behind other Latin American countries such as Brazil (47.9% in 2003), Mexico (32.5% in 2001) and Argentina (23.2).[4] Fewer than 50 employees of United States-owned MNEs are reported to be engaged in performing R&D (UNCTAD, 2005, p. 131). Moreover, the share of foreign (United States-owned) affiliates seems to have declined by about 10% since 1995 whereas in most OECD countries (including Mexico) as well as in countries like China and Argentina the share of foreign-owned affiliates engaged in R&D has increased as globalisation has accelerated. This situation reflects, among other things, the industry composition of the MNEs present in Chile.

1.3. Major structural features and structural change in the Chilean economy

Chile is a small, open economy with a strong base in – and dependence on – the production of commodities linked to natural resources. Since the 1970s the structure of the economy has changed in many respects but it remains relatively undiversified. While import-competing traditional manufacturing sectors (textiles, machine tools, etc.) have declined, growth has occurred in new natural-resource-based, export-oriented industries. Today the services sector plays a significant role in the Chilean economy. In fact, services industries represent almost half of Chile's national product and generate a large share of total employment. Services exports – especially from transport and tourism – are also gaining in importance.

According to the model proposed by Leamer, a country's production specialisation depends on its initial factor endowment and subsequent factor accumulation. Thus, an economy such as Chile's, with its abundant natural

4. The comparison is biased in favour of Brazil since for Argentina, Chile and Mexico, R&D expenditure by United States-owned affiliates is used as a proxy for the R&D expenditure of all affiliates.

resources, initially specialises in agricultural and forestry products with low levels of processing and extraction of basic minerals. However, as capital accumulates, the pattern of specialisation shifts towards the production of goods that are based on natural resources but more intensive in physical and human capital. Accordingly, one should not expect Chile to specialise in the production of clothing or textiles, for example, which are labour-intensive and can be produced much more cheaply in countries with an abundance of labour, such as China and India.

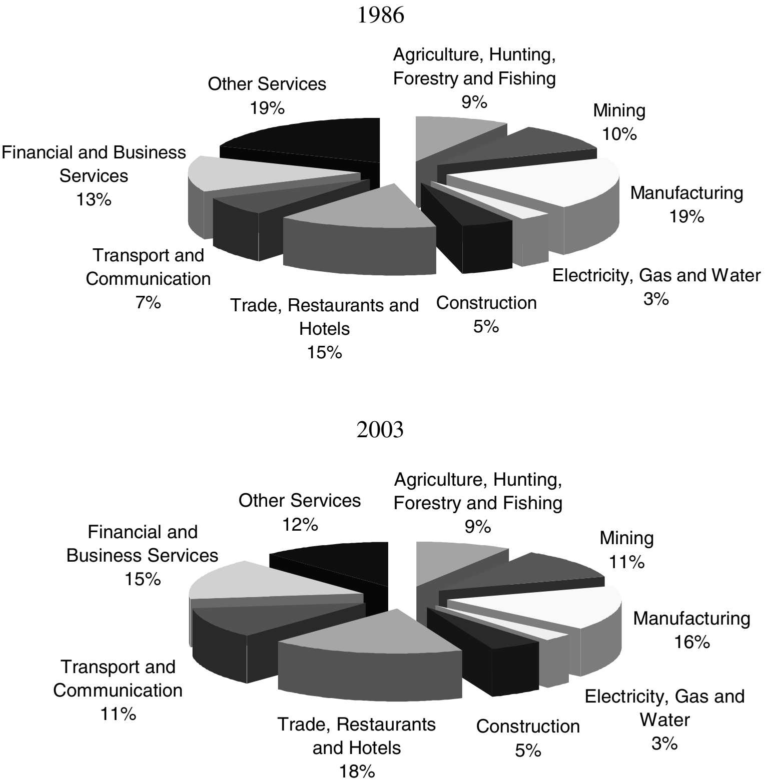
An economy such as Chile's would then move towards a pattern of specialisation based on increasingly processed natural resources, which would take place with the opening of the economy, its growth and (physical and human) capital accumulation. Without these, lower growth rates and even contraction could occur. The challenge is to develop a strategy that combines increasing production and export diversification by adding value to products and exports based on natural resources. Similar challenges are faced by other countries with a strong resource base, such as New Zealand and South Africa. Science, technology and innovation policy can play a major role in facilitating and supporting the further diversification of economic activity, notably by facilitating product differentiation in niche markets.

According to Alvarez and Fuentes (2004), the evidence for the period 1986-2003 is consistent with what may be expected given Chile's factor endowment. During that period, Chile's growth averaged 6%, but sectoral growth patterns were quite heterogeneous. The contribution to GDP of nine sectors of the economy is shown in Figure 1.4 (for 1986 and 2003). While the contribution of the communication, financial services, wholesale and retail trade, restaurants and hotels, and mining sectors increased, the contribution of "other services", which includes social and community services, as well as that of the manufacturing sector decreased. The contribution of other sectors remained constant.

1.4. Framework conditions for innovation

The existence of favourable framework conditions enables and facilitates innovation. The macroeconomic framework, the general business environment, the intensity of competition, product and labour market regulations, as well as the degree and quality of entrepreneurship – which is shaped by institutional and cultural factors – are all of key importance for a country's innovative performance.

Figure 1.4. Contribution to GDP by sector



Source: Alvarez and Fuentes (2004).

1.4.1. Macroeconomic framework, business environment and entrepreneurship

Chile has been able to establish a sound macroeconomic framework based on a prudent policy stance which has contributed to its strong performance. This is one of Chile's major assets. Economic reform and institution building have rendered the Chilean economy more resilient in the face of shifts in demand and other exogenous shocks. Strong macroeconomic performance and stability contribute to improved business confidence in the private sector. Because stability reduces uncertainty it encourages a climate conducive to investment and innovation. The high quality of Chile's institutions is reflected in the World Bank's measure of ease of doing business (which comprises an average of six indices: rule of law, corruption control, political stability, quality of regulations, government effectiveness and accountability).

In the World Bank's results for 2006, Chile ranks 28th out of 175 countries. However, the results are differentiated across topics. While Chile ranks very well (19) for protecting investors, it scores less well in other aspects: closing a business (time and cost required to resolve bankruptcies, 107), enforcing contracts (the ease or difficulty of enforcing commercial contracts, 73) and employing workers (the difficulties that employers face in hiring and firing workers, 58). The latter is due to high firing costs (which are high in the region as a whole).

1.4.1.1. Entrepreneurship

Chile offers a large spectrum of opportunities for entrepreneurial activity. In 2005, its total early-stage entrepreneurship activity (TEA) index[5] was 11.1%, and it ranked eighth among the 35 countries included in the GEM (Global Entrepreneurship Monitor, 2006). This is a decline of one-third from 2003, which however is entirely due to a decline in "necessity entrepreneurship". In contrast, "opportunity entrepreneurship", relating to businesses started in response to perceived market opportunities has remained nearly stable at about 8%. The drop in "necessity entrepreneurship" may be related to an increase in other options for work or participation in the economy in an environment of renewed vigorous economic growth. Overall, the level of early-stage entrepreneurial activity in Chile – as measured by the share of the adult population involved – is comparable to that of countries like Brazil and Argentina.

5. The Total Early-Stage Entrepreneurship Activity (TEA) index is defined as the share of adults between the ages of 18 and 64 who start up a company, expect to own and manage all or part of a business and have not received wages or salaries for 3.5 years.

Most entrepreneurial efforts involve businesses with little value added, such as retail or self-employment. Few entrepreneurial initiatives are perceived to have a high potential of wealth creation. It should be noted that in Chile, as in other countries, people are not taught about ways to start up a new business, although the country has good business schools. A number of OECD countries have addressed this shortcoming in recent years. While resources to finance entrepreneurial activity are generally sufficient, adequate instruments for financing initial stages are lacking.

Among a set of factors thought to affect entrepreneurial activity, expert opinion assigns very low marks (perception index) to Chile in "education" and "R&D transfer". The perception index of "government programmes", "market access", "social and cultural norms" and "government policies" is also fairly low. "Financial markets" and the "commercial and legal infrastructure" (legal and accounting advisors, etc.) are viewed as moderately negative or positive, respectively. Only the physical infrastructure (including telecommunications, ports, highways, etc.) receives a high mark.

1.4.1.2. Intellectual property rights

In 2005 a new law significantly changed the Chilean industrial property system. It allows Chile to meet the World Trade Organization's (WTO) minimum standards as laid down in the Agreement on Trade-related Aspects of Intellectual Property Rights (TRIPS agreement), which was signed by Chile in 1995. In addition, free trade agreements signed with the EU, Korea and the United States include chapters on industrial property. Legislation has thus been brought in line with Chile's contracted commitments (on Chile's intellectual property rights regime, see also OECD, 2003, p. 75).

Other topics relating to framework conditions and the business environment that are of importance for innovation are addressed in later parts of this review. Risk and seed capital (OECD, 2003, pp. 72 ff.) are addressed in Chapter 2, and Chapter 4 describes the tax incentive proposal that has been presented to the Congress. As it stands, Chile has a generally attractive tax system for companies, but so far lacks a tax incentive for R&D.

1.4.2. Competition, product and labour market regulations and other framework conditions

1.4.2.1. Competition

Chile has been "a quiet pioneer in the field of competition law and policy in South America and among developing countries" (OECD, 2006a, p. 191) and has been at the forefront in the "application of competition policy principles in some infrastructure sectors". Exposure to competition is increased by the openness of the economy. Pro-competitive regulatory reform has been high on Chile's "pro-growth" agenda.

1.4.2.2. Physical infrastructure

At the beginning of military rule in 1973, Chile had physical infrastructure facilities that facilitated growth of exports: several large ports, a new international airport and a North-South highway built with foreign aid (Andersson *et al*., 2005). The privatisation and deregulation of airlines and telecommunications improved quality of services while reducing costs. This contributed to the development of a fresh fruit industry based on exports. While Chile has made enormous efforts to develop the transport infrastructure – airports, roads (privately and publicly owned and managed) and ports – further developing the country's physical infrastructure, *e.g.* multi-modal hubs, remains a major task.

1.4.2.3. Product market regulation

Product market regulation is very important to economic performance and business dynamics (Brandt, 2004), Product market competition is an important driver of productivity growth, either directly or indirectly through a positive impact on innovation, at least up to a certain level of intensity (Aghion *et al.*, 2002). Chile's product market regulations are discussed in detail in the *OECD Economic Survey 2003* (OECD, 2003). Overall, these appear to be reasonably pro-competitive. Trade liberalisation has helped to move towards creating well-functioning product markets and an improved business environment. In network industries, further liberalisation in electricity retailing and better regulation in the telecommunications sector could help improve the business climate (OECD, 2005a).

1.4.2.4. Labour market regulation

Labour market regulations are an aspect of the regulatory environment that can have a major impact on the performance of the labour market. In particular, labour market regulations and institutions are an important factor in determining labour utilisation. Chile has a great potential for increasing the labour supply (OECD, 2003) owing to its relatively young population and low employment/population ratios for women and youths. Labour supply can be increased by various measures, including relaxing restrictions on the duration of temporary contracts, the allocation of the working time of full-time workers and improvements in child care and pre-school education. For those already working, human capital formation – a cornerstone of any strategy based on innovation and knowledge – can be strengthened by improving the efficiency of training at the enterprise level (OECD, 2005a, Chapter 5). Labour market regulations are not alone in affecting the performance of labour markets. Skill shortages, inequality in access to education and workforce immobility may also contribute to sub-optimal performance.

Box 1.3. Closing the digital divide

Almost all Chilean primary and secondary schools have computer labs. However, there are on average 30 students per computer; in Spain, for example, the ratio is ten students per computer.

In terms of connectivity, more than 70% of schools currently have Internet access. However only 60% have broadband access; the rest have dial-up internet connections. Furthermore, several schools with broadband connections lack adequate bandwidth for providing a fast and reliable internet connection.

In order to close the digital divide with developed countries, the government is implementing a three-year plan to: *i)* install new computers in schools to reduce from 30 to ten the ratio of students to computers; *ii)* dramatically increase the use of computers and projectors in classrooms as a teaching tool; and *iii)* provide schools with broadband Internet connections with an average connection speed of two Mbit/s.

New computers

- To reduce from 30 to 10 the ratio of students to computers, 220 000 new computers will be installed in schools at a cost of approximately USD 200 million.
- Enlaces, the government agency in charge of the programme, is assessing the technological requirements of more than 9 000 public schools. Once the assessment is completed, Enlaces will sign agreements with the schools to establish the financial and non-financial aspects of the project, such as computer maintenance, replacement, etc.
- By the end of 2007 the first purchase orders will be placed and computers will start being installed in schools.

Information and communication technologies (ICTs) in the classroom

- In order to improve the teaching of mathematics, languages and science in schools, a pilot programme will finance the development of specialised software, the installation of computers and projectors and training for teachers.
- In 2007 the programme will focus on 500 schools (3 500 classrooms) serving 122 500 students. In 2008 another group of 500 schools will benefit from the programme for a total of 245 000 students.

Broadband Internet connection in schools

- The objective is to provide 70% of the country's students with good quality broadband Internet connections (1 to 2 Mbit/s) through the development of an Internet service provider (ISP) specifically for public schools.
- The ISP will be privately administrated and the administrator will be chosen through a public tender. The terms of references are being developed and the administrator should be chosen by November 2007.

Source: Ministry of Finance.

1.4.2.5. Education

Human capital formation and availability of skilled personnel represent a major bottleneck in Chile's social and economic development, including its innovation capability (OECD, 2003, p. 74). Increasing human capital is one of Chile's most urgent challenges. Both national and international evaluations indicate that while educational attainment has increased in recent years, quality remains inadequate. This constitutes a serious obstacle to boosting growth based on knowledge and innovation. Chile should aim at to raise its educational performance to the level of the leading countries. In fact, significant measures to raise Chile's educational standards to international levels are being implemented, and new measures are on the way. However, for education spending increases to lead to better results, it is important to maintain this investment over time, accompanied by adequately monitored improvements in teaching quality. Initiatives have been taken to close the digital divide (see Box 1.3).

1.5. Inequality and poverty reduction

Reducing poverty levels in Chile has been a primary goal of public policy since the beginning of the 1990s, when the country returned to a democratic system of government. In 1990 almost 40% of the Chilean population lived in poverty, but in 2000 the figure had been reduced by half (Table 1.2). The last census confirmed a significant improvement in the living conditions of Chileans, as well as in other social indicators such as infant mortality and life expectancy. This is a noteworthy success when compared to any other period in the country's history and to other countries in the region.

The main cause of the reduction in poverty is the economic growth of the last decade. The empirical evidence suggests that economic growth accounted for about 80% of the reduction achieved over the period, mainly through job creation and increased wages. The country's various socio-economic groups benefited similarly: annual growth in income was nearly identical across income deciles between 1987 and 1998 (Table 1.3), which helps explain the sharp reduction in the poverty rate.

Table 1.2. Poverty and indigence, 1990-2003

As a percentage of the population

Year	Poverty situation				
	Indigent poor	Non-indigent poor	Total poor	Non-poor	Total
1990	13.0	25.6	38.6	61.4	100.0
1992	9.0	23.8	32.9	67.1	100.0
1994	7.6	20.1	27.6	72.4	100.0
1996	5.8	17.5	23.2	76.8	100.0
1998	5.6	16.1	21.7	78.3	100.0
2000	5.6	14.6	20.2	79.8	100.0
2003	4.7	14.0	18.7	81.3	100.0

Source: CASEN Survey, MIDEPLAN.

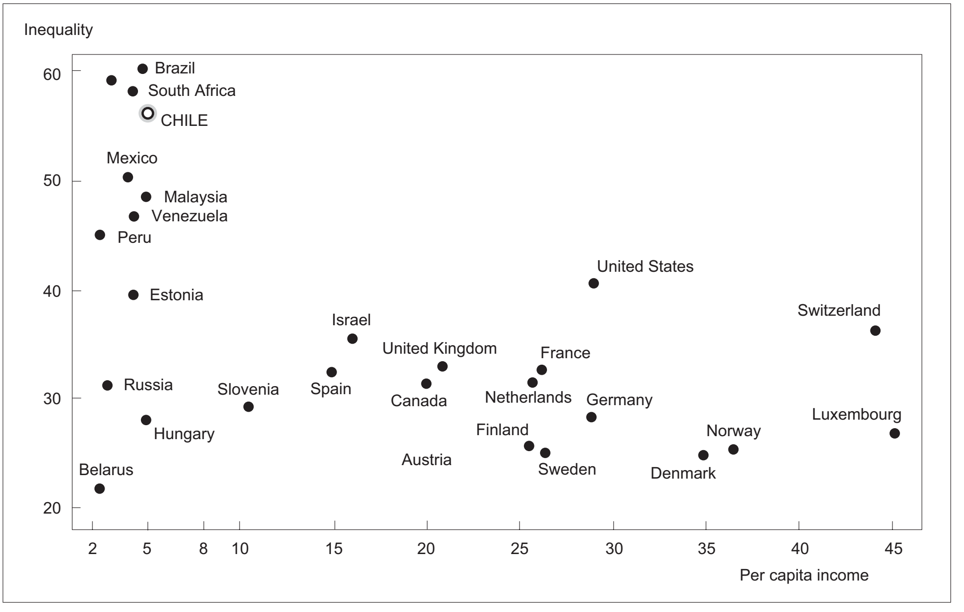
Table 1.3. Income growth by decile, 1987-98

Per capita income of the household

Decile	1987	1990	1992	1994	1996	1998	Annual variation (%)
1	6 017	8 403	11 866	12 058	13 984	15 222	8.8
2	10 910	15 645	20 099	22 165	24 869	28 028	9.0
3	14 664	20 793	26 702	29 520	33 663	38 338	9.1
4	18 747	26 464	33 237	37 486	42 763	49 183	9.2
5	23 438	32 873	41 028	46 911	53 405	61 350	9.1
6	29 408	41 135	51 336	58 603	66 856	76 909	9.1
7	37 789	52 225	65 233	74 025	85 963	98 380	9.1
8	51 298	69 063	86 065	99 231	115 468	132 963	9.0
9	79 800	104 758	127 345	147 987	173 687	202 639	8.8
10	226 552	305 257	384 565	400 724	493 519	579 726	8.9
Total	49 843	67 631	84 687	92 818	110 365	128 263	9.0

Source: Cooper and Neilson based on the CASEN Survey, 1987-1998.

Figure 1.5. Inequality (Gini coefficient) and per capita income worldwide



Source: Cooper and Neilson (2004).

However, the inequality of the income distribution has persisted and is high both in a worldwide comparison and even compared to countries with levels of income per capita similar to that of Chile (Figure 1.5). Only Brazil, Paraguay, South Africa and Colombia show greater inequality than Chile (as measured by the Gini coefficient). This uneven distribution continues to be a main weakness of the Chilean economy and society. While economic growth has reduced poverty, achieving growth with equity remains a challenge.

1.6. A strategy for more innovation-driven growth

In spite of Chile's impressive economic performance over the past two decades, there is still a significant gap with the income levels of developed countries. Chile's income per capita is somewhat above one-third of average income per capita in the developed economies. Further closing the gap in income and living standards will obviously require sustained high growth over an extended period of time. The distance to that frontier may represent an advantage (Gerschenkron, 1962) since it implies a significant potential for catching up, and Chile has already shown a significant level of social capability and absorptive capacity to realise this potential (*e.g.* Rodrik, 2004).

There appears to be a consensus that, to achieve sustained high and equitable economic growth, factor accumulation needs to be complemented by high productivity growth. Increasing the accumulation of human capital is one of the most urgent challenges facing Chile, and a cornerstone of any strategy for more innovation- and knowledge-based growth. Sustained productivity growth requires improving the country's innovation performance, including technology diffusion. In fact, a consensus has emerged in Chile regarding the key role of innovation in the further development of the Chilean economy.

It will be necessary to devote significantly more attention to innovation and make production chains more sophisticated. Compared to Chile's many achievements, its current innovation performance is much less impressive (see Chapter 2). Its level of innovation is not yet on a par with that of many countries at similar levels of development, and it lags behind other emerging economies – some of which are also based on natural resources – which have made substantial progress in the area of innovation in recent decades. Notwithstanding some noteworthy private and public initiatives, a pro-technology change in the entrepreneurial culture is not yet widespread. Innovative activity is rare and often isolated. In today's world, innovation is fast-paced in all sectors, including those based on the exploitation of natural resources. Business firms are using information technology, biotechnology, nanotechnology and other scientific and technological achievements within cultural and organisational frameworks that are open to change and innovation. (Box 1.4 discusses the main determinants of innovation in Chilean manufacturing.)

In the short term, Chile may continue to benefit from the revenue stream generated by natural resource-based exports. However, a decline in these revenues can be expected to lead to a slowdown in economic growth and diminish the country's capacity to generate employment and increase social well-being. If Chile does not make progress in the area of innovation, including technology development and transfer, there is a risk that it will start losing momentum and lag behind countries with a growth path less dependent on natural resources. Static comparative advantages can be seriously threatened and even wiped out in a relatively short period of time, as occurred nearly a century ago when synthetic saltpetre – a scientific-technological innovation – replaced saltpetre. More innovation would help make economic growth less dependent on the variations in revenues for commodity exports and thus help increase the population's income and reduce poverty. In order to mitigate this vulnerability of the Chilean economy, it is sensible to build on the country's strengths and comparative advantages in natural resources by adding greater value to natural resource-based products, especially those exported. Innovation can play a key role in such a strategy of long-term economic growth.

Chile should consider undertaking an increased and coherent effort on R&D and innovation and investing more in human capital. It should take advantage of the nascent clusters based mainly on natural resources and establish innovation practices that allow the static advantages of the Chilean economy to be turned into dynamic advantages. In order to diversify the national production system, new activities can be developed by diversifying the export base through products with high value added and by developing the specialised goods and services that were initially created and customised to satisfy the needs of natural resource clusters.

Box 1.4. Determinants of innovation in Chilean manufacturing

Based on information from the Chilean innovation surveys carried out by the National Statistics Institute (INE) for 1995, 1998 and 2001, an econometric study of the main determinants of innovation activity in Chilean manufacturing suggests that:

- The probability of effecting R&D expenditure in one year is positively correlated with spending on such activities during the previous year. This suggests that R&D spending has a significant temporal persistence. Larger firms have a higher probability to spend on R&D, reflecting economies of scale, product variety and the advantages larger firms may have in financing this type of activities.
- R&D intensity increases with firm size, but does so less than proportionately: For each 1% increase in the number of workers, research expenditure increases by between 0.8% and 0.6% depending on the year. This points to decreasing returns relative to firm size, and over time.
- Regarding innovation, research expenditure is found to indicate a higher probability of innovation in products as well as processes. This confirms that it is fundamental to innovation. The size of the firms measured by the number of employees is also positively associated with a higher probability of innovation.
- Together with R&D expenditure, innovative ideas originating from within the firm, the observation of competitors and ideas suggested by customers increase the probability of introducing innovation (the ratio of sales of innovative products to total sales). This suggests that, given investment in R&D activities, a greater "monitoring capacity", both internal and external, may bear fruit in terms of successful innovation by the firm.
- Finally, firm productivity is positively correlated with innovation intensity, even after controlling for the composition of the labour force and the physical capital of the firm. The findings suggest that the impact of innovation on productivity has been growing over time.

Source: Benavente (2004).

Box 1.5. High value added knowledge-based businesses: engines of growth

Boosting productivity and hence economic growth depends crucially on the ability to shift resources from low to high value added businesses. The latter command high prices for their products and services relative to the total costs of production. They are thus able to pay higher salaries and/or earn higher profits for shareholders. Both serve to raise the per capita contribution of the business's workforce to GDP. Growth in the scale of the activities of such businesses adds to the growth of aggregate output. To the extent that such businesses can repeat their success in overseas markets, national output can grow faster still. It is therefore in the national interest to foster the conditions under which high-value added businesses are able to prosper, export and grow and absorb resources from less productive parts of the economy.

High value added businesses tend to exhibit one or more of the following characteristics:

- They have a unique long-term source of competitive advantage which is difficult for prospective competitors to replicate or overcome. Such an advantage may be created through persistent innovation and greater efficiency, may reflect a natural monopoly or may be the result of anti-competitive practices. Generally speaking the second and third generate high value added at the expense of other sectors of the economy and do not add to national economic welfare;
- They are successful serial innovators able to generate temporary spells of competitive advantage which are constantly refreshed by the continuous introduction of new products and/or services.
- They operate in rapidly growing markets in which demand tends to outpace supply and in which the rates of innovation, technological change, learning by doing and creation of economies of scale and scope are all rapid.

High profits and rapid growth of sales together finance the investments that encourage expansion, innovation (including entry into new markets) and the creation and maintenance of competitive advantage. Enhanced competitiveness in turn enables the firm to gain market share and to further increase sales. Competition in the market place, which is mostly driven by technical progress, tends to continually erode the value added earned by companies unless they continually raise their game in response. Even if they appear to have some permanent unique competitive advantage market forces may eventually find a way to nullify or reduce its value.

In the course of the transition to more innovation-based growth, Chile should seek to combine the advantages and dynamism of its natural resource-based, export-oriented model with capabilities created by an increase in its human capital that could be used to transform, extend and link production processes initially developed to process raw materials. Chile does not yet exploit sufficiently the opportunities for developing innovative value-added products in natural-resource-based sectors. Natural-resource-based sectors offer considerable scope for the application of advanced science and technology: the development of new types of plants and trees, marine farming and the production of therapeutic compounds using genetically altered animals and plants. Synergies among human resources, technological innovation and natural resources could strengthen international competitiveness, encourage further growth in the global marketplace and generate more and better jobs with higher qualifications. This report does not advocate a narrow high-technology orientation, but a strategy that builds on the country's strengths to reinforce and broaden the foundations for long-term growth through a broad-based innovation strategy. Investment in science, technology and innovation is vital if Chile is to maintain its international competitiveness in these sectors, increase their productivity and create opportunities for innovation further up the supply chain.

Beyond the traditional segmentation used in policy analysis (manufacturing *versus* services, high-technology *versus* low-technology, small *versus* large firms, etc.) a cross-cutting objective of Chile's innovation policy should be to promote high-value-added knowledge-based businesses (see Box 1.5). In addition this would allow Chile to pursue complementary objectives simultaneously instead of overemphasising some at the risk of distorting the structural adjustment process: diversification of exports, building innovative clusters around resource-based industries, developing new comparative advantage based on knowledge, including in tradable services. Major opportunities for creating and fostering high value-added knowledge based businesses are to be found in the following areas:

- Using Chile's expertise in areas such as agriculture, fish farming, mining and other primary sectors and making better use of its science and technology base to develop high value products within and around those sectors, improve the efficiency and effectiveness of the processes used in those sectors, and develop novel equipment, services, software and other inputs in the domestic supply chain.
- Fostering the creation, growth and development of businesses based on the strengths of Chile's research base and on existing technological, design and organisational strengths within its business sector. Anything that Chileans know how to do really well (*i.e.* where they possess unique competence) can form the basis of a value-added business providing steps are taken to maintain and develop the initial sources of competitive advantage.
- Exploiting Chile's other advantages such as its scenery and geography to create value-added products and services and taking advantage of one-off opportunities for establishing competitive advantage.

Businesses created in this way can be said to be knowledge-based (see Box 1.6) in the sense that the competitive advantage which enables them to generate high value added mainly depends on the possession of unique knowledge or combinations of different kinds of knowledge which it is hard for competitors to replicate at least within a commercially relevant time scale. These suggestions are not of course a prescription for the future structure of the Chilean economy – opportunities for innovation leading to the creation of value-added businesses and activities can be found in all parts of the economy (see, for example, von Tunzelmann and Acha, 2005) – but a strategy for promoting innovation and the development of high value added business, which needs to be supplemented by programmes/policies designed to raise productivity throughout the Chilean economy.

Box 1.6. The role of knowledge and competitive advantage

In the 21st century the main source of competitive advantage lies in those business activities which the firm knows how to do well. Factories and equipment can always be bought, employees hired, and technology licensed in but unless the firm and its management know how to combine and exploit these resources effectively a viable and competitive business will not be created. The knowledge which the firm possesses, its "knowledge base", thus plays a key role in the survival, innovativeness, profitability and growth of the firm. Firms possess a number of different types of knowledge, including scientific and technological knowledge, knowledge of their markets and customer base, knowledge of sources of supply of materials and components, the knowledge and skills of its employees, etc. Firms need to know how to organise various activities such as procurement, production, marketing, after-sales service and innovation and how to combine these to secure the profitable delivery of competitive products to the market. The firm also needs to know how to recruit and develop skilled employees and managers, to motivate them to work effectively and to encourage them to co-operate in the best interests of the firm as a whole.

Some of this knowledge can be purchased in the market place or by investing in activities such as R&D. This knowledge is often codified, so that it can be written down and easily absorbed by someone with the necessary complementary knowledge and expertise. If not protected by some form of intellectual property rights or by secrecy it can be readily acquired by competitors. In contrast, other types of knowledge are only acquired through experience of the business concerned, through “learning by doing”. Such knowledge is often “tacit”, not easily written down or communicated except by direct human experience, and is not easily acquired by competitors who must create such knowledge for themselves. Much organisational knowledge is of this kind. Tacit knowledge is a major source of competitive advantage for firms. If the exploitation of easily transferable knowledge requires complementary knowledge (or other assets) which is (are) difficult for competitors to acquire then it is effectively protected as well. Innovation involves the creation of new knowledge and/or new combinations of knowledge which can then be exploited profitably.

(continued…)

Box 1.6. The role of knowledge and competitive advantage *(continued)*

The importance of knowledge in firms' competitiveness and economic activity is not new. However those changes which make up the transition to a "knowledge-based economy" greatly increase the importance of knowledge in economic activity and the competitiveness of firms. They are also changing the kinds of knowledge which firms need to possess, the way that knowledge is acquired and managed, the way firms are organised and the kinds of knowledge and skills required of their employees. The increasing importance of knowledge is shown by the fact that in many sectors there is now greater investment in intangible assets than in fixed capital equipment.

The number of technologies used in the production of a given product or service is increasing and firms need expertise in a greater range of technologies than before. Combined with the accelerating pace of scientific and technological change, this means that firms increasingly resort to R&D collaboration and outsourcing to acquire the technologies they need. Development of leading-edge science and technology is now undertaken in many more locations and, together with the increasing globalisation of markets, this means that firms must be prepared to seek technology relevant to their business from wherever in the world it is to be found.

Three decades ago advanced industrial economies were dominated by sectors that invested large amounts in plant and machinery. By contrast, the rapidly growing sectors of recent decades such as electronics, pharmaceuticals and telecommunications invest mainly in R&D, software and information technology, advertising and training. Some emerging sectors, such as those associated with the Internet, hardly invest in fixed assets at all. Managers and workers now need to be much better educated and much more highly trained. The increasing speed of technological and organisational change means that employees need to be much more flexible and require much more training and upgrading of their knowledge and skills during their lifetime. There will need to be mutual commitment between firms and their employees so that firms will have an incentive to invest in training while employees have an incentive to acquire knowledge and skills specific to the firm in which they work.

An essential component of this approach is to enable high value added businesses to enter foreign markets and meet the needs of demanding foreign customers. Otherwise, the businesses will not develop and their potential contribution to the economy will not be realised. Some may operate in specialised niches in which achieving a market of viable size requires exporting from an early stage in the company's development. They may need help to develop partnerships with foreign-based companies which are to the advantage both of these businesses and of the economy as a whole. Carefully targeted encouragement of inward investment can also provide a means for persuading foreign companies to establish high value added businesses in Chile that provide significant benefits to the domestic economy.

Efforts to upgrade education and training clearly have a very important role to play. Access to excellent electronic communications is also vital since it facilitates delivery of the fruits of that knowledge and skills to remote locations and enables Chile-based firms and individuals to co-operate much more effectively with overseas partners. Chile has much to gain from the "death of distance" and many of the opportunities for creating new high value-added activities will involve the Internet in one way or another. Various other innovation-relevant policies also have an important role to play, including those that support scientific research, promote the use of IPR, improve access to risk capital, etc.

The government's role is not simply to ensure adequate macroeconomic conditions to permit high rates of investment, both of domestic and foreign origin, but also to correct the market and systemic failures that keep the country from reaching its full innovative potential. Government policy can also play a significant role in facilitating and stimulating the emergence of that diversity that will, in the longer term, have an impact on the industrial structure of the economy. Given Chile's historical experience there is a consensus that one dimension of change should involve moving away from the traditional, heavy dependence on resource-based activities. Countries such as South Africa, and to some extent New Zealand, share this concern. A more varied specialisation pattern could help reduce the high risk associated with exposure to the volatility of commodity prices and may also offer new growth opportunities in areas of high and growing demand.

If efforts are increased in the areas with the greatest weaknesses – notably innovation and education[6] – Chile can strengthen and broaden the basis for sustainable high growth. This would contribute to the attainment of several goals, such as increasing income per capita, reducing poverty and making income distribution less uneven. However, it will be necessary to ensure the stability of the institutions and policies that have become major strengths of the country in recent decades. This is a prerequisite for facing future challenges successfully.

6 See, for example, World Bank (2004a; 2004b).

Chapter 2

CHILE'S INNOVATION PERFORMANCE IN AN INTERNATIONAL PERSPECTIVE

2.1. Benchmarking performance in science, technology and innovation

2.1.1. Inputs to innovation

2.1.1.1. Investment in R&D

R&D intensity is a key input to innovation and, despite its limitations,[7] one of the indicators most widely used to compare innovation activities in different countries. Chile's total R&D intensity – the ratio of gross expenditure on research and development (GERD) to gross domestic product (GDP) – is 0.68% (2004), less than one-third of the OECD average of 2.25% (2003). At 0.31% of GDP, its business enterprise expenditure on R&D (BERD) is even weaker relative to the OECD average of 1.53%. While R&D intensity has risen steadily since the 1980s in the OECD area, spending on R&D has remained fairly stable in Chile, although data limitations call for caution when undertaking international comparisons (Table 2.1).[8.]

Regarding the overall national R&D effort, available information suggests the following key observations:

7. R&D-related indicators are an imperfect measure of innovation inputs. Many other types of expenditure, such as fixed investment and labour training also contribute to the successful commercial development of innovations. Moreover, the limitations of input measures as proxies for innovation underline the importance of also looking at output measures and evaluating the efficiency of innovation processes themselves.

8. In 2002, a first National Census of Private R&D showed spending to be 74% higher in real terms than in 2001, compared to an increase of 7% in the public sector over the period. This may be an indication that own self-financed R&D efforts of the business sector had previously been underestimated.

- Chile has a higher propensity to invest in R&D than comparable Latin American countries, with the exception of Brazil.
- Compared to emerging OECD economies, Chile compares favourably with Turkey and Poland, but not with Hungary and the Czech Republic.
- Compared to non-OECD emerging economies, R&D intensity is lower in Chile than in countries with lower income per capita, such as China and India.
- Chile lags behind OECD resource-based economies, notably New Zealand.

Table 2.1. R&D intensity and structure of R&D funding in selected countries, 2004 or latest

Country	GERD (% of GDP)	GERD by funding source (%)		
		Business	Public	Other*
Mexico	0.39	29.8	59.1	11.1
Argentina	0.42	26.3	68.9	4.9
Poland	0.59	31.0	61.1	8.0
Turkey	0.66	41.3	50.6	8.2
Chile	**0.68**	**45.7**	**44.5**	**9.8**
Hungary	0.95	30.7	58.0	11.1
Portugal	0.94	31.5	61.0	7.2
Spain	1.03	48.9	39.1	12.0
Brazil	1.04	38.2	60.2	1.6
Ireland	1.13	67.2	25.2	7.7
New Zealand	1.16	37.1	46.4	16.5
Czech Republic	1.34	51.4	41.8	6.8
Singapore	2.15	49.9	41.8	8.3
United States	2.60	63.1	31.2	5.7
Korea	2.64	74.0	23.9	2.1
Japan	3.12	73.9	18.2	8.0
Finland	3.46	69.5	26.1	4.3
Sweden	4.27	71.9	21.0	7.2
Israel	4.90	69.6	24.7	5.6

*Other national sources and foreign funding.

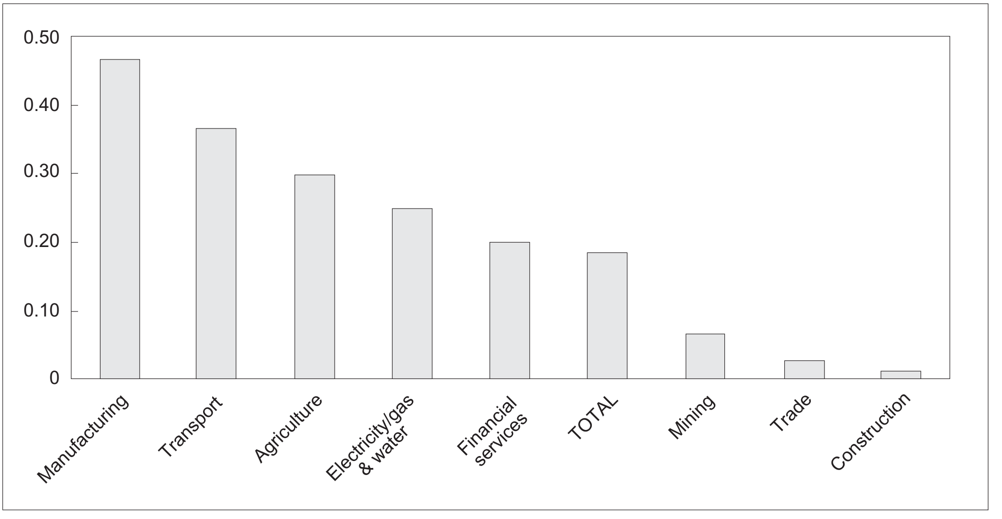
Column 1: 2003 for Argentina, Czech Republic, Hungary, Israel, South Korea, and United States; 2002 for Chile, Finland, Poland, Japan, Portugal, Singapore, Spain, and Turkey; 2001 for Ireland, Mexico, New Zealand, and Sweden; 2000 for Brazil.

Columns 2, 3 and 4: same years as column 1 except 2000 for Israel, and 2001 for Portugal.

Sources: OECD, RICYT (Brazil and Mexico) and CONICYT (Chile).

Figure 2.1. R&D intensity in Chile's main economic sectors, 2002

Spending as a percentage of value added



Source: Ministry of Economy.

It seems that Chile's low level of R&D intensity cannot be ascribed entirely to the combination of *i)* an income gap which could be closed automatically through continued fast growth and *ii)* a comparative advantage in resource-based industries which reduces the scope for R&D-based innovations (Figure 2.1). Other reasons have to do with the degree of maturity and efficiency of the national innovation system, to be examined later in this report. An international comparison of the composition of R&D investments points to some structural unbalances, with encouraging signs of improvement in the most recent period:

- As in the rest of Latin America, and more generally in less advanced economies, most R&D in Chile is financed by government and carried out in the public sector (Table 2.2), in contrast with OECD-wide patterns, where the business sector is the main actor in both respects (Figures 2.2 and 2.3). In Chile, firms finance slightly more than one-third of GERD.[9] Almost two-thirds of Chilean public spending on R&D in 2002-04 was allocated to higher education institutions and related funds.

9. 36.5% by private companies and 8.9% by public companies (2004). These percentages do not consider private funding through donations. If the latter are included, the share of private companies rises to 45.7%.

Figure 2.2. GERD by source of funding

As a percentage of the national total, 2003

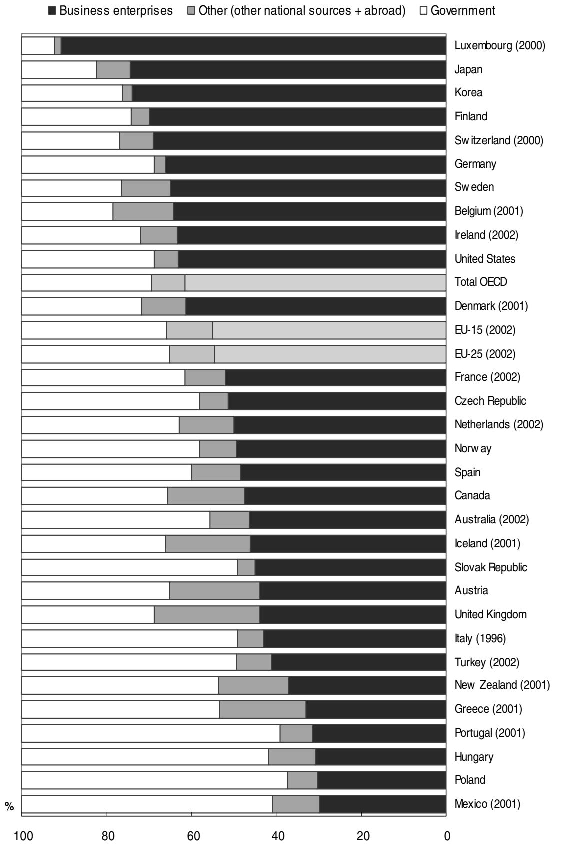


Figure 2.3. GERD by performing sector

As a percentage of the national total, 2003

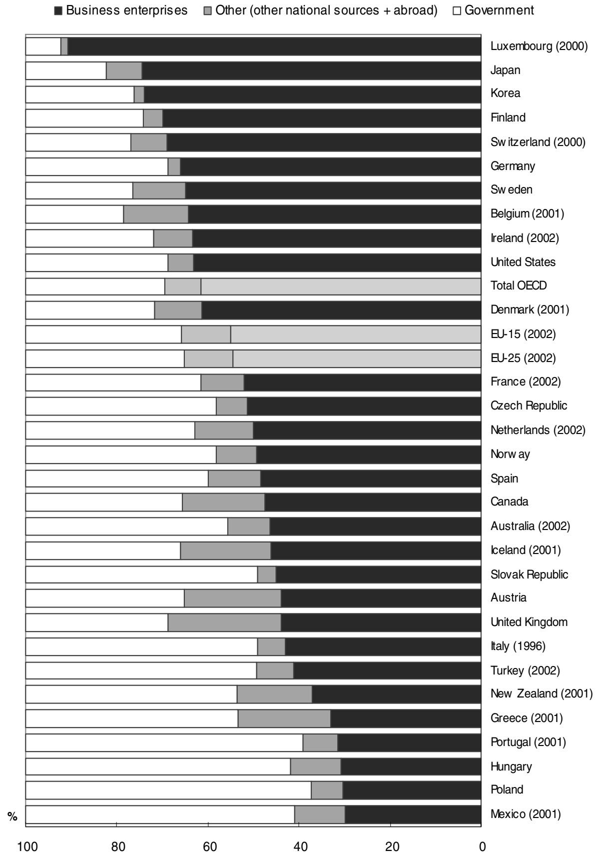


Table 2.2. GERD by funding and implementation sector in Chile, 2004

Sector	Funding (%)	Performance (%)
Companies	45.7	46.1
State	44.5	10.2
Higher education	0.8	32.0
Private non-profit organisations	0.3	3.2
Foreign	8.7	8.5
Total	100.0	100.0

Source: CONICYT.

- The orientation of R&D investment partly reflects the still dominant, although declining, role of higher education in the performance of research (Table 2.3). The latest figures for 2003 indicate that one-third of R&D funding goes to basic research, a relatively high share compared to most OECD countries, but comparable to the situation in Mexico and New Zealand. Earlier, the share of spending on basic research exceeded 50% and peaked at around two-thirds in the early 1990s.

Table 2.3. GERD by type of research in Chile, 2003

Country	Basic research	Applied research	Experimental development
Chile	35.7	51.5	12.8
Argentina	25.6	46.9	27.5
Mexico	34.5	40.2	25.2
New Zealand	33.9	37.8	28.3
Spain	20.2	38.8	41.0
Portugal	24.1	29.8	36.1
United States	19.1	23.9	57.1

Source: CONICYT; RICYT; Statistics New Zealand.

- The level of public financial support to private R&D is very low by international standards, confirming that the innovation system is in every respect closely linked to the public research sector (Figure 2.4).

Figure 2.4. Public funding of R&D performed in the public and private sectors, 2004 or latest

As a % of GDP

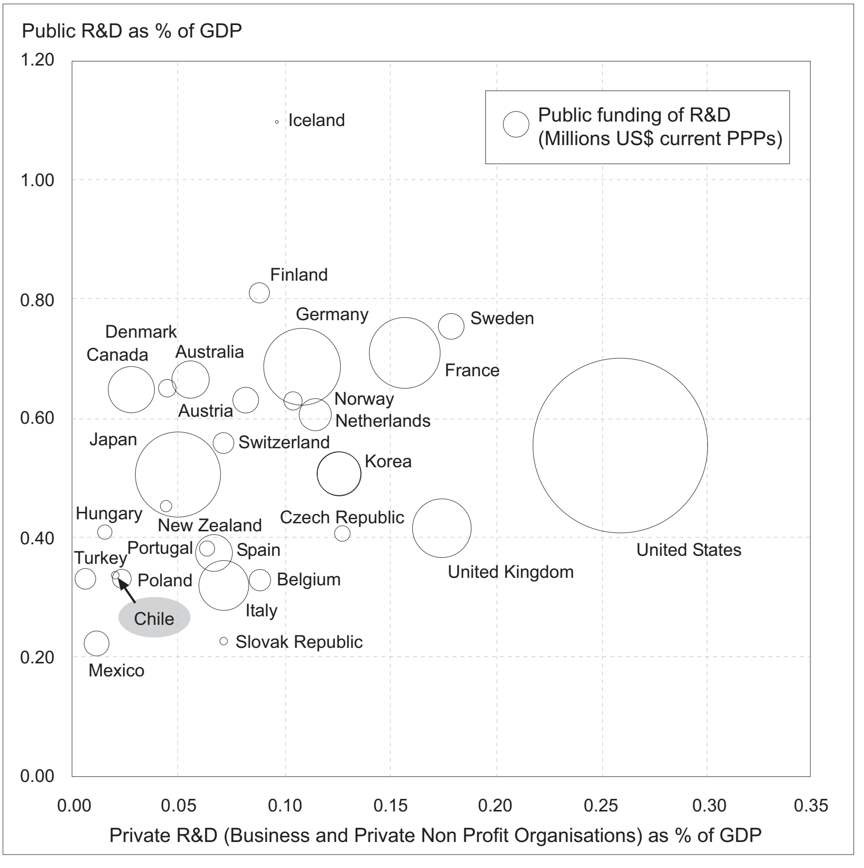
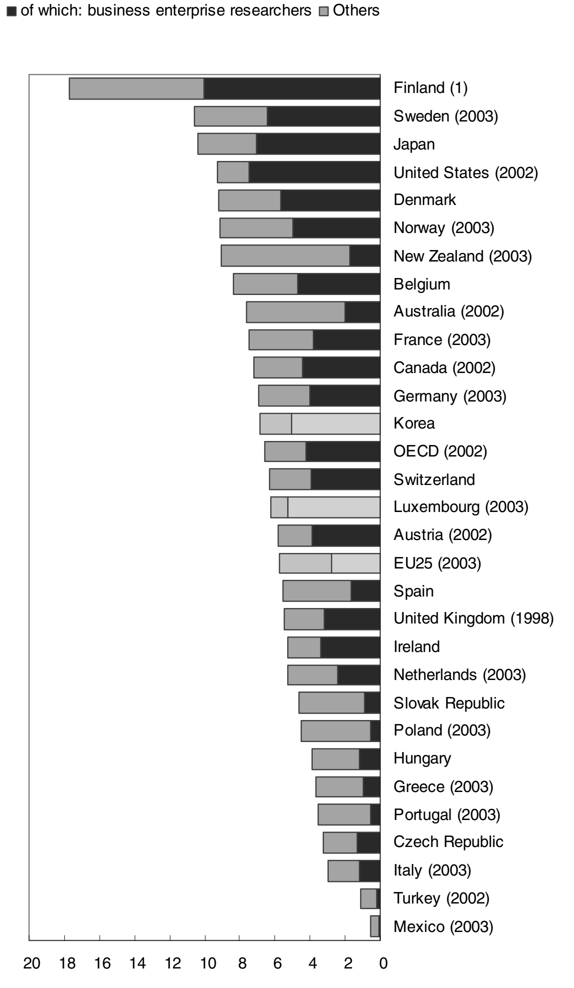


Figure 2.5. Researchers per thousand employees in OECD countries, 2004



1. Overestimated. Also include holders of engineering degrees and graduates of vocational polytechnics.

2.1.1.2. Human resources

Although the situation has improved over the last decade and current university enrolments in S&T and engineering studies are promising, the scarcity of human resources for science and technology (HRST) remains an important bottleneck in the Chilean innovation system.

Stock and sectoral allocation of researchers

In 2004, Chile had at most 3.2 researchers[10] per 1 000 employees,[11] less than half than in the OECD area as a whole. Researchers are highly concentrated in the public sector, mostly in universities (Table 2.4).

Table 2.4. Number of researchers in Chile classified by institutional sector

Year	Universities	State	Companies[1]	PNPI[2]	Other[3]	Total
1990	3 639	1 080	346	356	n.a.	5 421
1995	4 356	973	574	377	108	6 388
2000	5 075	1 003	650	401	89	7 218
2004	6 880	615	10 064	635	231	18 507

1. From 2002, data on companies are expressed in FTE.
2. Private non-profit institutions.
3. Refers to international organisations.
Source: Academy of Sciences based on CONICYT estimates.

Among the 8 500 Chilean researchers 2 250 are identified by the Academy of Sciences as highly qualified scientists, *i.e.* those who have completed their postgraduate studies and have publications in journals indexed by the Institute for Scientific Information (ISI). Regarding these researchers some features and trends are worth noting:

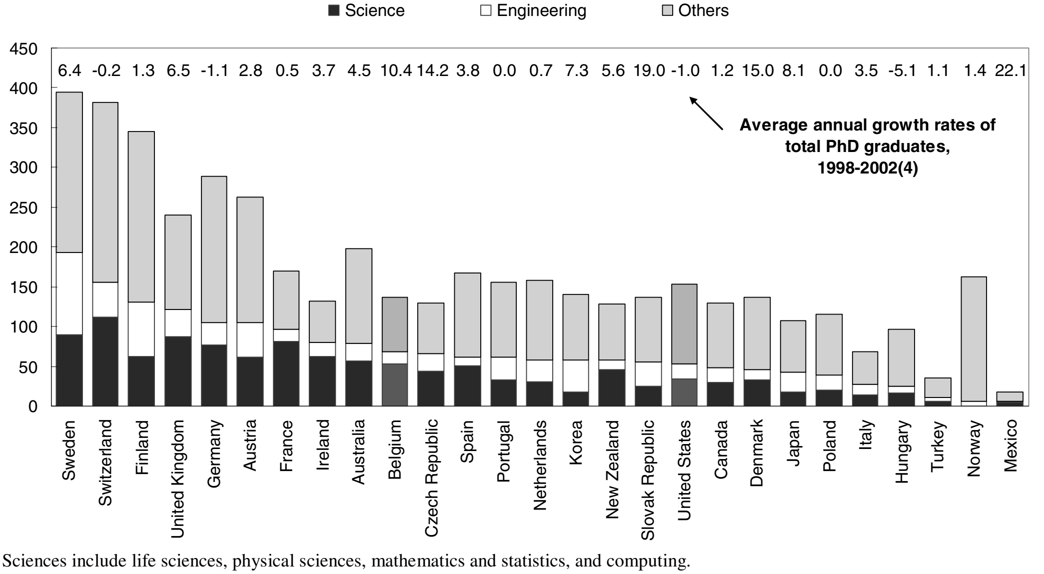
- They are in the following areas: biomedicine (22%), biology (19%), chemistry (11.6%), engineering sciences (10.9%), physics (8.9%), agronomy (8.5%), environmental sciences (7.3%), mathematics (7.5%), marine sciences (7.2%), Earth sciences (6.6%) and astronomy (1.9%).

10. In the OECD *Frascati Manual* researchers are professionals dedicated to conceiving or creating new knowledge, products, processes and systems, and also to managing the respective projects

11. This is probably an overestimation since this ratio is calculated based on data that are not fully adjusted to full-time equivalent.

- Most of them work in the five leading universities (three in the metropolitan region and two in the regions).
- The percentage of researchers with PhDs has more than doubled, from 33% in 1993 to around 70% in 2003. Among younger researchers, the percentage approaches 100%. However, in international comparisons the "PhD gap" remains large. Chile has relatively few PhD graduates in science and technology per million population, probably amounting to about one-fifth of the average of OECD countries (Figure 2.6) and fewer than Brazil, for example.

Figure 2.6. PhD graduates in science[1] and engineering[2] and other fields, 2002,[3] per million population



1. Sciences include life sciences, physical sciences, mathematics and statistics, and computing.
2. Engineering includes engineering and engineering trades, manufacturing and processing and architecture and building.
3. 2000 instead of 2002 for Canada and Portugal.
4. 1999 instead of 1998 for Denmark, Mexico and the Slovak Republic; 2000 for Belgium and Portugal; 2001 for Poland.

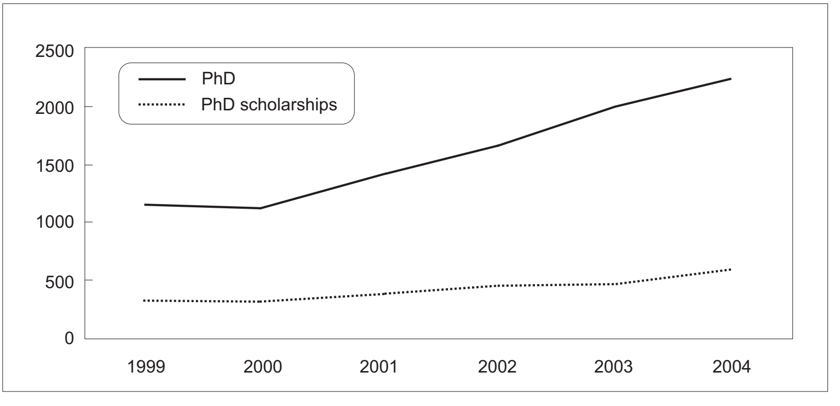
The scarcity of research scientists has detrimental effects today and poses severe challenges for the future. First, it weakens the link between education and research: university courses with significant scientific and technological components are often taught by professors who do not themselves do research, particularly in the private system. Second, despite the increased production of doctorates in recent years, the supply of young scientists is insufficient to meet the demand from universities as they seek to bring down the average age of their academic staff.

Therefore, most of the researchers currently being educated may be absorbed by the universities for quite a long time, although the reinforcement and expansion of the innovation system will mean stronger demand from other institutions, especially businesses. Policies aiming to balance the supply of and demand for HRST over the medium to long term are needed in view of the inherent inertia of the process of producing scientists.[12] They should address both the supply and the demand sides. Currently, the demand for researchers by the business sector, both state-owned and private, is picking up somewhat but remains too weak and requires stimulus (Academia Chilena de la Ciencia, 2005). For its part, the HRST supply pipeline should be assessed, keeping in mind the need to accelerate the transition towards a more firm-centred innovation system.

The HRST pipeline

Although enrolments in postgraduate programmes are still insufficient, the number of PhD students has increased significantly in recent years. Scholarships for these students have also been on the rise (Figure 2.7 and Box 2.1).

Figure 2.7. PhD students and scholarships, 1999-2004



Source: CONICYT.

12. The period of formation for a scientist, from when he/she starts a doctoral programme to his/her debut as a researcher at the end of the post-doctorate, takes between eight and ten years.

Box 2.1. Postgraduate scholarships in science and technology in Chile, 2005

Funding for postgraduate studies in science and technology comes mainly from budget resources administered by CONICYT, MIDEPLAN and MECESUP. There are also significant international sources, including Fundación Andes, the Ford Foundation, the Fulbright Commission, OAS, ALBAN, AGCI and the British Council. The table below summarises the available data on postgraduate scholarships awarded in 2005.

Scholarships	Science and technology		Other	
	PhD	Master	PhD	Master
National				
CONICYT 2005	186	2	34	18
PBCT	166			
MECESUP 2005 (Academicos)	8	1		
MECESUP 2005 (Alumnos)	81	0	27	3
MILENIO Scientific Initiative 2005	10	6		
FONDAP (CONICYT)	24	8		
Regional Programmes (CONICYT)	49			
Total national	524	17	61	21
Foreign				
Pdte de la Republica (MIDEPLAN)	25	7	47	26
Commission Fulbright 2005	6	7	4	13
MECESUP 2005 (Academicos)	6	2	14	6
ALBAN 2005/2006	7	6	4	12
New Zealand	4			
CONICYT - INRIA	5			
Other	12			
Total foreign	65	22	69	57
Grand total	589	39	130	78

Source: Ministry of the Economy.

There are now 91 PhD programmes in science, technology and engineering (more than two-thirds of all PhD programmes), compared with only 15 in 1993. However, their throughput is modest since only 117 students graduated in 2003,[13] compared with 22 in all areas in 1993. This reflects quite an impressive increase in enrolments, from 238 in 1993 to 1 985 in 2003, but the increase is less than in higher education enrolments overall: while postgraduate students represented 1.3% of total higher education enrolments in 1992, today the proportion is only 0.66%. The share of disciplines related to science, technology and engineering in total higher education enrolments has been quite stable over the last decade, between 33% and 35%, and in this regard Chile fares well in international comparisons (Table 2.5).

Table 2.5. University enrolments in science and engineering in selected countries, 2002

As a percentage of total enrolments

	%		%		%		%
Korea	41	Mexico	31	Sweden	27	Japan	20
Finland	38	Israel	31	Ireland	25	Poland	20
Chile	**32**	Czech Republic	31	Hungary	21	New Zealand	19
Spain	31	Portugal	29	Turkey	21	Argentina	15

Source: The World Bank.

Discussion of the "human capital pipeline" from the perspective of the national innovation system should not focus to narrowly on the higher end of skills,[14] on R&D as the only activity in which human resources contribute to innovation, and on the school and further/higher education system as the sole organisational mechanism for creating the required human capital. The role of business enterprises as creators of human capital for innovation, notably through formal training, should receive close attention. Unfortunately, there is little information available for making reliable international comparisons. In Chile, training within companies is encouraged through a tax exemption, administered by the National Training and Employment

13. Of which 94 in the basic sciences, one in agricultural sciences, ten in health and 12 in engineering and technology.

14. A variety of skills at different levels in production, design, engineering and associated management and marketing activities contribute to innovation. In Chile the low quality of part of the schooling system together with weaknesses in vocational training translate into deficiencies in basic skills among the labour force. A detailed discussion of these issues would be beyond the scope of this report.

Service (SENCE).[15] In 2004 15% of employees received training, one-quarter of them in science and applied techniques and in computing and information technology.

International flows of human resources increasingly influence the balance of the supply of and demand for HRST. Chile does not have an active policy regarding migration and mobility of skilled labour and does not appear to suffer from a significant "brain drain". According to the 2004-05 Competitiveness Report of the World Economic Forum, Chile has a low level of "brain drain" (it ranks seventh out of 104 countries) but insufficient "brain gain", *i.e.* the capacity to attract highly skilled scientific personnel. While Chile certainly has some favourable conditions, it has not been very successful at attracting significant advanced human capital except from Latin American countries dogged by chronic or temporary crises. Moreover, it lags significantly behind in numbers of foreign students received and of Chilean students studying abroad. In other words, the level of internationalisation of the educational process is too low (Brunner and Elacqua, 2003).

2.1.2. Innovation outputs

2.1.2.1. Scientific production

The now outdated linear model of innovation saw new scientific contributions to knowledge as an input to innovation. In the current systemic approach, the science system is viewed as an integral part of an interactive learning process in which feedback loops make market-led innovation contribute to the advancement of basic research. A country's scientific capacity is reflected in the quantity and quality of its researchers' publications in internationally recognised journals.

The Chilean scientific community is small but of good quality, although the lack of critical mass is clearly an issue in some fields. Scientific activities in Chile have been under less pressure than in most OECD countries to demonstrate their economic relevance. The portfolio of scientific activities has been shaped by the policy of a few dominant universities[16] and opportunities for international co-operation within the academic community. An increasingly market-led demand for scientific inputs to innovation presents the science system with new opportunities but also new challenges.

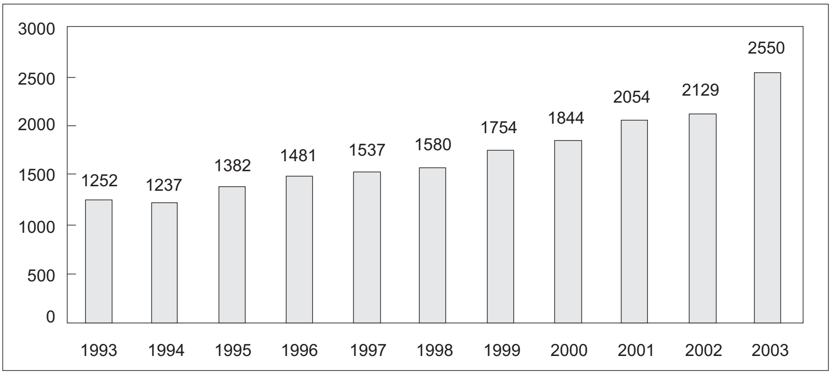
15. Companies can deduct training expenses from their tax liabilities. The maximum annual amount is 1% of total taxable wages paid by the company in the same period.

16. Over 75% of scientific publications originate in only five of the 60 Chilean universities.

Scientific publications from Chile registered by the Institute of Scientific Information doubled between 1993 and 2003,[17] growing much more rapidly than in most OECD countries (Figure 2.8), but more slowly than the general trend in Latin America and much more slowly than in Brazil and Mexico.

Although the quality or importance of a scientific discovery is not easily measured, an internationally used proxy is its so-called "impact", reflected in the number of times a publication is mentioned in other publications. According to this criterion, the quality of Chilean publications exceeds the Latin American average in most areas but is nevertheless appreciably below the levels of developed countries (Table 2.6).

Figure 2.8. Scientific publications in Chile, 1993-2003



Source: Academy of Sciences.

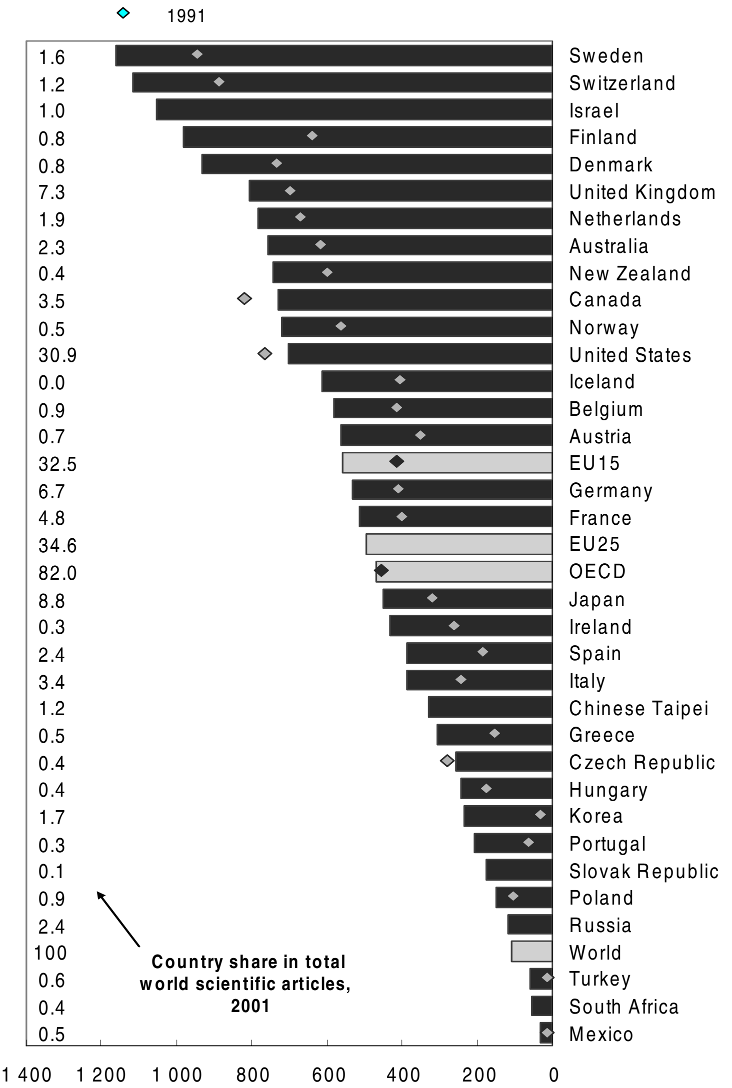
17. Above average growth was recorded for publications in engineering, Earth sciences, mathematics, ecology and physics.

Table 2.6. Number and impact of scientific publications in selected disciplines and countries, 1993-2003

Country	Mathematics		Physics		Engineering	
	Impact	Publications	Impact	Publications	Impact	Publications
Argentina	2.24	542	5.6	6 421	3.1	1 663
Australia	3.34	3 736	7.2	16 524	3.4	14 112
Brazil	2.30	2 040	4.9	17 288	2.2	4 576
Canada	3.07	7 943	n.a.	n.a.	n.a.	n.a.
Chile	2.67	629	6.1	1 387	2.8	879
France	3.02	17 011	7.8	83 325	3.8	25 522
Germany	2.76	14 061	8.8	111 934	3.4	31 662
Israel	3.15	4 348	9.3	15 626	4.2	6 509
Japan	2.26	8 057	6.3	135 953	3.0	46 975
Mexico	1.69	852	4	9 487	2.6	1 862
New Zealand	2.70	728	7.3	1 981	2.9	2 183
Spain	2.26	6 162	7.2	26 869	3.9	10 771
United Kingdom	3.93	10 044	9.0	65 372	3.8	46 771
United States	4.07	52 139	11.9	23 431	4.9	193 469
Pacific Asia	2.38	21 307	4.1	163 375	2.4	92
European Union	3.12	61 644	7.8	360 535	3.6	166 718
Latin America	2.40	4 522	4.8	35 007	2.5	10 108

Source: Academy of Sciences.

Figure 2.9. Scientific articles per million population, 1991-2001



2.1.2.2. Patents

Despite some limitations,[18] patents are a useful indicator for benchmarking national trends in technological innovation. The level and evolution of patenting activities in Chile and by Chilean institutions abroad are revealing in several respects:

- Chile's triadic patenting, *i.e.* patents registered simultaneously in the United States, the European Union and Japan, is almost negligible (Figure 2.10), as is its patenting in the United States alone.[19] This reflects the limited capability of Chile's innovation system to generate first-to-the-world new products and processes, but also the fact that Chile is specialised in industries with a low propensity to patent worldwide and that successful exporting industries rely on imported technologies and show innovativeness in non-patentable know-how, such as business models and marketing.
- An examination of patents presented and processed by the Department of Industrial Property confirms the very low rate of accumulation of intellectual property (IP) by Chilean actors, although their propensity to patent has increased, especially since 2000 (Table 2.7). It also reveals that foreign firms, mainly from North America and Europe, are more and more interested in protecting their IP in Chile, which suggests an intensification of the knowledge content of their dealings (foreign direct investment [FDI] or exports) with the country. Finally, it shows that the universities that carry out over 80% of Chilean scientific-technological research account for only a tiny proportion of patents granted to domestic inventors (Table 2.8).

Table 2.7. Patent applications and registrations at the Chilean Department of Industrial Property (DPI) by applicant country

	Patent applications by year		Patents granted by year		
	1995	2004	1995	2004	Total 1995-2004
Chile	170	582	19	51	194
North America	764	1125	53	216	1397
Europe	347	650	29	95	927
Other	134	172	9	23	199

Source: Academy of Sciences, based on DPI.

18. Especially the fact that the propensity to patent varies from one industry to the other, reflecting the sectoral variation of the relative efficiency of the different modes of appropriation of the benefits of innovation (patent, trade secret, first mover advantage, etc.).

19. About 15 patents issued annually between 2001 and 2005.

Figure 2.10. Triadic patents per million population, 2004

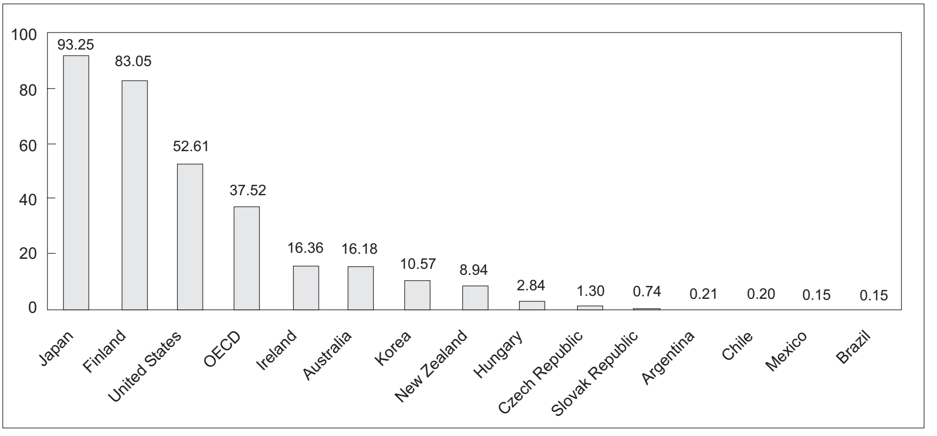


Table 2.8. Patents by type of national applicant, 1995-2004

Applications by nationals	Number	%
Total	2 509	100.0
Individuals	1 738	69.3
Institutions	771	30.7
Universities	*138*	*5.5*
Centres	*2*	*0.1*
Institutes	*3*	*0.1*
Foundations	*11*	*0.4*
Companies and others	*617*	*24.6*
Patents granted to nationals	**Number**	**%**
Total	194	100.0
Individuals	111	57.2
Institutions	83	42.8
Universities	*12*	*6.2*
Centres	*5*	*2.6*
Institutes	*0*	*0.0*
Foundations	*1*	*0.5*
Companies and others	*65*	*33.5*

Source: Academy of Sciences, based on DPI.

2.1.2.3. Technology content of exports

The technology or R&D content of exports is an indicator often used for international benchmarking of innovation capabilities. Caution is advised, however, since this indicator can easily be misleading.

Table 2.9. High technological content of manufactured exports, 2003

Country	%
Turkey	2
Chile	3
Poland	3
Spain	7
Portugal	9
Argentina	9
New Zealand	10
Brazil	12
Czech Republic	13
Sweden	15
Israel	18
Mexico	21
Japan	24
Finland	24
Hungary	26
United States	31
Korea	32
Ireland	34
Singapore	59

Source: World Development Indicators 2004, World Bank.

First, the relationships between innovation and trade specialisation are complex, as discussed in Chapter 1; consolidating or building new comparative advantages through innovation does not necessarily mean maximising the R&D intensity of exports. Second, what is measured by trade statistics is the degree of a country's insertion into global value chains in R&D-intensive activities, not their contribution to the most innovation-intensive links in those chains. The most striking example is China, which is increasingly specialised in high-technology exports, the bulk of which comes from affiliates of multinational firms and only a small fraction of the R&D involved in the production of these goods is carried out in China. The same apply to Ireland and Mexico[20] (Table 2.9). Third, this indicator overlooks the qualitative importance of technological innovation in extracting value from natural resources,[21] as well as of non-technological innovation in developing higher value added activities, especially in the services sector. Therefore it is particularly inadequate for assessing the degree of technological sophistication of an economy, like Chile's, which is based on natural resources.

In fact, Chile has very few high-technology activities, no matter the statistical tool used. A recent study carried out by the Ministry of Economy attempted to evaluate the country's export performance using two methodologies: the OECD classification of high-technology trade based on the International Standard Industrial Classification (ISIC) (Table 2.10), and the Clasificación Uniforme para el Comercio Internacional (CUCI – Standard Classification for International Trade) list of high-technology products (Table 2.11). The share of high-technology products in total exports appears to be in the 0.4% to 1.1% range, *i.e.* lower than the World Bank estimate given in Table 2.9. Another finding is that Chile hosts meaningful segments of global value chains in high-technology production only in chemicals and automobiles, which jointly account for over 80% of its exports of high-technology goods. However, in 2004, 42.6% of exports were in medium-high-/medium-low-technology activities in which the scope for creative combinations of technological and softer innovations is very large.

Table 2.10. Manufacturing industry exports by technological content (%)

Classification	2000	2001	2002	2003	2004
Non classified*	28.3	27.8	25.5	28.4	30.9
High	0.6	0.7	0.7	0.6	0.4
Medium high	7.9	8.4	8.1	7.8	6.2
Medium low	32.7	31.5	32.8	31.9	36.4
Low	30.5	31.6	32.9	31.2	26.0
Total	100	100	100	100	100

*Non-industrial exports.
Source: Technology Innovation and Development Programme (2006).

20. This explains why Mexico, the least R&D-intensive economy in the OECD area, appears in Table 2.9 ahead of Israel which is the world's most R&D-intensive economy.

21. For example, a rather low investment in biotechnology in order to develop vaccines to prevent some diseases can have a huge impact on the viability of fish farming.

Table 2.11. Exports of high-technology products (%)

Product family	2000	2001	2002	2003	2004
Aerospace	0.04	0.03	0.03	0.02	0.01
Office machines and computers	0.07	0.08	0.08	0.07	0.05
Electronic-communications	0.11	0.14	0.18	0.11	0.06
Pharmaceuticals	0.05	0.06	0.07	0.07	0.06
Scientific instruments	0.03	0.03	0.02	0.05	0.02
Electric machines	0.00	0.00	0.01	0.01	0.00
Automobile	1.13	1.00	1.01	0.74	0.44
Chemistry	0.21	0.24	0.20	0.23	0.41
Machinery and mechanical equipment	0.04	0.00	0.04	0.01	0.00
Weapons	0.00	0.00	0.01	0.00	0.01
Total	1.67	1.59	1.67	1.30	1.07
Total exports	100	100	100	100	100

Source: Technology Innovation and Development Programme (2006).

2.1.3. Innovation input/output efficiency – an interim diagnostic

In summary, what does international benchmarking of Chile's investment and achievements in innovation, based on a few available indicators, say about three main questions:

- Has the country so far underperformed, compared to countries with a similar level of income or comparable comparative advantages in resource-based industries, in terms of innovation outcomes, as measured by publications, patents and knowledge-intensive exports? The answer is undoubtedly "yes", even if there are recent signs of improvement.
- Has the country invested sufficiently in R&D and specialised human capital? Obviously not, especially in the private sector, but also at all levels of the education system.
- Is low investment the main cause of insufficient outcomes, is it the opposite or is it both? The fact that in an international comparison the gap in innovation output seems even larger than that in input suggests that the main cause is inefficiencies in the national innovation system. In other words, supply and demand factors may reduce returns on investment in knowledge in some areas and create other types of

obstacles to investment in others.[22] Such inefficiencies need to be investigated further.

Drawing on OECD countries' experience, the following section discusses how to identify these inefficiencies using an innovation system approach.

2.2. The innovation system approach: main lessons from OECD countries' experience[23]

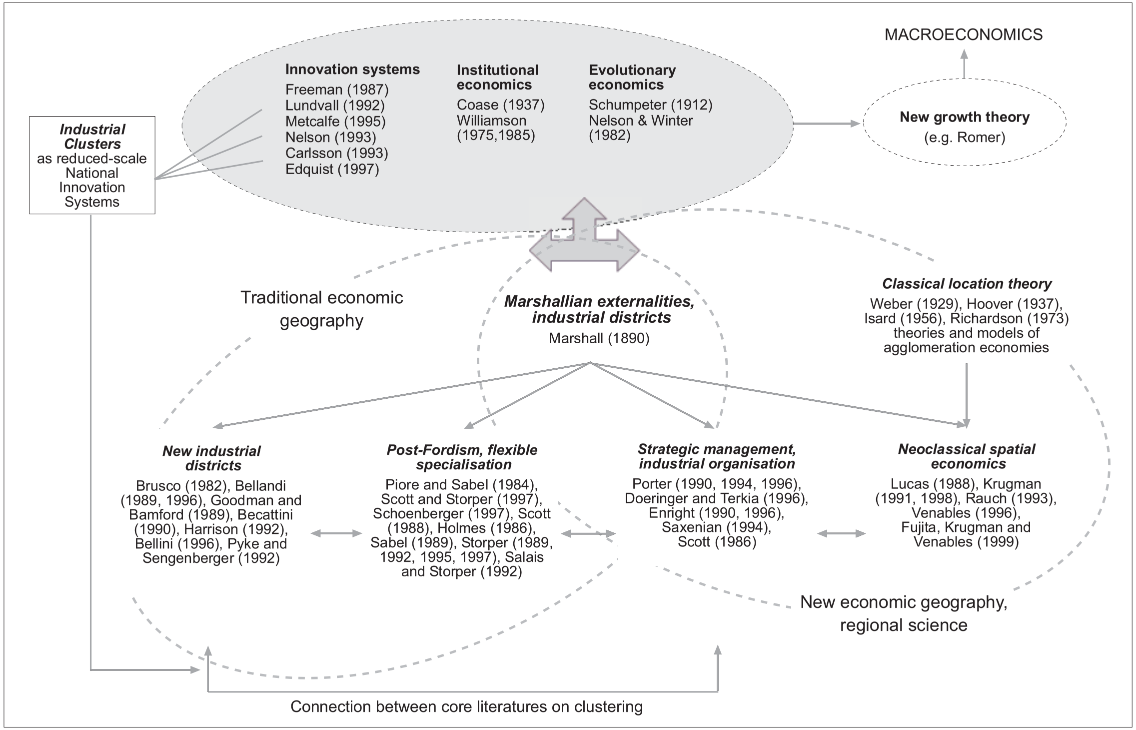
In trying to frame its policy making for science, technology and innovation within an innovation-system perspective, Chile should draw on the experience of the most experienced and most successful OECD countries in this respect. When Freeman (1987) first introduced the term "innovation system", it referred largely to the institutions involved in research and innovation. In recent years it has become more clearly understood that overall innovation performance depends on many more actors and capacities as well as on a range of framework conditions. This section points out some of the key aspects and implications of this wider perspective. This is not "merely" a question of getting the theory and our understanding right. It has major implications for the balance and mix of policies needed in order to improve innovation system performance and for the amount of communication and co-ordination required to create the required holistic innovation policies. To the extent that countries operate with a narrow "innovation system map" that focuses on science and technology and the formal R&D system, they are likely to be guided into making policy choices that optimise the formal part of the system at the expense of the whole.

There is no single "right answer" for drawing and delimiting an innovation system map. As ever, there are important risks in transporting developed country concepts and techniques uncritically to less advanced countries because tacit assumptions that hold good across most OECD countries may not be appropriate in other contexts. (A significant example in Chile is the types of assumptions made in OECD countries about the existence of a large number of innovative or "innovation-ready" firms on the demand side of the system.) This section outlines a number of aspects of the Chilean innovation system.

22. *Country Innovation Brief: Chile*, Office of the Chief Economist for Latin America and the Caribbean, The World Bank.

23. This section draws heavily on a contribution by Martin Bell (SPRU) and Erik Arnold (Technopolis).

Figure 2.11. The theoretical foundation of a systemic approach to innovation



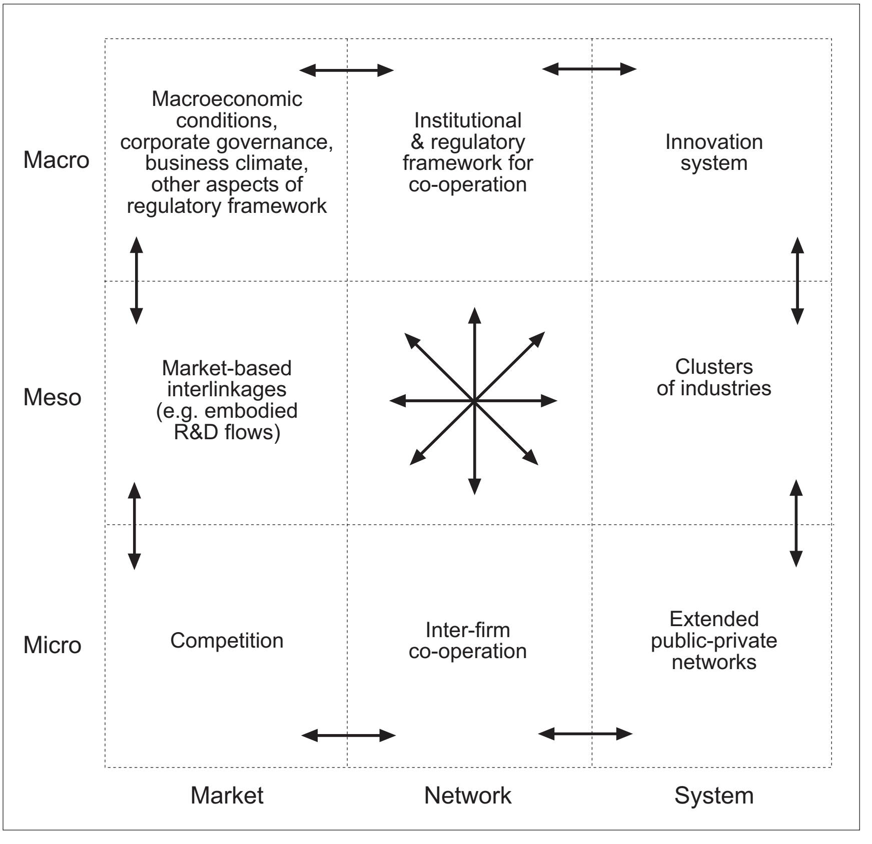
Source: OECD, adapted from Pim den Hertog.

2.2.1. The nature of the innovation system

Interconnection and interdependence are at the heart of the innovation system concept. The innovation system perspective originated in deliberate opposition to simpler, more or less monocausal ways of understanding innovation and the economy. In particular, it is a reaction to the treatment of technology as a residual factor of production in the neoclassical economic model and to the popular mental model – the so-called "linear model" – of the relationship between research and innovation, which suggests that basic science leads to applied science, which causes innovation and so generates wealth. While there was some limited research support for this "technology-push" or "science-push" view in the 1950s, in its crude form it does not stand up to scientific scrutiny. More modern models of the innovation process are complex, with many linkages among actors (see Mowery and Rosenberg, 1978; Kline and Rosenberg, 1986; Mullin *et al.*, 1999). Innovation processes do not always start at a particular place (basic science or the market) but can be prompted by changes anywhere.

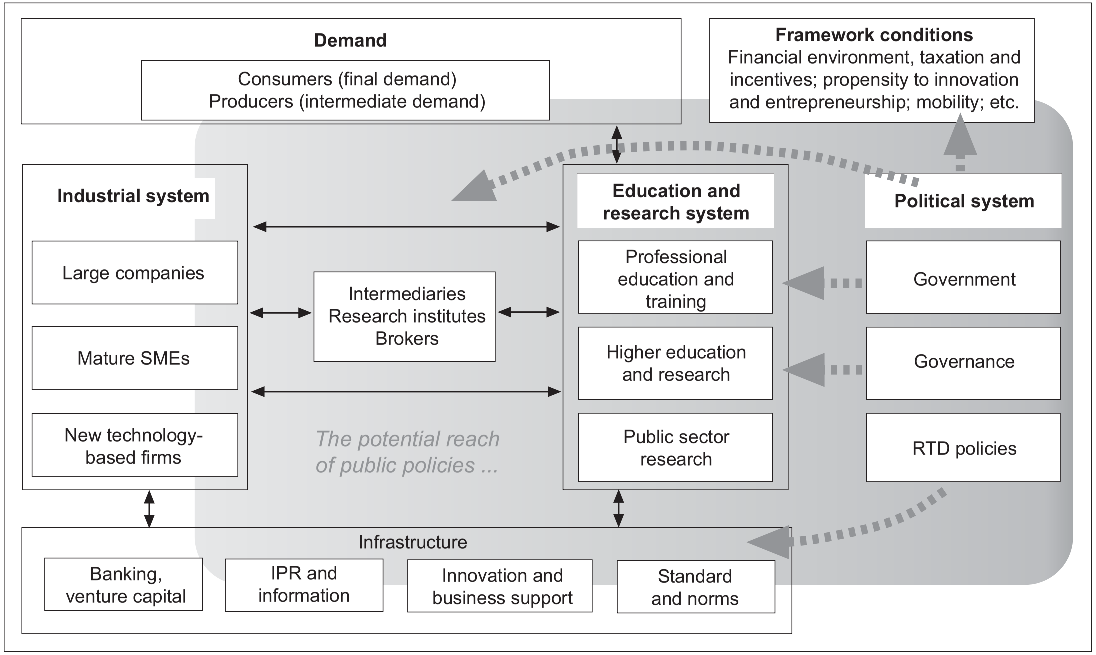
The concept of a national innovation system has eclectic theoretical foundations and relates to several streams of economic thinking (Figure 2.11). It is defined here as a web of interactions at different levels (Figure 2.12) between distinct organisations (*e.g.* firms, research institutes, universities) which jointly and individually contribute to the development and diffusion of new know-how and technologies (Metcalfe, 1995; OECD, 1999). They do so within a wider set of institutions and social, economic and political conditions that influence the actors and provide the framework within which governments form and implement policies to influence the innovation process. It is, therefore, a system of interconnected organisations or core actors and wider framework conditions (see Chapter 1) within which societies create, store and transfer the knowledge, skills and artefacts which contribute to innovation (Figure 2.13). From this perspective, the innovative performance of an economy depends not only on how individual organisations perform in isolation, but also on how they interact with each other and on their interplay with social institutions (such as values, norms and legal frameworks; see Smith, 1996). In effect, each component of the system needs to work at least at an acceptable level of quality and efficiency and the linkages between them need to function effectively.

Figure 2.12. Interactions in innovation systems



Innovative activity encompasses a wide range of phenomena. Innovation systems are not concerned solely with the types of innovation that are globally novel. Instead, especially after the growing number of innovation surveys following the guidelines of the *Oslo Manual* (OECD, 2005), it is now recognised that important forms of innovative activity include changes that are new to particular industries or individual firms. Innovation encompasses not only "hard" technological innovations, but also softer forms concerned with organisational arrangements and procedures. Much innovation therefore does not involve R&D. Indeed, R&D is often not a source of innovation but an effect of decisions regarding innovation (Smith and West, 2005). Firms very often seek to innovate by exploiting their existing knowledge assets. Unforeseen problems often emerge, however, which require R&D to resolve them. From this perspective R&D should be seen not as a process of discovery, but as a problem-solving activity within existing innovation processes.

Figure 2.13. A heuristic: the national research and innovation system



Source: Arnold and Kuhlman (2001).

Business enterprises are central actors in the system. Since the earliest contributions to discussions of the innovation system, different system components have received different emphases. For example, although Freeman's commentary on the Japanese system of innovation (Freeman, 1987) noted the importance of firms, it highlighted the importance of public organisations and the wider social, cultural and macro-institutional framework within which they were embedded. Subsequently, Nelson's comparative studies of national innovation systems pushed this emphasis further: business enterprises were included in maps of national innovation systems, but the priority focus was on public-sector scientific and technological organisations and the organisational structures for government policy making (Nelson, 1993). Subsequent studies of national innovation systems have often narrowed these emphases. Many studies have focused on public-sector organisations and policy-making structures, leaving business enterprises as minor appendages on the edge of system maps. In some cases, national innovation systems have been defined almost exclusively in terms of public-sector actors, quite commonly depicted within the hierarchical structures through which they influence and drive other actors, including business enterprises.

An alternative perspective was developed which focused on the interactions between business enterprises as users and producers of innovative technologies (*e.g.* Lundvall, 1992). Business enterprises were at the centre of this idea of innovation systems, and public scientific and technological organisations were somewhat peripheral, although the importance of wider cultural and macro-system environments was recognised. Some subsequent studies have focused almost exclusively on business enterprises as the core of innovation systems, with public-sector organisations taking marginal supporting positions on the system map.

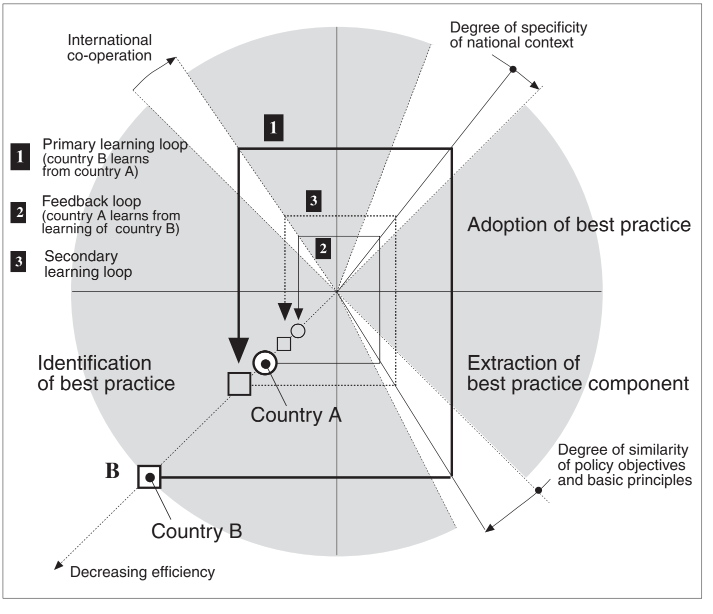
As Figure 2.13 illustrates, the approach in this report is informed by a map that combines these two perspectives, each of which has had a variable influence on policy making in OECD countries, depending on the most pressing issues to be addressed, while their convergence occurred gradually through international policy learning (Box 2.2). Chile can benefit from this experience to overcome the current divide, which surfaces in many policy discussions, between an "economic" approach which focuses too exclusively on pure market-based drivers of innovation, and an "institutional" approach which focuses on the government-driven supply side of the innovation system.

Box 2.2. Learning from international best practices

In the area of innovation policy, it is difficult to provide "off-the-shelf" policy prescriptions. Because factors specific to countries and points in time impinge on what can be achieved or should be attempted by policy makers, few policies represent best practice in an absolute sense (except in very broad terms or at the very detailed level of designing specific policy instruments). At the same time, the diversity of conditions and experience at the country level provides a vast accumulated stock of observations for assessing and comparing relationships between practice and performance. Assessing why some countries are more successful than others at achieving a given goal can enable countries to learn from each others' experience, from their similarities as well as their differences.

This learning process must, however, be fuelled by an organised collection of information and evaluation of actual outcomes of policies against objectives that are more or less common to all countries. By identifying best-practice policies in another country, extracting the components which are most relevant to a country's own situation and desired goals, and adopting the appropriate policies, a country can move from a position of lesser efficiency to one of greater efficiency (path 1 in the figure below). Once it has reached this new position, there is still potential for further improvement, as each country renews its search for best-practice examples in other countries. To the extent that exchange of experience can also help countries co-ordinate policy adjustments to generate greater mutual benefits, additional gains arise.

The learning wheel



continued…

Box 2.2. Learning from international best practices *(continued)*

The notion of best practice must be understood from this perspective, i.e. as *a learning device rather than a normative concept*, recognising that:

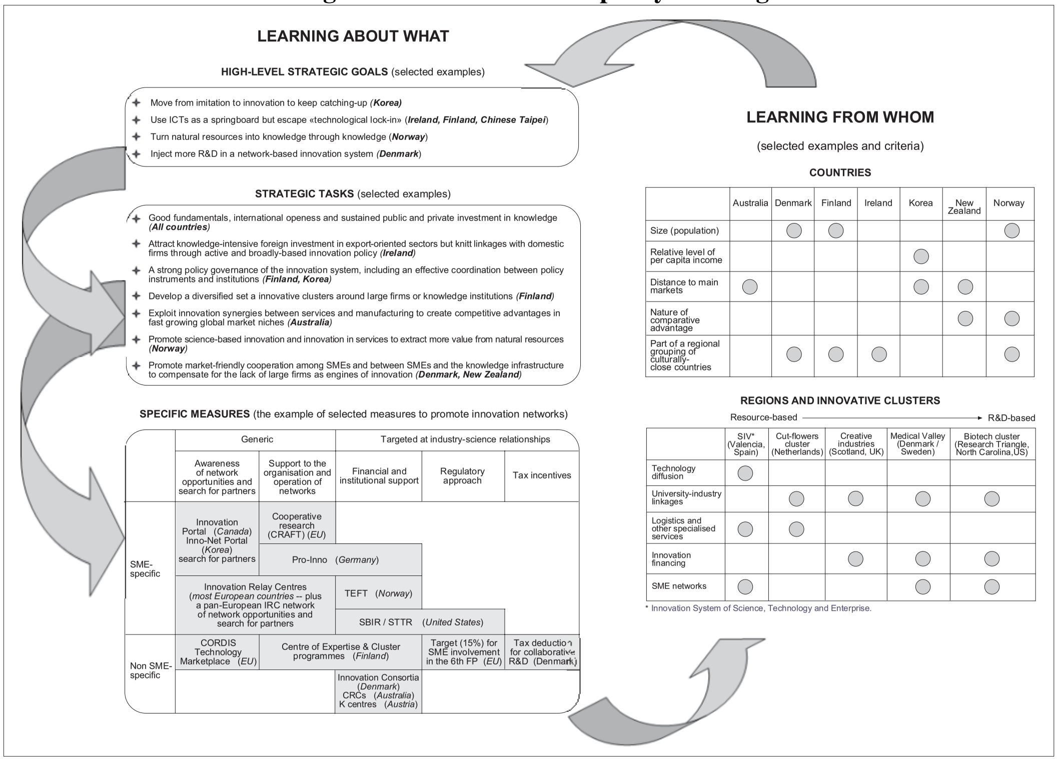
- There is not necessarily a unique best practice for a given policy objective.
- Given differences in political feasibility and other specificities of national innovation systems, countries will not always be in a position to draw the same lessons from recognised best policy practice.
- There is a risk of "not seeing the forest for the trees" and attributing success to specific support programmes. The effect of framework conditions and the interaction between different policy measures must always be taken into account.

There are limitations to government's ability to identify and correct market and systemic failures, which vary from country to country. International transfer of best policy practices should only be advocated when a country's national implementation capabilities are well proven.

Demand, not just supply, drives innovation systems. It is now commonplace to argue that linear models of knowledge that run in one direction from R&D to commercialisation provide an inadequate representation of what happens in the innovation process. Instead, various knowledge flows running in the opposite direction (from markets to research) have been highlighted as drivers and shapers of the innovation process. However, this demand-side perspective, though widely accepted in micro-level studies, has much more rarely been carried through to the mapping of innovation systems at the macro level. Instead, such maps frequently highlight only knowledge flows running from "producers", such as universities and research institutes, to various "users", often depicted as business enterprises.

A different approach is taken in this report. The articulation of effective demand for innovation and for knowledge and skill inputs to innovation is identified as central to stimulating or constraining innovation and the directions it takes. In Chile a specific set of demands for innovation from the dominant resource-based clusters greatly influenced the shaping of the characteristics of key actors in the innovation system, the forms of interaction between them and the nature of the innovative activities they undertook. Over the last decade, however, new forms of demand for innovation have emerged and new conditions affecting demand have been created. Important questions arise about whether and how some parts of the innovation system have responded to the new conditions.

Figure 2.14. International policy learning



2.2.2. The innovation process

Innovation activities are much more than R&D. Discussions about the core scientific and technological functions in national innovation systems often jump quickly from "science and technology" to "research and development". Consequently, maps of the R&D system easily become taken as maps of the innovation system.

As pointed out in section 2.1, this tends to be reinforced by heavy reliance on data about R&D inputs and outputs as the only available internationally comparable indicators of the main features of innovation systems. This seriously distorts the situation, because it leaves out many other kinds of S&T activity that play a central role in innovation. This is illustrated by the kinds of activity undertaken by personnel with degree qualifications in science and engineering disciplines in the United States in 2003 (Table 2.12).

Table 2.12. The main activities of scientists and engineers in the United States, 2003

Research (basic and applied) and technological development	10%
Design (of equipment. processes, structures, models, plus computer programming and systems development, etc.)	13%
Management/supervision (of people, projects, quality, productivity, etc.)	19%
Business, administrative and production activities (in accounting, personnel, sales, maintenance, etc.)	21%
Professional services (financial, healthcare, legal, etc.)	23%
Teaching	11%
Other specified	3%
All above	100%

Source: US NSF, aggregated from more detailed categories.

Bearing in mind that these data are about one of the most R&D-intensive economies in the world, the relative importance of the first three categories is striking.

- Only 10% of all the responding scientists and engineers undertake R&D as their main activity. In other words the main activity of about 90% consists of non-R&D activities.
- A larger proportion (13%) carries out various engineering design activities, including the design of computer applications, systems, etc.

- Even more (19%) undertake various management-related activities, frequently concerned with managing projects, quality and productivity.

It is almost certain that most of the people in these first three groups (42% of the total) are involved in some way or other in innovation – generating new knowledge as an input to it, designing specifications for its component elements, or managing aspects of its implementation. But only about one-quarter of those contributors to innovation undertake R&D. Beyond that, a large number of scientists and engineers undertaking other non-R&D activities almost certainly also contribute to innovation – for example scientists and engineers working in professional services such as finance and health care.

Similar profiles of the activities involved in innovation can be derived from innovation surveys in countries more comparable to Chile. For instance, as summarised in Table 2.13, data from the innovation survey in Argentina's manufacturing industry in 2001 indicate the proportions of all professional employees with qualifications in the natural sciences and engineering that undertake various activities. Again the picture is telling.

- The overwhelming majority (73%) of qualified scientists and engineers employed in manufacturing industry apply their S&T capabilities in activities other than full-time or even part-time R&D.

- Less than 1% of all employees in manufacturing are engaged in "formal" R&D; but nearly 20 times that number contribute to innovation via their activities in "informal" R&D, industrial engineering, design and related management activities

Table 2.13. Innovation activities in manufacturing in Argentina, 2001

Proportions of professional employees with qualifications in the natural sciences and engineering	
R&D on a full-time basis	17%
R&D on a part-time basis	10%
Other (non-R&D) activities	73%
Proportions of all employees who undertake various activities that specifically contributed to innovation	
"Formal" R&D (organised in a designated R&D department/section)	0.9%
"Informal" R&D (not organised in a specific R&D department) or various industrial engineering, design and related management activities contributing to innovation	17%

Source: INDEC (2001).

These indications of the relative magnitude of different activities involved in innovation illustrate the narrowness of R&D-dominated perspectives. They also highlight the importance of a bundle of other activities concerned with design, engineering, and management.

Design, engineering and management in fact play key roles in innovation systems. The activity at the heart of almost all innovation is the creation of a set of specifications (or "designs") of the change that is to be implemented. These may be complex designs held in computer-aided design facilities. They may be drawn in the dust on a workshop floor. They may also consist of specifications for procedures and organisational arrangements.

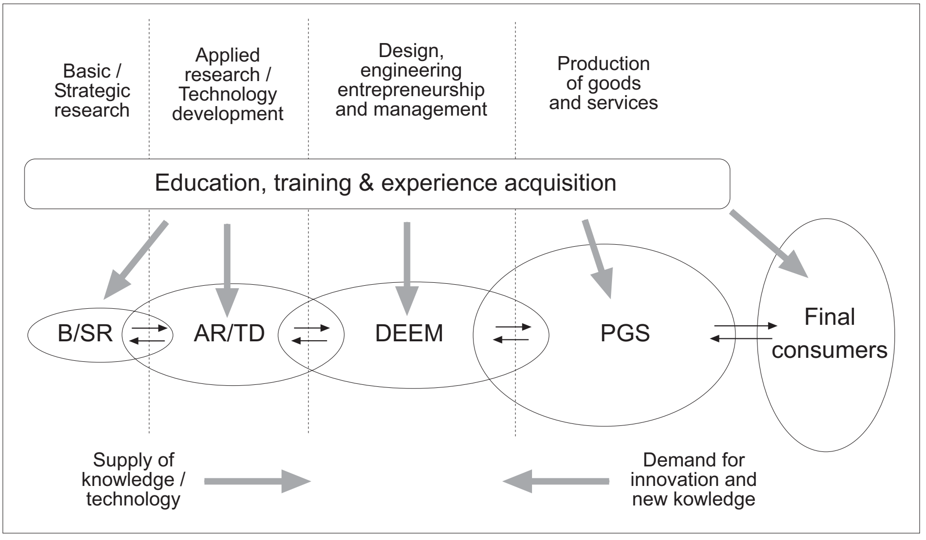
For modern types of technology, the creators of these designs and specifications are various kinds of engineer, such as a university-educated graduate working in a software design office. But they may be quite different, such as a farmer who designs the planting configuration for crops on a small holding. Other actors may identify the needs or opportunities for innovation for which the designers and engineers provide the specifications. "Entrepreneurs" play that important role, but again one needs a broad view of who they are. They may be the classic type of entrepreneurial individual who creates a small firm, an engineer or manager in a manufacturing company who identifies a local market opportunity to exploit a well-established technology, or a provincial official who exploits an opportunity to bring technology and financial resources together to create a series of new rural health clinics. Even for quite simple innovations, various actors may have to be co-ordinated and scheduled in order to integrate the various inputs needed to achieve innovation. Hence "managers" are often involved, and again these can span a wide spectrum.

These design, engineering, entrepreneurial and management (DEEM) actors play three key roles in innovation systems. First, they generate the specifications for changes in the production of goods and services by drawing on existing knowledge without any direct input of new knowledge from R&D. For example, engineers designing the exploitation plans for new mines draw on available design principles, methods and data, and they apply these, plus large quantities of experience, to the varying requirements of different mining situations; they may also introduce advances and improvements on previous plans.

Second, and probably much less often, DEEM activities are triggered by recently developed, new knowledge – perhaps created by their own R&D, perhaps licensed from more distant R&D performers, or possibly drawn from immediately preceding and closely located R&D. In these roles they contribute to the process of translating knowledge outputs from R&D into the concrete realities of implemented innovation.

Third, in addition to these two supply-side roles, they play an equally important role in a process running in the other direction, from the production of goods and services to the execution of R&D. When their existing knowledge base is inadequate to meet the demand for innovation they face, they actively "pull" on R&D to supply new knowledge. This does not constitute simply a vague demand for "innovation" in general; DEEM activities serve to concretise generalised demand into specific technical configurations or performance requirements that help to shape the process of technological development.

Figure 2.15. Core S&T functions in the innovation system



Given the importance of their two-way role in the innovation system they deserve to be placed among the core S&T functions (Figure 2.15).

Innovation functions do not map tidily onto organisations. This section's approach to system mapping has focused on functions or activities (research, engineering, production, etc.). Many other approaches define innovation systems primarily in terms of organisations (universities, research institutes, firms, etc.). It is important to emphasise that single functions rarely map onto single types of organisation. Many of the principal organisations in innovation systems are multifunctional: for example, universities have extended their traditional function of basic/strategic research into technology development and even further downstream to design, engineering and entrepreneurship. Similar functions may be undertaken in different organisations; for example, part of the process of creating scientific and technological human capital for innovation systems is carried out by specialised education and training organisations, but a very important part is also carried out by business enterprises via large expenditures on education and training and by active management of the process of accumulating experience.

National systems are internationally open. Many maps of national innovation systems place heavy and sometimes exclusive emphasis on national activities and interactions within the system. This too easily obscures from policy attention international elements that can be critically important in influencing how all aspects of the system function. These international components of the system are very diverse and growing in importance. They include:

- Inward flows of technology embodied in final consumer goods and services.
- Collaboration along global value chains in creating, transferring and implementing innovation in local production for export.
- The execution of local investment projects that draw on imported engineering and project management services, licensed technology and capital goods.
- Collaboration with foreign partners in scientific research or technological development.
- Inward and outward flows of foreign direct investment by multinational enterprises.
- The emigration, return and original immigration of qualified scientific and technological human resources.
- Inward and outward flows of students.

The quantities, qualities and directions of all these flows are highly variable, and that variability has major implications for the domestic parts of the national innovation system. In many countries the active management of international interfaces of the innovation system is increasingly seen as a major area for policy attention.

2.2.3. An extended rationale for government innovation policy

Another important aspect of the innovation systems heuristic (a term taken from evolutionary economics) is the idea that firms and other actors have "bounded rationality" and this – together with the idea of interdependence – makes knowledge, learning and institutions key to overall performance. Learning means "path dependency": what you can do tomorrow depends upon what knowledge and resources you have today and what you can do to adapt them. Interventions to improve knowledge and capabilities can change the trajectory of the innovation system and therefore its performance. Correspondingly, funding for innovation and R&D increasingly aims to improve participants' capabilities by promoting learning and not only to "help firms" or "fund science".

However, accumulated capabilities and experience can lock parts of the system into configurations that perform badly. It may be necessary to unlearn as well as to learn. Innovators succeed not only because of their personal qualities and actions but also as a result of their interplay with the research and innovation systems they inhabit, and the quality of those systems.

The idea that market failure leads to underinvestment in research (Arrow, 1962; Nelson, 1959) has been the principal rationale for state funding of R&D since the early 1960s. In the innovation systems perspective, the presence of bottlenecks or other failures that impede the operation of the innovation system can constitute crucial obstacles to growth and development (Arnold, 2004):

- Capability failures. These amount to inadequacies in potential innovators' ability to act in their own best interests.
- Institutional failures. Failure to (re)configure institutions so that they work effectively within the innovation system.
- Network failures. These relate to problems in the interactions among actors in the innovation system.
- Framework failures. Effective innovation depends partly upon regulatory frameworks, health and safety rules, etc., as well as other background conditions, such as the sophistication of consumer demand, culture and social values.

These failures justify government intervention not only through the funding of research, but more widely by ensuring that the innovation system performs as a whole. Because system failures and performance are highly dependent upon the interplay of characteristics of individual systems, there can be no simple rule-based policy such as exists in a static view of market failure. Rather, government policy making requires "bottleneck analysis" in order to continuously identify and rectify structural imperfections (Arnold *et al.*, 2001).

To this end, the following chapter reviews the actors in Chile's innovation system, the roles they play, the activities in which they are engaged and the patterns of interaction among them.

Chapter 3

INNOVATION ACTORS IN CHILE

This chapter describes the key players and processes in Chile's innovation system ("performers" in Figure 3.1). It focuses on the actors performing research and development (R&D) and innovation activities, mainly the business sector, the universities, public research institutes and intermediary organisations involved in both technological development and diffusion. Interactions among these groups are examined. The role of government in steering the public research system and in providing basic incentives, institutional frameworks and support measures for business R&D and innovation is examined in Chapter 4.

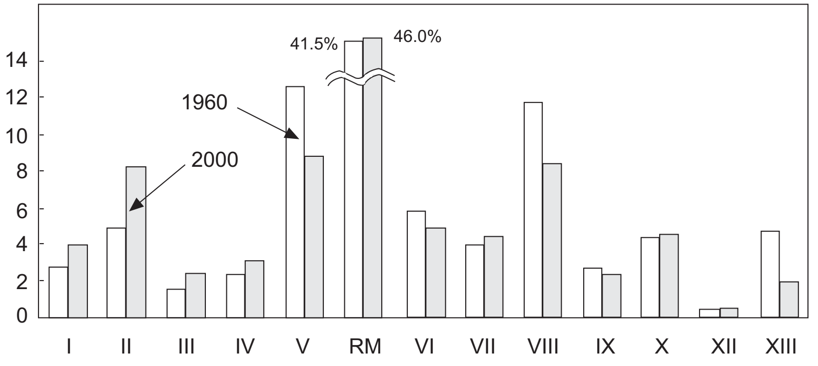
Some characteristics have shaped Chile's innovation system, particularly:

- *Size and geography.* Chile stretches over 4 300 km, a distance roughly the same as that from San Francisco to New York or from Edinburgh to Baghdad. At the same time, its width never exceeds 240 km, so that its length is more than 18 times its widest point. This peculiar topography creates a number of challenges, especially in terms of the development and management of the country's infrastructures. Some 90% of a population of almost 14 million is concentrated in central Chile, a third in the Santiago metropolitan area alone. In fact, Chile is one of the most urbanised countries in Latin America, with 86% of its population residing in cities.

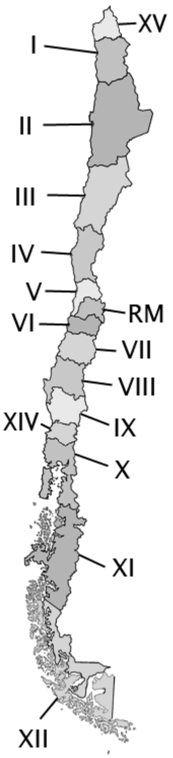
Box 3.1. Chile's regions

GDP of Chile's regions as a share of total GDP, 1960 and 2000

Percentage

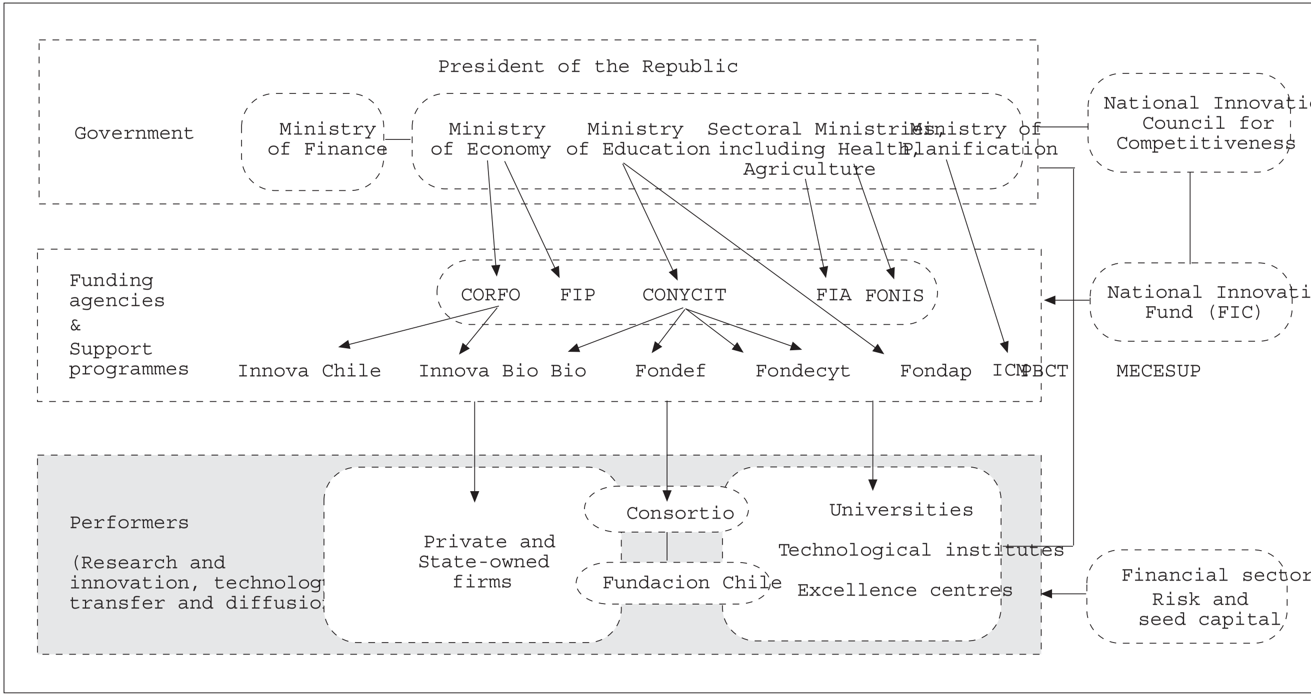


Source: Central Bank of Chile (2007).



N°	Region	Capital city
I	Tarapacá	Iquique
II	Antofagasta	Antofagasta
III	Atacama	Copiapo
IV	Coquimbo	La Serena
V	Valparaíso	Valparaiso
VI	O'Higgins	Rancagua
VII	Maule	Talca
VIII	Bío-Bío	Concepción
IX	Araucanía	Temuco
X	Los Lagos	Puerto Montt
XI	Aysén del General Carlos Ibáñez del Campo	Coyhaique
XII	Magallanes y la Antártica Chilena	Punta Arenas
XIV	Los Ríos	Valdivia
XV	Arica-Parinacota	Arica
RM	Santiago Metropolitan Region	Santiago

Figure 3.1. Institutional profile of Chile's innovation system



Source: OECD based on Ministry of the Economy.

- *Political centralisation.* Chile is a unitary and relatively centralised state consisting, until a recently adopted law comes into force, of 13 regions, 51 provinces and around 350 municipalities or communes. In terms of the balance of power among different levels of government, and despite mounting pressures for more decentralisation over the last decade, Chile's current institutional structure is still largely the one developed under the military dictatorship in the 1970s. Local governments are in a weak position, as they have little policy-making autonomy and remain heavily dependent on government transfers.[24] Consequently, they have not developed the institutional capabilities and managerial skills to play a greater role.

- *Geographical concentration of economic power and intellectual capital, contrasting with widespread export-oriented activities.* Political centralisation and other factors, *e.g.* the historical tendency for knowledge institutions to agglomerate near the strongest and oldest,[25] have led to a probably excessive physical separation of knowledge producers and some users, especially in resource-based industries located in many, sometimes remote, locations. This inhibits the development of producer-centred regional innovation systems and innovative clusters that could contribute to economic diversification around strong export industries.

- *The legacy of a "physiocratic" culture.* As pointed out in Chapter 1, Chile's economy has traditionally depended on exports of natural resources, above all copper, with the share of non-mineral exports increasing over time, especially forestry and wood products, fresh fruit and processed food, fishmeal and seafood. As a consequence, rent-seeking behaviour is pervasive throughout the economy. Technology and innovation are often seen primarily as an readily imported tools, to be used to appropriate these rents. An innovation culture, which views technology and knowledge as the main source of sustainable wealth creation, is not yet widespread in the business community and society in general.

24. This includes Santiago, which is made up of over 30 communes but remains without any metropolitan authority or structure.

25. The University of Chile was created in 1843, and the *Pontificia Universidad Católica* de Chile in 1888.

- *Specific internationalisation patterns.* These patterns are shaped by tradition (*e.g.* strong links with North America and some European countries in higher education), trade and investment opportunities (Chile's export markets are fairly balanced among Europe, Asia, Latin America, and North America and the country is attractive for foreign direct investment [FDI]), and constraints, notably the relatively low level of economic co-operation within the South American sub-continent, including in science and technology (S&T).

3.1. The business sector

3.1.1. Overall R&D and innovation patterns

As pointed out in Chapter 2, the very weak role played by the business sector in the financing and performance of R&D distinguishes Chile's innovation system from those of more advanced economies. Innovation surveys, which also capture non-R&D-based innovation, reinforce the impression that the vast majority of Chile's firms have both a low propensity to innovate and an insufficient level of innovativeness (Box 3.2). Only a small proportion of firms have put the development of new products and processes at the centre of their competitive strategy. Most firms focus instead on adapting imported technologies and know-how. In 2002, more than four-fifths of spending on innovation (90% in manufacturing, Table 3.2) was on machinery and equipment embodying new technology, whereas in the European Union (EU), according to the 1998-2000 Community Innovation Survey, this share was around 40% on average and it was even lower in New Zealand (Table 3.3). Intramural R&D accounted for about 10% of spending on innovation, compared to an average of over one-fifth in the EU. Labour training accounted for only 5% of innovation spending, compared to one-fifth in the EU (Benavente *et al.*, 2005).

Table 3.2. Composition of innovation investment in manufacturing in Chile

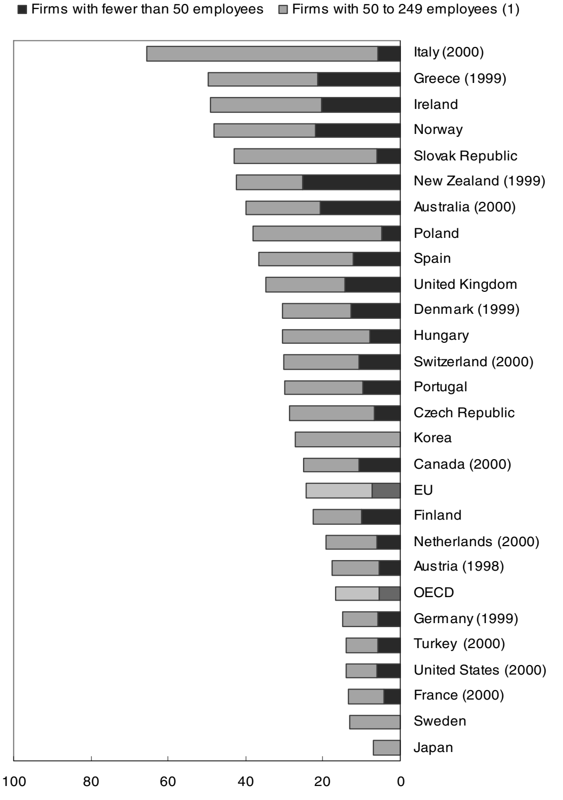
Index, R&D = 100, 2001

R&D	Labour training	Trials, licences and patents	New equipment and machinery
100	43	26	760

Source: Chile Innova.

Box 3.2. Propensity to innovate and level of innovativeness

Figure 3.2. Share of business R&D by size class
(2001, %)



There is ample evidence that innovation capacity decreases with firm size and that many small and medium-sized enterprises (SMEs) do not innovate (Figure 3.3). They are caught in a “low capability trap”:

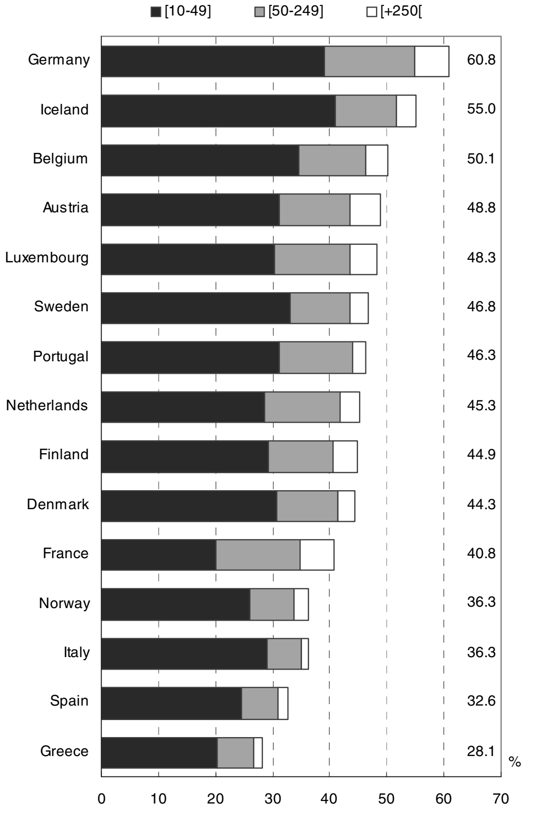
- Until a firm has learned something, it cannot properly specify what it needs to learn. Organisational inadequacies, unavailability of key information, and/or deficiencies in managerial skills prevent sound self-diagnosis of needs and reduce the perceived value of technological or organisational innovation, including networking.
- More generally, many firms lack certain competencies for managing innovation, especially when it involves developing and mastering external linkages.

continued…

Box 3.2. Propensity to innovate and level of innovativeness *(continued)*

Figure 3.3. Share of innovative firms by size class

(1998-2000, %)



Firms that do innovate vary considerably in their level of competence. In broad terms, one can distinguish four levels of innovativeness (OECD, 2002):

- Level 1: The static firm innovates from time to time but may have a stable market position under existing conditions.
- Level 2: The innovating firm has the capability to manage a continuous innovation process in a stable competitive and technological environment.
- Level 3: The learning firm has, in addition, the capability to adapt to a changing environment.
- Level 4: The self-regenerating firm is able to use its core technological capabilities to reposition itself on different markets and/or create new ones.

Firms at level 1 focus on adapting, through physical investment and *ad hoc* organisational adjustments, rather than on creating new technologies and know-how and, consequently, they do not invest in R&D. Investing in R&D and engaging actively in innovative networks is a prerequisite for progressing to level 2 and above.

Table 3.3. Investment in innovation in New Zealand, 2002-03

	Ratio of R&D investment to total investment in innovation (%)	Ratio of investment in innovation to expenditure on fixed assets (%)
Business size		
10-29 employees	52.2	32.7
30-49 employees	42.6	64.1
50 or more employees	47.4	27.7
Industry		
Agriculture, forestry and fishing	51.6	16.5
Mining and quarrying	16.1	4.5
Manufacturing	44.9	31.6

Source: Statistics New Zealand, *Innovation in New Zealand 2003*.

As in most other countries, innovation activity is concentrated in large enterprises. In 2002, according to a census covering all sectors of activity except wholesale and retail trade, business R&D was carried out by about 1 000 researchers and another 1 000 technicians. These were concentrated in the largest firms, of which 26 accounted for 60% of total expenditure. Three-quarters of R&D spending was by firms in the metropolitan area of Santiago, which accounts for about one-half of all of the country's formally registered firms. In terms of sectoral distribution, most spending was in manufacturing (mainly pulp and paper products, wood and furniture, and food and beverages), transport, and agriculture, in line with Chile's comparative advantages.

Motivation to innovate differs across sectors. Information available from the 2000-01 Innovation Survey shows that, in manufacturing, most innovative ideas come from within the firm, with the prime objective of improving working conditions, while in the mining and electricity sectors innovation is also motivated by environmental concerns. Acquiring external knowledge, at least as far as can be gauged by spending on royalties for the use of patented inputs, know-how transfers and licences, played a minor role in all three sectors, except in a few large mining companies. These companies were the most active in developing linkages with scientific and technological institutions, either directly, through contracts, or indirectly, through participation in seminars and co-authorship of scientific publications.

In contrast with their significant contribution to investment, employment and exports, local subsidiaries of multinational enterprises (MNEs) essentially do not perform R&D in Chile.[26] Firm-level surveys in the 1990s showed them to be less involved in innovation than domestic companies. This has gradually changed over the last decade with the encouragement of public policy (*e.g.* CORFO, see below).

Box 3.3. Risk and seed capital in Chile

The risk and seed capital markets are important instruments for funding innovation projects, particularly for entrepreneurs at an early stage of the R&D process, with no record of successful research, limited access to external funds and facing internal financing constraints.

Sources of funds for private R&D spending, 1998 and 2001
As a percentage of establishments

	Manufacturing 2001	Manufacturing 1998	Electricity generation 1998	Electricity distribution 1998	Mining 2001
Source of funds for innovation over past three years					
Exclusively own funds	56.8	66.1	90.0	68.2	76.3
Exclusively public funds	0.3	0.1	0.0	0.0	2.6
Exclusively private external	3.3	1.5	3.3	0.0	5.3
Own and private external	26.8	28.6	6.7	9.1	10.5
Other combinations	12.9	3.7	0.0	22.7	5.3

Source: Chile Innova.

continued…

26. Over the last decade a number of technologically sophisticated multinational companies have invested in Chile, notably: Motorola, Unilever, Ericsson, Hewlett Packard, Delta, Air France, CellStar, Software AG, Nestlé, IBM, Citigroup, Zurich Insurance, General Electric, Kodak, Intel Capital, Barrack Gold, A.I.G. Some of their subsidiaries in Chile are active in technological development, design and innovation management, others are call centres or technology management platforms.

Box 3.3. Risk and seed capital in Chile *(continued)*

The development of the venture capital industry in Chile is hindered by the low level of liquidity in the capital market, which reduces exit options for venture capital investors; restrictions on the exit of foreign capital, such as the requirement that foreign equity investment must remain in Chile for at least one year, which may discourage entry; prudential regulations on pension and mutual fund investments in venture capital, which reduce the investment pool; insufficient competition in the financial sector; and the country's small size and geographical remoteness, which may discourage foreign investors. To some extent, the preponderance of government financing for innovation may be crowding out equity financing. Based on a survey conducted by a non-governmental organisation in 2003, of the USD 38 million in funds available for new business ventures and projects in 2002, 87% were public. They included FONDEF and CORFO, through FONTEC and its Seed Capital Programme. The main private funds in 2002 were Fundación Andes, Negocios Regionales and Santiago Innova.

Demand factors, and not only supply constraints, have contributed to the relative under-development of venture capital. Anecdotal evidence suggests that there is a lack of high-quality projects because Chile's economy is small and resource-based and has low R&D intensity. Another impediment is the traditional ownership structure in the business sector: firms are unwilling to grant special rights to minority shareholders, while this is essential for venture capital, and stock options are not widespread as a means of labour compensation. New businesses are typically financed with credit from family or friends, and when their venture matures, they switch to bank financing, skipping the intermediate steps of equity financing through seed and venture capital. This is at odds with OECD trends, as equity financing became more important relative to bank credit during 1996-2000.

Policy initiatives to foster the development of venture capital have so far focused on capital market regulations. In 1989 pension funds were allowed to invest 5% of their assets under management in FIDES (Investment Funds for Enterprise Development). Mutual funds were allowed to invest 10% of their assets in FIDES in 2000. The 2002 capital market reform created a new stock market for emerging companies, eliminated taxes on capital gains for high turnover stocks and for short sales of bonds and stocks, reduced the tax on international financial transactions and strengthened minority shareholder rights. Recent initiatives to develop venture capital include the Capital Market Reform, MK II. First, tax incentives would be granted, including the introduction of a capped exemption from income tax on the capital gains on equity holdings of firms in which capital funds participate with at least 20% of the firm's capital and for a minimum of one and a half years. Second, a new type of limited liability corporation would be created, facilitating the participation of venture capitalists. Third, CORFO would be authorised to invest in venture capital funds through quotas (currently, CORFO can only lend to those funds). Finally, legal barriers to the management of small companies by venture capital fund managers would be lifted. To encourage demand for venture capital, government initiatives include CORFO's National Incubator Programme for private firms with obligatory participation of universities or technological institutes. Fundación Chile would also promote ventures among risk capital investors.

Source: OECD Economic Survey of Chile 2005.

The reasons for the country's poor private R&D and innovation performance are still debated among Chilean economists, businessmen and policy makers. However there is some degree of consensus in considering as plausible some combination of the following factors:[27]

- A lack of innovation culture in the society and a shortage of specialised human capital. The roots can be traced from the schooling system to the professional education of the labour force. This is compounded by the dominant "non-application-prone" mindset in academia and a business culture that has been shaped by longstanding practices in the natural resource-based industries and also reflects a deficit in training in the advanced management skills and business leadership required for incorporating innovation into firms' strategies. According to some views, the lack of a widespread innovation culture also translates into loose enforcement of intellectual property rights (IPR), which might deter would-be innovators and limit the expansion of a market for knowledge.
- Higher and quicker returns on alternative investments. Returns on activities that require lower than average innovative capabilities under current market conditions, notably the extraction of natural resources, remain very high and crowd out investment in knowledge. In addition many firms seem to consider that they still have significant room for productivity gains through the improvement of management and logistics before they have to engage in more costly and risky endeavours.
- Lack of maturity of the capital market. The financial sector has not yet learned how to cope with the uncertainty and manage the risk involved at different stages of innovation processes in different business environments. The risk and seed capital markets are shallow although they are particularly important for entrepreneurs at an early stage of the R&D process, who have no record of successful research, have limited access to external funds and face internal financing constraints (see Box 3.3).

27. The hypothesis that private R&D efforts could be to some, but probably a limited, extent underestimated by official statistics cannot be ruled out entirely, in particular because the tax system has in the past given firms no financial reason to record their R&D expenditures.

Table 3.4. A typology of Chilean firms' innovation capabilities and strategies

	Advanced technology-adapting firms	Commodity-producing firms	Technology-based firms	Traditional technology-adapting SMEs	Multinational producers of goods and services
Definition	• Large or smaller firms that master best practice production and marketing management techniques.	• Medium to large firms that master best practice production management techniques and logistics.	• Small highly innovative firms, often created by new graduates, or spin-offs from public research or spin-outs from large firms.	• A highly heterogeneous population with variable productivity performance they share a common feature, at best a very limited ability to innovate.	• A heterogeneous population of firms mastering world best practices in all fields.
Market dynamics and significance within Chilean economy	• Intense competition on domestic and international markets. • An important fraction of export-oriented firms (fruit, wines, salmon and wood products) and large services firms aimed at the local market.	• Competition on international markets. • The largest share of Chilean exports, mainly in the mining and forestry sectors.	• Intense competition to enter highly segmented markets • Electronics, software, and machinery and equipment. Still only a small group.	• Most Chilean companies belong to this category which cuts across all sectors.	• Only a few multinational firms are actively engaged, on a limited scale, in innovation in Chile.
Firms' dominant competitive strategy	• Segmentation of market via product improvements and the incorporation of new technologies.	• Reduction of production costs, quality control and sustainable management of renewable resources.	• Exploitation of fast-growing market niches through product and service differentiation based on novelty.	• Overcoming basic productivity gaps to survive on competitive markets.	• Access to markets and resources.

continued…

Table 3.4. A typology of Chilean firms' innovation capabilities and strategies *(continued)*

	Advanced technology-adapting firms	Commodity-producing firms	Technology-based firms	Traditional technology-adapting SMEs	Multinational producers of goods and services
Firms' dominant innovation strategy	• Soft innovation plus adoption and/or adaptation of foreign technology and know-how.	• Improvement of the production process and of the quality of renewable resources.	• R&D-based product innovation or knowledge-intensive services.	• Invest mainly in technology-embedded machinery and equipment.	• Expand markets for innovative products. • Access complementary knowledge assets. • Exploit IP through subsidiaries.
Obstacles to innovation and shortcomings of innovation processes	• Limited appropriability. • R&D necessary to face new problems requires scales and timeframes that may be out the reach of individual companies. • Obstacles to collective action in the field of R&D, marketing and international outsourcing.	• Limited appropriability • Limited own research capability. • Reluctance to work with and/or support non-established local suppliers. • Low private incentives for the generation of spin-outs.	• Limited size of domestic market. • "Invented here" syndrome for some products and services. • Lack of seed and venture capital. • Lack of entrepreneurial and managerial skills.	• Lack of managerial skills. • Limited basic skills of labour force. • Limited information on technological and market opportunities • Limited access to external funding.	• Lack of managerial skills. • Insufficient local supply of human resources skilled to their standards. • Lack of international visibility of Chilean pockets of scientific and technological excellence.
Current policy responses (selected observations)	• Good in some clusters, notably through Fundación Chile • Innovation in services needs more attention. • Some support programmes (*e.g.* consortia) need to be scaled up and more industry-led.	• Limited success in promoting vibrant clusters of diversified activities around the mining industry. • Relevant public technological organisations have had difficulty adjusting to changing firms' needs and strategies.	• Good awareness, relatively new support measures, limited achievements so far. • Fundación Chile pioneered efficient approaches. • Universities and public technological organisations have a poor record in terms of spin-offs.	• Disappointing achievements, and the challenge is huge. • Many support instruments do not reach the many firms unable to articulate their needs. • Cluster- and network-based approaches should be pursued more systematically.	• Invest Chile is a promising programme. • Need for a broader approach to enhancing Chile's attractiveness for "knowledge-carrying" FDI.

- Little inter-firm learning from national and international best practices. Probably no more than 3 000 companies in Chile are aware of the strategic relevance of innovation and, among them, few are committed to "hard" innovation based on R&D and a long-term vision. There is in fact a "negative demonstration effect", since many more firms succeed by capturing rents. Moreover, the absence of a significant number of technology-intensive subsidiaries of foreign companies means that they make a limited contribution to the generation of positive externalities such as learning about innovation management, acquisition of know-how, and technological spillovers to suppliers and clients.
- An unbalanced innovation policy mix is still biased towards curiosity-driven research to the detriment of more applied research with identifiable end users and towards support to the generation of knowledge to the detriment of its diffusion. There are also some other mismatches between public policies and the variety of firms' needs, especially given the low absorptive capacity of most SMEs (see Chapter 4).
- Taken together, these factors slow the emergence of a critical mass of new technology-based firms (NTBFs), *i.e.* companies whose "raison d'être" is innovation and have the potential to be socially visible new role models.

However, the relevance and relative weight of each of these factors varies depending on the characteristics of individual companies. Economic research in Chile has identified at least five types of companies according to their innovation style, their field of activity and structure of ownership. Table 3.4 summarises the main policy-relevant findings.

3.1.2. Innovation in resource-based industries

As discussed in preceding chapters, Chile's enviable economic performance over the last decade has resulted from sound macroeconomic management together with policies to foster structural adjustment in line with the country's comparative advantages, largely in resource-based industries. Innovation to increase value added in these industries is and should remain a major thrust of Chile's economic development strategy. This section looks at the role and forms of innovation in two of the most successful export-oriented Chilean industries, the salmon cluster and the wine cluster.

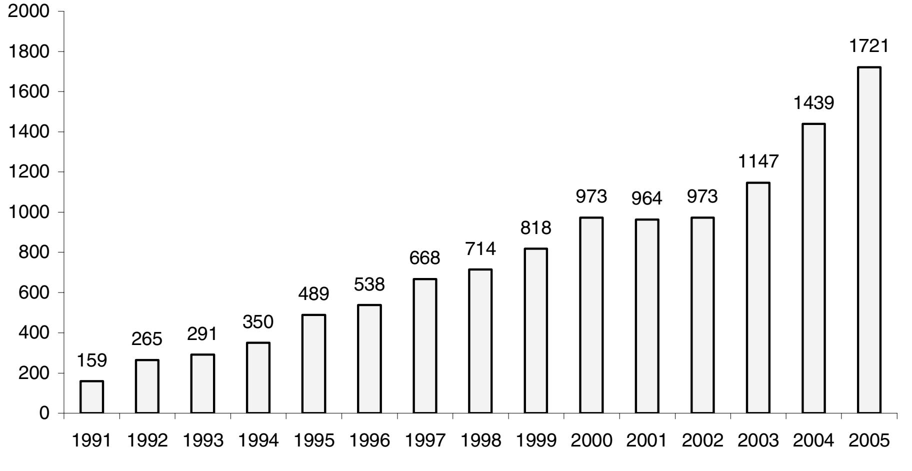
3.1.2.1. The salmon cluster

The development of salmon and trout culture in Chile may in itself be considered an innovative endeavour, since these are introduced species that require complex production techniques. An accelerated collective learning process over less than 15 years led to the creation of an industry that is currently the world's main producer of cultured salmon.

The development of salmon exports illustrates the significance of the salmon cluster for the national and regional economies (Los Lagos and Aysén del General Carlos Ibáñez del Campo regions) (Figure 3.4). Exports rose from barely over USD 150 million in 1991 to over USD 1.7 billion FOB in 2005, an increase of 20% compared to 2004. Salmon exports currently represent more than half of Chilean fisheries' exports and just over 4% of total Chilean exports.

Figure 3.4. Chilean salmon and trout exports

USD millions



Source: SalmonChile.

Box 3.4. High technology for resource-based industries in Chile: the example of biotechnology

The Chilean biotechnology industry includes some 123 organisations with a strong focus on improving the competitiveness of the export sectors.

In ***agriculture***, genomics and genetic engineering may help improve the quality of fruit exports to remote destinations. Molecular markers to genetically improve vegetal varieties are another biotechnology application being used. For example, a genomics consortium develops plant genomics projects to combat fungal rot, improve quality and delay ripening in varieties of grape and nectarine. It involves the National Commission for Science and Technology, the National Institute of Agricultural Research, the Chilean Exporters Association, Fundación Chile, the Fruit Development Foundation, and the Life Science Foundation, and five universities: Chile, Santiago, Catholic of Chile, Talca, and Federico Santa María Technical University.

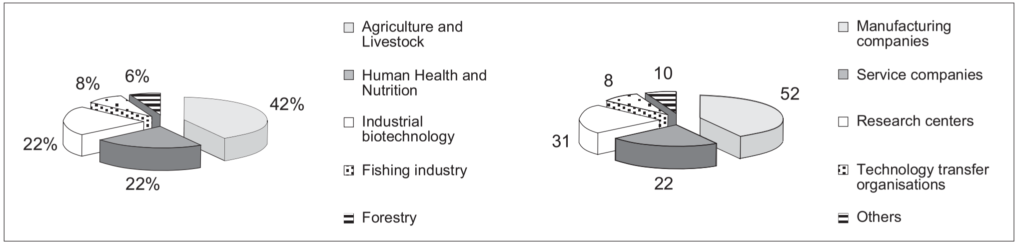
In the ***mining*** sector, bioleaching technology is developed to extract copper from ore. BioSigma, a biomining consortium, was created by Codelco (Chile's leading mining company) and Nippon Mining (Japan) to develop genetic engineering of lixiviating bacteria for biological extraction of low-grade reserves of copper.

In the ***forestry*** sector, biotechnology applications are used for pine and eucalyptus transgenic plantations. A silviculture consortium with CORFO, Fundación Chile, Instituto Forestal and Austral University of Chile in Valdivia develops cloning technology to improve the productivity of forest plantations (see figure below). A "Consorcio de Genómica Forestal para pino y eucaliptos" funded by CORFO was started in 2006 and involves the university of Concepcion, Fundación Chile, Centro Forestal de la Universidad Austral de Chile (CEFOR), and forestry companies such as Forestales de Arauco and Mininco.

In the ***fish farming*** sector, biotechnology applications include the production of vaccines for the salmon industry and other species. An aquaculture consortium, financed in part by CORFO, in collaboration with Fundación Chile and the company BiosChile developed vaccines against *Piscirikettsia salmonis*, a bacteria that caused annual losses of USD 150 million in Chile's farmed salmon industry, and diagnostic kits for fish farming.

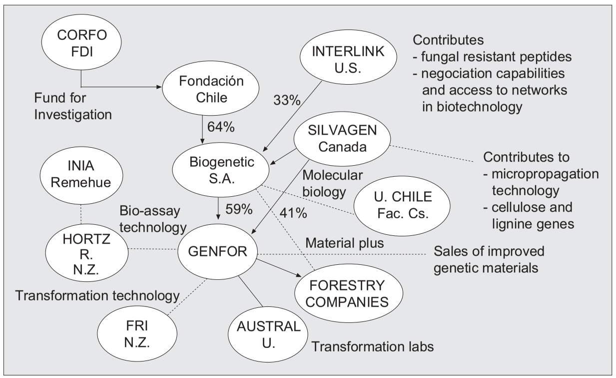
continued...

Sectors and types of organisation involved in biotechnology



Source: CORFO.

Consortium forestry genetic



Source: Fundación Chile.

Foreign biotech players with presence in the Chilean market include: Pioneer, Monsanto, Seminis, Genzyme, Rare Diseases Therapeutics, Davis University, University of Wisconsin, InterLink Associates, Silvagen Inc., Aqua Bounty Farms Inc., Ag-West Biotech, BioAtlantech, Agri-Food Technologies, AgrEvo Canada, Microtek International.

Currently the salmon cluster is composed of around 300 companies, 70% of which are in the Los Lagos region. The salmon industry employs directly and indirectly 45 000 people and trained 2 500 workers in 2003. These levels are expected to increase. According to the projections of SalmonChile, the industry expects to invest some USD 1.46 billion by 2010, much of it to be targeted at development of the sector in the Aysén del General Carlos Ibáñez del Campo region, with 19 000 new jobs projected. Projected growth to 2010 will bring the industry's exports to over USD 2 billion.

This spectacular growth has fostered the parallel development of a series of production activities linked to the direct or indirect requirements of the salmon culture industry. Thus, a cluster has taken shape around this activity, which has fostered economic activity and employment in the two regions concerned.

Collective learning in the salmon production system has involved: *i)* exploitation of the comparative advantages of the southern regions of Chile for the farming of this species (climate, geography and water quality), and *ii)* maximising these advantages through a permanent process of searching for and adapting external technologies, generating local technologies, sustained investment in human capital and infrastructure, and helping in the creation of supply companies for practically the whole production chain, most of them SMEs.

These firms cover areas such as the manufacturing of cages for fish farming, nets, floating houses and warehouses, feed for salmon, laboratories, vaccines and medicines (see Box 3.4), ground and air transport companies, underwater services, quality control, training centres, educational establishments, financial institutions, insurance companies, specialised consultancy and legal services.

Most of the larger companies, some of which are diversified food producers (Box 3.5), have vertically integrated the phases of fish farming, fattening and, to a lesser degree, processing. The other associated activities mainly depend on services or outsourcing. In line with international trends, the tendency in Chile in the salmon industry is towards a concentration of companies; at the beginning of the 1990s there were around 80, today there are 44. This concentration is apparent in the fact that in 2004 ten companies were responsible for 83% of total shipments.

Box 3.5. A Chilean innovation in business models for resource-based industries: Invertec Foods

The history of Invertec illustrates the type of entrepreneurship and innovation underpinning the success of the Chilean food industry. Invertec had its origin in 1937 when the Montanari group started to construct and operate industrial plants in various sectors.

A turning point came in 1987 with the creation of Invertec Ltda, when the Montanari family, having analysed Chile's potential and global consumption trends, decided to focus on food development. Four main companies were subsequently created: Invertec Pesquera Mar de Chiloe to exploit Chile's potential in aquaculture; Invertec food to develop dehydrated vegetables and fruits; Invertec Agricola Rengo to produce kiwis; and IGT, a consulting company, to provide management solutions to the food industry. In 1995 a salmon research centre was established, and in 1999 Smoltecnics was established to supply Invertec Pesquera Mar de Chiloe with salmon smelt. In 2000 Invertec acquired Ostimar to enter the production of scallops.

In 2005, Invertec became the first salmon company to be introduced on the Santiago stock market.

Source: www.invertecfoods.cl

R&D in the sector is carried out by individual firms with a view to generating competitive advantages. Estimates for 2004 indicate that approximately USD 12 million was spent on salmon culture R&D. However, the lack of R&D programmes and technology transfer in areas of common interest for the industry led CORFO to launch in 2005 the Integrated Territorial Programme targeted at strengthening the salmon cluster in southern Chile. This programme aims to co-ordinate and target research efforts of public and pre-competitive interest and to help increase the competitiveness of the industry through specific technological programmes.

3.1.2.2. The wine cluster

The Chilean wine export sector or, in its broadest sense, the Chilean quality wine industry, involves all of the economic, public and private agents that take part in the production, sale, consumption and export of fine wines, including suppliers of inputs and services.

Box 3.6. The Chilean wine revolution

The Chilean wine industry dates back a long time. However, until just over two decades ago, its production systems were outdated, which made expansion and export difficult. In 1978, Miguel Torres, Spain's main wine producer, invested in Chile. He brought modern wine-producing techniques to the Maule Region: cold fermentation, fruit flavours, new wines and complex aromas. Then, from the late 1980s to the early 1990s, the large Chilean vineyards began to incorporate the innovations introduced by Miguel Torres. The new trends helped vineyards that had been sidelined by the large national producers in the domestic market to emerge and begin to innovate and export directly. The private sector's leadership, supported by the government, was crucial in allowing the innovation process to take off. This example highlights how a virtuous circle can emerge, with foreign investment bringing innovation, which in turn can draw additional innovative foreign investment.

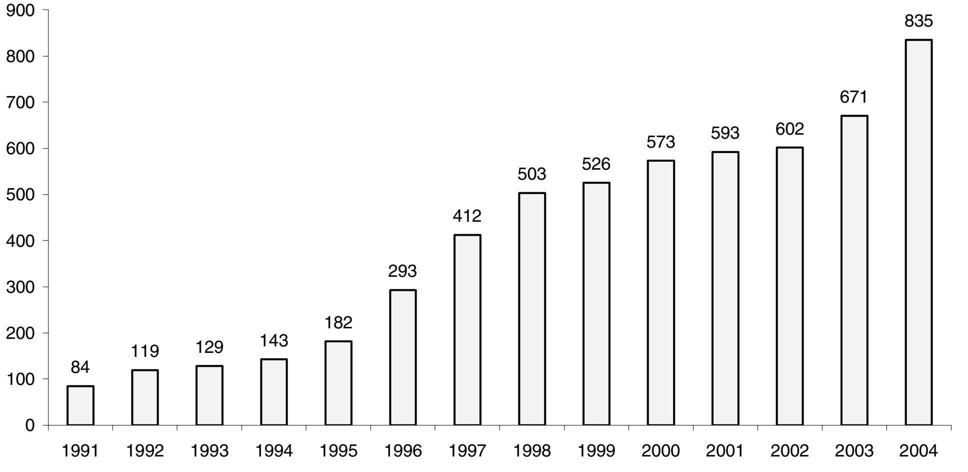
Following a pioneering foreign investment in the late 1970s (Box 3.6), the wine sector undertook a wide-ranging transformation at the end of the 1980s, changing from a traditional sector aimed at the domestic market and immersed in a deep crisis, towards a new dynamic technology-oriented sector mainly targeted at export markets. This profound structural change involved redirecting all aspects: production technologies, product development, distribution channels, packaging, new production companies and international alliances. The cultivated surface area doubled from 50 000 to over 100 000 hectares, with over half of production exported for a value of USD 835 million in 2004 (Figure 3.5).

Today, the national wine sector generates, all stages included, approximately 75 000 direct permanent jobs and 19 000 temporary jobs for 94 000 jobs at peak times of the year. In addition, the sector has significant production chains in aspects such as packaging, transport, and supply of equipment and inputs, among others, which are mainly concentrated at the local and regional levels. It is also linked to services such as tourism and gastronomy.

R&D initiatives in the wine sector have been varied but isolated and lacking in coherence. In general, there has been a lack of direction to ensure increased productivity and competitiveness for the industry as a whole. In fact, local technological innovation is scarce and essentially consists of importing and adapting knowledge from diverse sources. However, this mechanism has led to significant progress in wine industry technology and in the modernisation of equipment and installations, placing Chile on a par with other more developed producers and exporters of fine wine.

Figure 3.5. Chile's wine export industry

USD millions



Source: Viñas de Chile.

As for the salmon cluster, an Integrated Territorial Programme for the wine industry has been implemented in the Maule region in order to encourage the development of the region and improve its productivity. Moreover, two technological consortia were set up at the end of 2005, notably to promote technological development by means of a co-operative and multidisciplinary R&D endeavour that maximises the use of the available resource; carry out applied research in viticulture and oenology along research lines prioritised by the industry; collect and disseminate technical and economic information; and develop patentable technological products specific to the wine industry.

3.2. Public research and technological organisations[28]

In all countries public research and technological organisations make an important contribution to innovation, in addition to or in connection with the fulfilment of their missions of public interest in areas such as such as

28 "Public research organisation" is the conventional expression used by the OECD to designate all non-profit organisations involved in the innovation system, irrespective of the nature of their ownership. In Chile some technological organisations and universities are private.

security, health or impartial scientific expertise. They provide training for the skilled workforce necessary for innovation in the business sector. In the emerging "open model of innovation" public research institutions are vital sources of knowledge for firms, which increasingly tend to outsource the knowledge they need in order to complement and empower their core competencies. All countries also rely on technological organisations to facilitate technology diffusion and to help to ensure effective feedback from market-led innovation to basic research. In Chile higher education is the main actor in public research and a set of public and private technological institutes perform a variety of functions: thematic research, technological development and knowledge diffusion.

3.2.1. Universities

As mentioned above, the Chilean research system is heavily university-centred since higher education institutions alone account for almost 40% of total R&D expenditures, *i.e.* slightly more than the business sector. Chile has more than 60 universities, 25 of which are members of the Council of Rectors (CRUCH).[29] This group of 25 is very diverse in terms of size and research capacities. The two largest universities in Santiago (the University of Chile, the Pontifical Catholic University of Chile) account for the lion's share of university-performed R&D. Other significant players include the University of Santiago, the Pontifical Catholic University of Valparaíso, the Federico Santa María Technical University, the University of Playa Ancha, the Catholic University of the North, the Austral University of Chile and the University of Concepcion.

Competitive grants are the main source of university research funding and are largely channelled through four sources: FONDECYT, which provides project-based support, FONDAP, which supports group of researchers, the Millennium Scientific Initiative, which finances scientific institutes and nuclei of excellence in selected thematic areas, and FONDEF, which supports research collaboration with industry.

29. CRUCH was created in 1954 as a co-ordination body. One of its most important contributions has been the establishment of a selection and admissions system for participating universities, the Academic Aptitude Test, PAA (1967-2002) and the University Admission Exam, PSU (2003 to date). It has also made significant contributions to the creation of laws related to higher education, particularly regarding the accreditation of programmes of its member institutions, and the creation of student assistance instruments, such as the University Loan Solidarity Fund, for facilitating university access to students with scarce resources. It is currently composed of 25 universities, six of which are in the north of the country, five in the central zone, five in the southern zone, four in the Valparaiso Region and five in the Metropolitan Region.

Box 3.7. Major facilities for big science in Chile: the observatories

Chile possesses the natural conditions and the political will to attract major international scientific infrastructures. It has hosted major international astronomical observatories in the Atacama Desert for over 40 years. These include the Cerro Tololo Inter-American Observatory in La Serena, the European Southern Observatory (ESO) at La Silla, and the Carnegie Southern Observatory at Las Campañas. New optical telescopes have been built at Las Campañas (the Magellan telescope), at Cerro Pachon (the Gemini Southern Telescope, which has a Northern Hemisphere counterpart at Mauna Kea) and at Cerro Paranal (the ESO Very Large Telescope). The Millimetre Array (MMA), which extends high-resolution radio astronomy to millimetre wavelengths, is located at Llano de Chajnantor.

The Chilean government has facilitated construction by granting duty-free and tax-free status to the observatories. In general, the boards of the observatories have granted Chilean astronomers 10% of the viewing time in return for the use of the sites and in recognition of the contribution of the Chilean government. Chile itself has not contributed directly to construction costs.

Despite the limited number of its scientists, Chile has excellent research in several disciplines. Public initiatives such as the Millennium Scientific Initiative and FONDAP seem to have helped university research to focus more on critical mass and quality. A recent evaluation of the output of university research reveals favourable trends in publications and citations in the Institution for Scientific Information (ISI) (Chilean Academy of Sciences, 2005). Although Chile's contribution to world science is quantitatively modest, its quality, as measured by the "attraction index", is very high in some disciplines. It is clearly the case in astronomy (16.6), which is line with Chile's "comparative advantage" in big science (Box 3.7), and to a smaller extent in ecology and environment (2.9), reproductive medicine (2.8), physiology (2.1), Earth sciences (2.1), chemistry (1.2), physics (1.2) and pharmacology and toxicology (1.1).[30]

30. The Attraction Index (AI) is a way of representing quality of research. An AI of 1.0 means that the impact of publications originating in the country in a given discipline is similar to the world average in the same branch of knowledge, which is defined as the ratio of the number of citations in a certain discipline to domestic publications, divided by the number of citations in a certain discipline to the publications of the whole world.

Some more problematic features of the Chilean academic research landscape identified by Mullin *et al.* (1999) have been attenuated but not yet corrected, notably:

- Research infrastructures are weak.
- Extensive reliance on part-time instructors for teaching limits de facto the pool of teachers who can effectively engage in research activities.
- The relatively low level of salaries of full-time academics limits the pool of teachers who want to engage in research activities. They have little incentive to use non-teaching time for research at the expense of generating additional income through other activities.
- As a result, research-active academics constitute a minority of faculty members, even in the two major universities in Santiago, and a much smaller minority in others.
- Enrolment in postgraduate programmes is still insufficient, despite the improvement brought about by the MECESUP programme. Only 117 students graduated in 2003; this is almost six times more than ten years earlier, but still very low by international standards.

3.2.2. Technological institutes

Chile has a range of technological institutes (ITPs) which depend on various ministries or private non-profit organisation such as Fundación Chile. They are dedicated to applied research and technological development, technology transfer, the supply of technological services and the generation of information on national natural resources (Box 3.8). Most are located in the Santiago metropolitan area, but may have regional "subsidiaries", as in the case of INIA. They are complemented by smaller regional scientific and technological centres which have a narrower focus (Box 3.9). Compared to universities they represent a modest share of total budget outlays for R&D (Table 3.5).[31] Evaluating individual ITPs is beyond the scope of this report. Some general observations are based on limited evidence and the results of interviews by the OECD review team.

31. Statistics for budget outlays for R&D may actually overestimate the true amount of R&D as opposed to technological services, etc.

Box 3.8. Public and private non-profit technological institutes in Chile

Instituto de Investigaciones Agropecuarias (INIA) (Agricultural and Livestock Institute). INIA, created in 1964 and run by the Ministry of Agriculture, carries out research for and provides information, technological and training services to the agricultural sector.

Instituto Forestal (INFOR) (Forestry Institute). The mission of INFOR, created in 1965 and run by the Ministry of Agriculture, is to help public organisations, funding agencies, and private firms in the forestry industry by providing information and technology that help achieve efficient and sustainable use of forestry resources.

Centro de Investigaciones de Recursos Naturales (CIREN) (Natural Resources Research Institute). CIREN was created in 1985 to provide information on natural resources, including: climate; water, fruit, and forestry resources; land use; mining and geology; geomorphology; and rural assets.

Instituto Nacional de Normalización (INN) (National Institute for Standardisation). The INN, part of the Ministry of Economy, was created in 1973 to contribute to the productive development of the country by promoting the use of standardisation, accreditation and metrology to the benefit of firms in all sectors.

Instituto de Fomento Pesquero (IFOP) (Fisheries Promotion). Created in 1965 under the Sub-department of Fishing, the mission of IFOP is to provide technical information and the scientific basis for regulating fisheries and aquaculture, with a view to preserving hydro-biological resources and their ecosystems.

Comisión Chilena de Energía Nuclear (CCHEN) (Chilean Nuclear Energy Commission). Created in 1964 under the Ministry of Mining, the mission of CCHEN is to provide scientific expertise on issues concerning the production, acquisition, transfer, transport and peaceful use of nuclear energy, as well as radioactive and fertile fissionable materials. The CCHEN Research and Development Department carries out a variety of research projects on nuclear science and its applications.

Servicio Hidrográfico y Oceanográfico de la Armada de Chile (SHOA) (Hydrography and Oceanography Service of the Chilean Navy). Created in 1990 under the Chilean Navy, SHOA provides technical material, information and support for navigational safety on rivers, lakes, interior waters, territorial seas and on the high seas off the Chilean coastline.

Instituto Geográfico Militar (IGM) (Military Geographical Institute). The mission of IGM, created in 1992 under the Chilean Army, is to provide information and technical advice in all matters concerning the country's geography and mapmaking.

National Hydraulic Institute. Created in 1953 under the Ministry of Public Works it carries out studies on the security and efficiency of future hydraulic infrastructure projects.

Instituto Antártico Chileno (INACH) (Chilean Antarctic Institute). INACH, created in 1963 under the Ministry of Foreign Relations, plans and implements all scientific, technological, environmental and informational activities concerning Antarctica, co-ordinating these activities with the National Antarctic Programme.

Servicio Nacional de Geología y Minería (SERNAGEOMÍN) (National Geology and Mining Service). Created in 1980, this service's mission is to produce and provide information on mining and geology to satisfy the needs of government agencies, companies, public and private organisations, individuals and other entities interested in participating in geological and mining activities.

Fundación Chile. This private non-profit institution was created in 1976 by the Chilean government and ITT Corporation of the United States. Its mission is to introduce innovation and develop human capital in key clusters of the Chilean economy (see also Box 3.9).

Centro de Investigación Minera y Metalúrgica (CIMM) (Mining and Metallurgy Research Centre). CIMM was created in 1970 as a private non-profit foundation to carry out scientific and technological research in mining.

Source: Ministry of Economy.

Box 3.9. Regional scientific and technological centres in Chile

Name	Location	Partners	Focus
Centro de Investigaciones del Hombre en el Desiert (**CIHDE**) (Man in the Desert Research Centre) *o*	Tarapacá	CONICYT, Tarapacá Regional Government, Tarapacá University and Arturo Prat University	Biology and anthropology
Centro de Investigación Científico para la Minería (**CICITEM**) (Scientific Research for Mining Centre)	Antofagasta	CONICYT, Antofagasta Regional Government, Catholic University of the North and Antofagasta University	Mining
Centro De Estudios Avanzados en Zonas Aridas (**CEAZA**) (Centre for Advanced Research in Arid Zones)	Coquimbo	CONICYT, Coquimbo Regional Government, La Serena University, Catholic University of the North and INIA	Climate change, hydrology, biology
Centro de Investigación en Biotecnología Silvoagropecuaria (**CIBS**) (Centre for Forestry, Agriculture and Cattle Biotechnology Research)	O'Higgins and Maule	CONICYT, O'Higgins Regional Government, Maule Regional Government, Catholic University of Maule, Talca University and the Forestry and Agriculture Research Institute through its Rayentué and Raihuén stations	Forestry and agriculture biotechnology
Centro de Investigación de Polímeros Avanzados (**CIPA**) (Centre for Advanced Polymer Research)	Bío Bío	CONICYT, Bío Bío Regional Government, Concepción University and Bío Bío University	Polymer science
Centro de Genómica Nutricional Agroacuícola (**CGNA**) (Agro-aquaculture Nutritional Genomic Centre)	Araucanía	CONICYT, Araucanía Regional Government, Agricultural and Cattle Research Institute, INIA Carrillanca, Catholic University of Temuco and La Frontera University	Agro-aquaculture
Consorcio de Investigación en Nutrición, Tecnología de los Alimentos y Sustentabilidad del Proceso Alimentario en la Acuicultura (**CIEN AUSTRAL**) (Group for Research in Nutrition, Food Technology, and the Feeding Process in Aquaculture)	Los Lagos	CONICYT, Los Lagos Regional Government, Austral University and Santiago University	Sustainable animal production

Centro de Investigación en Ecosistemas de la Patagonia (**CIEP**) (Patagonia Ecosystems Research Centre)	Aysén	Aysén Regional Government, Austral University of Chile, Concepción University, INIA, Salmon Technological Institute, Ice Fields Institute, SHOA, Fishery Industry Trade Federation, Salmon Industry Association, Coyhaique Tourism Association, University of Montana in the United States and University of Siena, Italy	Ecosystems
Centro de Estudios del Cuaternario de Fuego-Patagonia y Antártica (**CEQUA**) (Centre for Quaternary Period Research in Tierra del Fuego, Patagonia, and Antarctica)	Magallanes	Magallanes and Chilean Antarctic Regional Government, Magallanes University, Chilean Antarctic Institute, and Institute of Fishing Development	Multidisciplinary scientific research on the evolution of the natural environment
Centro Regional de Investigación y Desarrollo Sustentable de Atacama (Regional centre of Investigation and Sustainable Development)	Atacama	Atacama Regional Government, University of Atacama, CORPROA company, ASOMICO company and ACUPRAT company	Mining, aquaculture, agriculture
Centro Regional de Estudios en Alimentos Saludables **(CREAS)** (Regional centre of Healthful Food Studies)	Valparaíso	CONICYT, Regional Government of Valparaiso, Catholic University of Valparaíso, University of Valparaíso, Universidad Técnica Federico Santa María and INIA	Agro-food technology
Centro de Ingeniería de la Innovación asociado al CECS de Valdivia (Centre of Engineering of the Innovation associated to the CECS of Valdivia)	Los Lagos	CONICYT, Los Lagos Regional Government Scientific Centre of Valdivia	Physics, biology and climate change
Centro Regional de Investigación de Energia y Aguas Arica y Parinacota **(CIDEA)** (Regional centre of Water and Energy Investigation of Arica and Parinacota)	Tarapacá	CONICYT, Regional Government of Tarapacá, University of Arturo Prat y University of Tarapacá	Engineering and aquiculture

Source: Regional Programme, CONICYT.

Table 3.5. Budget outlays for R&D allocated to technological institutes, 2002

Institute	Million CLP
Agriculture and Livestock Institute (INIA)	6 955
Forestry Institute (INFOR)	934
Natural Resource Research Institute (CIREN)	185
Fisheries Promotion Institute (IFOP)	401
Chilean Nuclear Energy Commission (CCHEN)	4 194
Hydrographic and Oceanographic Service (SHOA)	764
Military Geographical Institute (IGM)	824
National Hydraulic Institute	410
Chilean Antarctic Institute (INACH)	1 583
National Service for Geology and Mining (SERNAGOMIN)	254
Fundación Chile	2 153
Total budget outlays for R&D	175 696

Source: CONICYT.

ITPs have contributed to the technological development of the Chilean economy. They have undergone an important institutional and collective learning process and accumulated vast experience that should be used when devising the future of the national innovation system (NIS). Today, however, their performance is quite uneven. Many are generally seen as expensive, inefficient and quite detached from the sectors they serve. The research they carry out is not considered of top quality and is not always economically relevant. They are also perceived as being cut off from international trends.

ITPs must cope with different challenges depending on their mission. ITPs that have a quite stable and unique mission of public interest have mainly to keep pace with international best practices in their field (*e.g.* INN, IGM). Others have, to a variable degree, two main difficulties: *i)* handling simultaneously their dual role of public good and business service providers (*e.g.* INFOR, IFOP); and *ii)* adjusting to evolving business needs and capabilities. For example, CIMM has been vulnerable to changing Codelco strategy, and INIA, INFOR and IFOP have had difficulties relating to dynamic business development in forestry, aquaculture or fruit production. In addition ITPs' positioning on the market for technological services vis-à-vis private providers may be questioned.

Box 3.10. Fundación Chile: A Chilean international best practice

Fundación Chile is the largest private non-profit organisation for the promotion of innovation in Chile. Founded in 1976 by the Chilean government and the US ITT Corporation, its core mission is to transfer state-of-the-art technology, management techniques and human skills to natural-resource-intensive sectors in alliance with local and global knowledge networks.

Fundación Chile has developed an original and effective model for transferring technologies and developing innovative responses to economic opportunities. It creates new companies and joint ventures, carries out R&D, adapts foreign technology for product and process innovation for client companies in the public and private sectors, and fosters the creation of technological consortia and the diffusion of technology to SMEs.

Achievements include:

- Creation of pioneering salmon firms and provision of technological services that were fundamental for the take-off of the industry in Chile.
- Abalone and turbot farming.
- Development of the technological concept of vacuum-packed meat and other innovations.
- Quality control and certification of fruit for export.
- Introduction of new berry species and varieties in Chile.
- Associative development in the forestry industry, which led to the implementation of new forestry management models.
- High-quality wine production.
- Furniture for export.
- Lota tourist circuit.

In recent years, Fundación Chile has been increasingly active in the field of biotechnology (forestry genetics and DNA vaccines for aquaculture, among others), financial engineering and information (venture capital), and management. Its activities in the areas of skill upgrading focus on lifelong learning, distance education, the use of ICT in education and management education.

Source: www.fundacionchile.cl.

Fundación Chile is an exception which deserves special attention (Box 3.10), not only because of its outstanding performance and its original business model as a non-profit venture capitalist but also because it is an "agent of change" in the Chilean innovation system.[32] Now widely recognised as an international best practice, Fundación Chile has creatively filled institutional gaps in the innovation system and has shown a remarkable ability to adapt to the changes it has itself helped to promote.

3.3. Interaction among actors

The efficiency of a national innovation system depends much on its "knowledge distribution power", *i.e.* its capacity to stimulate and optimise the diffusion, sharing and creative use of ideas in any form – printed in a scientific publication, expressed orally in a conference, embodied in a piece of equipment, a software or a business practice, etc. Whereas intellectual property rights play a crucial dual role (ensuring that exchange of knowledge does not discourage its productive use, but also providing information about trends in such use), the main modes of interaction for "distribution power" are internationally open networking and clustering of firms and science-industry relationships. From this perspective, Chile's innovation system presents serious weaknesses. Various bottlenecks, disincentives and capacity failures impede knowledge flows between actors and institutions. This section points to some of them, based on the very limited information available to the OECD review team.

In Chile, the lack of sufficient interaction among actors in the innovation system is already noticeable among public actors. In particular, the technological institutes seem to have quite a low propensity to collaborate and work in broader national and international networks involving universities and firms than those of their "regular clients". This limits their efficiency as "technological antennae", especially in an era in which the scientific basis of innovation is increasingly multidisciplinary. There are also indications that the research-oriented institutes tend to compete, rather than collaborate, with universities.[33]

32. For example, INTEC (the ITP specialised in IT and environmental technologies) was absorbed by the *Fundación Chile* in 2003.

33. In 1999, J. Mullin *et al.* noted for example that in earth sciences, which are of great importance to Chile, there was little co-ordination between the public institutions involved in research and/or related technical activities (Ministry of Mines, SERNAGEOMIN, the Institute of Geophysics at the Universidad de Chile, INACH, CIMM and Codelco).

3.3.1. Firms' networking and clustering

With growing competition and globalisation and rapid advances in knowledge, new technologies and innovative concepts have a wider variety of sources, most of them outside the direct control of firms as these have become more specialised and focus on their core competencies. For complementary knowledge and know-how, firms increasingly rely on collaborative arrangements, in addition to market-mediated relations (*e.g.* purchase of equipment, licensing of technology). In advanced countries inter-firm collaboration within networks is now by far the most important channel for knowledge sharing and exchange.

Empirical studies have confirmed that collaborating firms are more innovative than non-collaborating ones, irrespective of their size (OECD, 2001a). But they have also shown that the propensity to engage in knowledge-based networks decreases with firm size (Box 3.11). This is both a reflection, and part of the explanation, of the limited innovativeness of many SMEs.

In Chile, the bulk of SMEs are not part of innovation-oriented networks simply because they do not innovate. But many of those that would have incentives to develop linkages with other firms and knowledge institutions experience difficulties in devising and implementing a networking strategy. These difficulties are notably due to:

- A lack of trust vis-à-vis potential partners. Although some countries are better endowed with "social capital" than others, trust, as an economic asset, is not entirely a socio-cultural feature that can only change over the very long term. It can be built more quickly through learning from success in balancing competition and co-operation. In Chile it would be important to find ways to diffuse the positive experience gained in sectors where some form of collective action has been successful.

- The relatively high input in terms of senior management resources required for initiating and sustaining participation in any co-operative venture. For Chile this suggests that public knowledge infrastructures should find a better balance between their role as providers of services to individual companies and their role as platforms for facilitating inter-firm co-operation.

Box 3.11. Inter-firm collaboration in innovation

The economics of networking

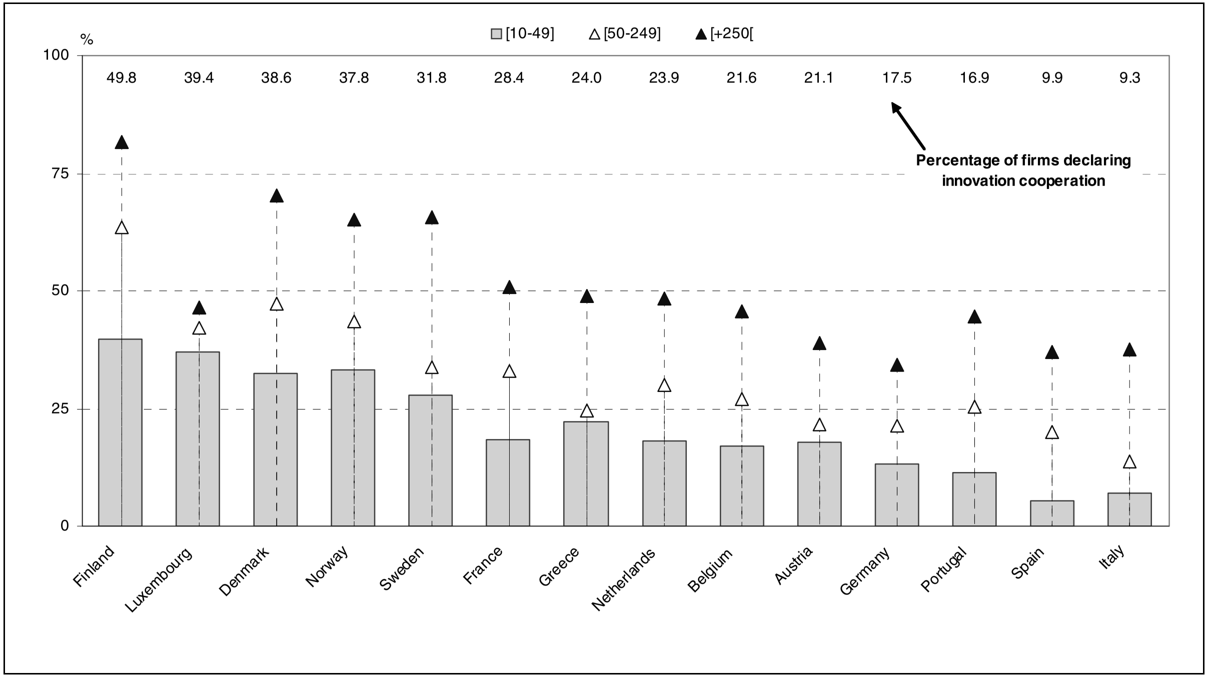
Markets, hierarchies and networks have long co-existed as complementary organisational forms of economic activity. However, their relative importance may change along with the dominant techno-economic paradigm, depending on certain of its characteristics: the degree of specificity of resources and knowledge required by interdependent activities, the level of transaction costs incurred in managing and co-ordinating such activities, and the nature of innovation processes.

Theoretical advances in the understanding of the micro and macro drivers of innovation-led growth explain why the rise of the comparative advantage of networks over markets and hierarchies seems to have increased in the last decade:

- *New growth theory* stresses the importance of increasing returns to investment in new technologies and human capital, based on an exponential increase in both the volume and diversity of codified and tacit knowledge.
- *Evolutionary and industrial economics* demonstrates that this accumulation process is non-linear (involving interaction among the different stages of research and innovation) and shaped by the interplay of market and non-market organisations and by various institutions (social norms, regulations, etc.).
- *Institutional economics* stresses the importance of organisational innovation within firms and government in the design and co-ordination of institutions and procedures involved in handling more complex interdependencies, as growth leads to the increasing specialisation of tasks and productive tools.
- The *sociology of innovation* stresses the role of "trust" in coping with uncertainty and in avoiding the escalation of transaction costs that results from increased specialisation and the role of non-monetary incentives and barter trade within innovation networks in boosting creativity.

Innovation and co-operation in small and large firms

Share of firms declaring innovative co-operation arrangements, by size class
1998-2000, %



Source: OECD; Eurostat (CIS3).

Barriers to technological entrepreneurship magnify the negative impact of other obstacles to networking, since new technology-based firms[34] perform a special function within and across innovation networks. In particular, and most importantly for Chile, they are bridging institutions that close the information gap between large knowledge organisations and firms in traditional industries. In addition to serving different markets, NTBFs complement large firms through their interaction with other actors in innovation systems. The small number of NTBFs in Chile is in this regard a key bottleneck in the innovation system.

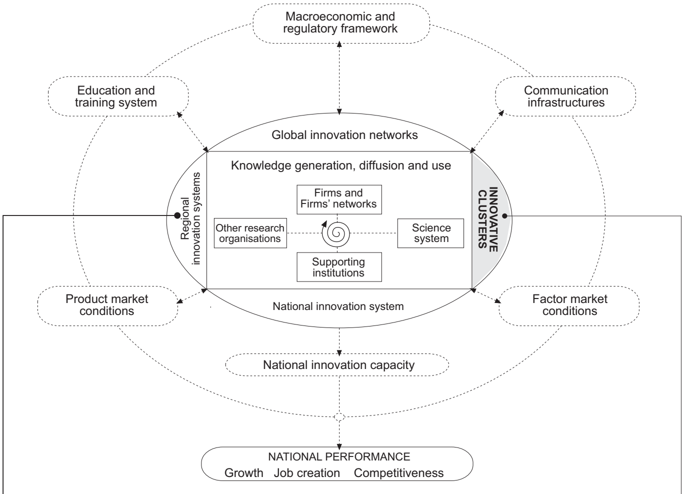
Table 3.5. Nationwide and regional clusters of competence in Denmark

	National	Regional
Existing	• Thermal technology • Technical appliances for the disabled • Pork • Dairy products • Water environment • Fur • Seed-growing • Power electronics • Hearing aids • Wind technology • Maritime industry	• Mobile/satellite communication in northern Jutland • Business tourism in the capital region • Stainless steel in eastern Jutland • Horticulture at Funen • Pharmaceuticals in the Oeresund region • Textiles/clothing in Herning-Ikast • Offshore industry in Esbjerg • Furniture in Salling • Transport in eastern-southern Jutland
Emerging	• Organic food • Children's play and learning • Waste management • Sensor technology • Bioinformatics	• Movies/broadcasting in the Copenhagen region • Oeresund Food Network • PR/Communication in the Copenhagen region • Pervasive computing in Copenhagen and Aarhus

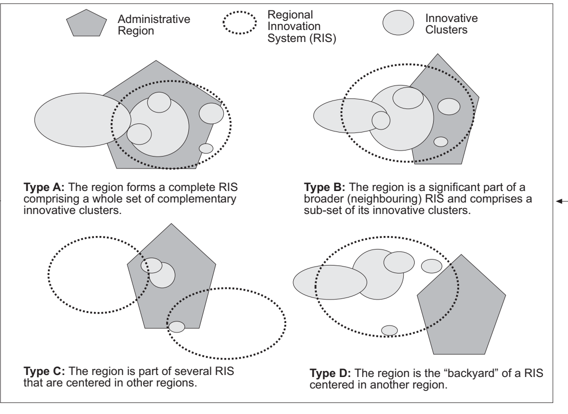
Source: Dalsgaard in OECD (2001b).

34. NTBFs can be spin-outs from large firms, spin-offs from public research or *ex nihilo* creations. In OECD countries, they account for between 1 and 3 per cent of all firms.

Box 3.12. Clusters in innovation systems



Regions, regional innovation systems and innovative clusters



A typology of innovative clusters

		Knowledge intensity		
		Low	Medium	High
Sectoral focus	High	Some industrial districts (e.g. shoes, textile) Product-specific agro-food cluster ○	Sub-contactors co-located around a large firm ○ Some industrial districts (e.g. machine tools)	Small bio-tech firms co-located around a major university or public lab
	Medium to low	Natural resource-based network of small firms (e.g. tourism) ○	A diversified set of interrelated activities serving a localised physical infrastructure (e.g. the port of Rotterdam)	A diversified set of interrelated activities drawing from a localised knowledge infrastructure (e.g. Silicon Valley)

○ Typical existing or potential Chilean clusters

The role of clusters in national innovation systems is now well established (Box 3.12). Innovative clusters can be defined as networks of interdependent firms, knowledge-producing institutions (universities, research institutes, technology-providing firms), bridging institutions (*e.g.* technology extension services) and customers, linked vertically or horizontally in a production chain which creates value added, all of which co-operate in developing and using sector-specific public goods, based on common physical and knowledge infrastructures. Innovative clusters can contain small or large numbers of enterprises, as well as small and large firms in different ratios. They can be more or less knowledge-intensive, involve a larger or smaller set of knowledge-producing and bridging institutions, and have a narrow or broad sectoral and technological focus, since they occur in traditional as well as in new industries (Table 3.5).

The geography of innovative clusters is generally complex, transcending the various geographic levels of economic regulation. As every collection of firms and industries linked in a value chain cannot be defined as an industrial cluster, and every cluster is not an innovative one, not every region functions as an innovation system, *e.g.* a set of complementary innovation clusters (Box 3.12). Geographically concentrated clusters generally serve world markets. Localised markets are often served by clusters that are tightly connected to global production and innovation networks. In most clusters one can identify international and national as well as regional elements.

Box 3.13. The international dimension of networking: examples of successful publicly sponsored co-operation in innovation

The CORFO-Sweden programme is an example of successful industrial co-operation. Its original aim was to foster strategic partnerships in the secondary wood industry. This led to the creation of several joint ventures and induced significant technological transfer, including the transfer of good practices in work organisation. This was followed by a similar programme in the field of environment. Today, there is a CORFO-Sweden Fund, through which the Swedish Co-operation Agency and CORFO contribute in equal parts to the promotion of technological transfer and joint technological initiatives.

In the high-growth and innovative wine sector an example of successful technological transfer has been the re-discovery of the carménère varietal in Chile thanks to a co-operative venture with France, funded by CORFO.

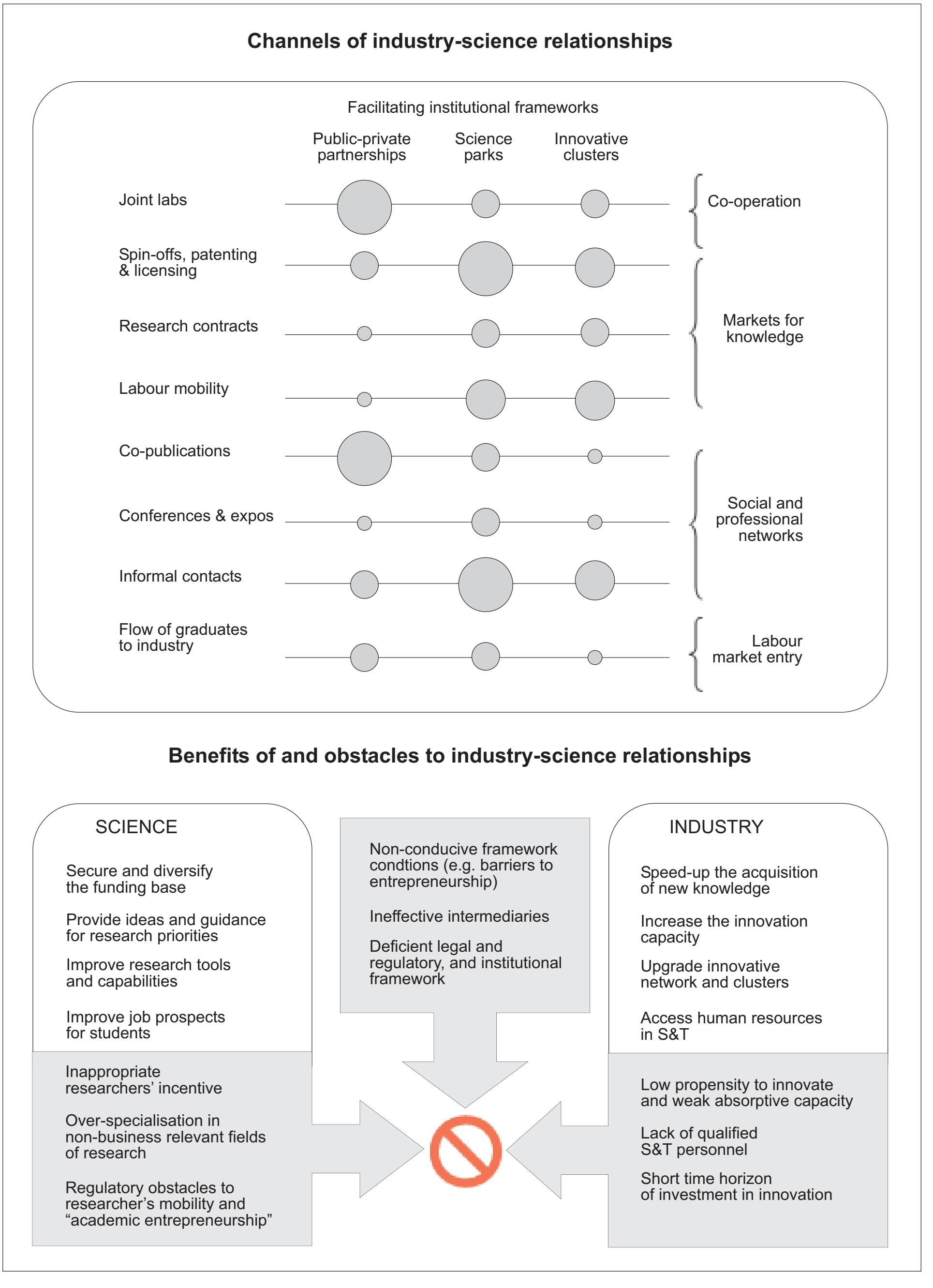
Box 3.14. Innovation in services

Chile has a large and growing services sector, and the development of financial services, logistics and tourism is particularly attractive. Innovation in the services sector is not intrinsically different from innovation in manufacturing in that both involve some combination of changes in technology, design, marketing, organisation, knowledge and skills. However, in the case of services there is much less emphasis on the development and acquisition of new technology and much more on the so-called "softer" aspects of innovation. The language in which innovation is described in services may also be somewhat different. Innovation in services may be just as difficult and risky as in manufacturing and offer a similar prospect of high but uncertain returns. Most but not all services sectors are low-technology sectors in the sense that they rely on technology acquired from other parts of the economy. However, some are extremely sophisticated in the way they absorb and exploit that technology (*e.g.* collection and delivery of small packages). In addition, many knowledge-intensive services, such as information technology companies, design houses and many aspects of health provision, are technologically highly sophisticated and on a par with R&D-intensive goods. The boundary between some business services and manufacturing is also changing and many manufacturing businesses now include a significant service element in what they deliver to customers (*e.g.* aero-engine companies now sell hours of operational flying time along with the engine). In addition, services such as design and software development, which manufacturing companies formerly supplied for themselves, are now outsourced. Thus innovation by a manufacturing company may often require complementary innovation by its service suppliers.

Innovation in services is widespread and very important for aggregate productivity and economic growth and it is therefore vital that the needs of the services sector are fully taken into account when innovation policy is designed and implemented. This means an approach to innovation policy which takes a broad view of the innovation process and does not focus narrowly on the creation and exploitation of new technology. Encouraging the diffusion of technology and of promising business practices must be seen as equally important as should the spread of appropriate non-technological knowledge and skills. It is only recently that policy makers in OECD countries have begun to see innovation in services in this way, and the process of broadening the innovation policy agenda has only just begun. Chile needs to play an active role in this exploratory process so that its innovation policy can draw on learning by other countries in order to address the specific needs of its services businesses.[35]

35. This section draws on studies commissioned by the UK Department of Trade and Industry in connection with a forthcoming economics working paper on innovation in services. See also the chapter on "Fostering Innovation in Services" in OECD (2005c).

Box 3.15. Industry-science relationships



For Chile, clustering is both an economic reality and a key policy concept since it is instrumental in achieving "clever targeting" of innovation policy. Some structured Chilean clusters have already emerged (*e.g.* the salmon and wine clusters) although, as pointed out in section 3.1.2, their functioning could be further improved. Others are underdeveloped, for example the mining industry could be the nexus of a broader set of diversified interrelated services and manufacturing activities. Many more are latent and should be rigorously mapped and subsequently organised, taking an approach to innovation which includes innovation in services (see Box 3.14). In this regard, a major obstacle to the development of a full-fledged cluster-based innovation policy in Chile is political centralisation, since the active and competent involvement of regional and municipal governments is crucial for the success of industry-led cluster initiatives.

3.3.2. Industry-science relationships

Industry-science relationships (ISRs) are at the heart of the most innovative networks and clusters, but they are more pervasive in the most advanced economies and take many forms: casual contacts between academic scientists and engineers, spin-offs from public research, licensing and patenting by universities, mobility of researchers, public-private partnerships for research, etc. (Box 3.15). They allow for two-way exchange between curiosity-driven research and market-led innovation to the benefit of both. They are therefore not simply channels of knowledge transfer; they stimulate creativity throughout the innovation system.

In Chile the creation of ISRs is impeded by the same factors as in other countries, such as a lack of demand by firms, an academic research culture which does not emphasise economic relevance, low mobility of researchers, and competition between public research and industry for public support. However, these problems are more acute in Chile than in most OECD countries for two main reasons:

- *Capability failures.* There is a shortage of the type of human resources necessary for vibrant ISRs. In particular, the engineering disciplines are not playing their bridging role between science and innovation early in the education system and later on the work place. On the supply side, neither the institutional culture of universities nor their curricula encourages engineers to complete their studies with a PhD or Master's degree in areas relevant for technological innovation. On the demand side, job prospects in industry for graduates in scientific disciplines is limited by the lack of awareness among company managers and owners of the importance of innovation for long-run productivity improvements.

- *Institutional failures.* The institutional frameworks commonly used to promote ISRs are underdeveloped. This is particularly the case for public-private partnerships; the government has only quite recently started to promote them through a pilot programme. Also, there does not seem to be a specific mechanism for stimulating and organising a dialogue between companies and educational institutions, both high schools and universities, regarding current and prospective needs of specialised human capital.

Chapter 4

THE ROLE OF GOVERNMENT

For a long time, Chile's innovation system was rudimentary, having developed through a series of *ad hoc* decisions in the absence of a strategic vision for the role of innovation in economic development and for the role of government in its promotion. It consisted mainly of a funding agency which supported mostly academic research and financed scholarships and a set of publicly owned or funded technological institutes that performed public missions and provided some technological services to the industrial and agricultural sectors. A turning point occurred in the early 1990s, following the reestablishment of democracy, when policies explicitly aimed at strengthening capabilities in the areas of science, technology and innovation in the various sectors of production were first introduced. Chile is currently going through a new, probably more fundamental, transition. A growing political awareness of the importance of innovation for the country's further catching-up has motivated three bold decisions: the creation of an Innovation Council for Competitiveness entrusted with the mission of proposing guidelines for a long-term national innovation strategy; the introduction of a specific mining tax to increase resources available to implement this strategy; and the introduction of an R&D tax incentive to motivate private-sector participation.

This chapter first briefly reviews the evolution of Chile's innovation policy and then describes and assesses the support of innovation by Chile's government and government agencies.

4.1. The evolution of Chile's innovation policy

4.1.1. The initial phase

Chile's initial efforts in research and development (R&D) date from the 1960s, when the first public technological institutes were founded; the university system was strengthened through the creation of regional campuses; and CONICYT, the National Commission for Science and Technology research, was created. The aim was capacity building in the public sector through direct public funding but there were no mechanisms to gear such allocation to the needs of businesses.

A true research and innovation policy, which sought to address identified market and system failures, emerged at the beginning of the 1990s, with the creation of matching funds that were available to universities, companies and other public and private organisations. The most important new initiative was the Science and Technology Programme (PCT) (1992-95), set up with Inter-American Development Bank (IDB) resources.[36] The programme's main objective was to foster technological innovation in Chilean companies and strengthen R&D.

Two new entities were created: the Fondo Nacional de Desarrollo Tecnológico (FONTEC, National Technological Development Fund), part of CORFO (the Corporación de Fomento de la Producción, Chilean Economic Development Agency), whose purpose was to promote technological innovation in private enterprises by co-financing innovation projects carried out by the companies; and the Fondo de Fomento al Desarrollo Científico y Tecnológico (FONDEF, Scientific and Technological Development Promotion Fund) established under the Comisión Nacional de Investigación Científica y Tecnológica (CONICYT, National Commission for Scientific and Technological Research), whose purpose was to strengthen R&D capabilities and to improve technological infrastructure by co-financing pre-competitive projects carried out by universities and technological institutes jointly with private companies.[37]

During that time, the funding model shifted from a direct type to a contestable one, based on competition among recipients without any discrimination between productive sectors or technology areas. The idea was to achieve an across-the-board increase in the number of companies participating in technology transfer, absorption and diffusion activities and to provide them with a supporting infrastructure (Teubal, 1998).

During this stage, which has been referred to as "a horizontal technology policy", the strategic objective was to create a critical mass of R&D and technological projects throughout the public and private sectors in order to initiate a collective, cumulative and multidisciplinary learning process.

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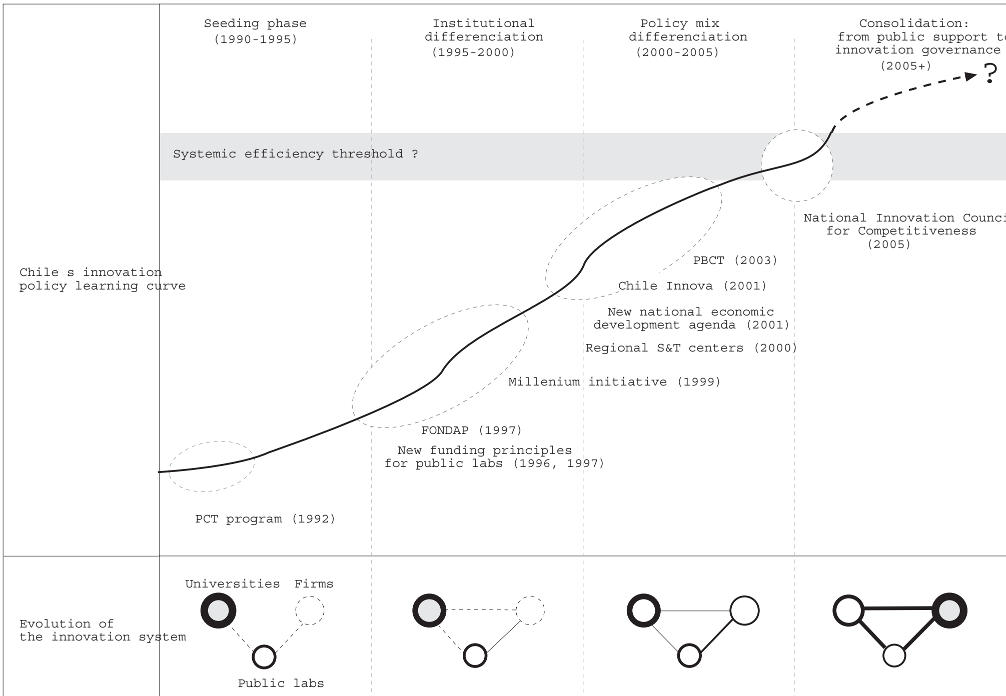
36. The IDB approved a loan to the Chilean government of USD 67 million, which represented 36% of the total cost of the programme.

37. In addition, additional backing was given to the Fondo Nacional de Desarrollo Científico y Tecnológico (FONDECYT, the National Fund for Scientific and Technological Development, under CONICYT) which was geared toward basic research. This fund, created at the beginning of the 1980s, was, until that time, the only source of public financing for scientific and technological activity in the country.

Figure 4.1. Chile's innovation policy: the learning trajectory



Trigger	First policy push	Growth of export-oriented industries		Second policy push
Type of learning	Assisted learning from foreign practices	Accelerated own learning from best practices in advanced countries plus elements of endogenous institutional learning		Endogenous national and institutional learning, including within the OECD community
Policy focus	Horizontal promotion of R&D projects through a pure bottom-up process	Engage firms; concentrate funding of scientific research on areas of excellence	Build stronger linkages between actors in targeted areas; improve specific framework conditions	Improve overall governance, streamline and prioritise
Funding instruments	Grants to individual projects; unconditional funding of public labs	Introduction of grants to research groups; new funding mechanisms for public labs	Development of consortia, emergence of a cluster-based approach	Introduction of a R&D tax incentive

The PCT ended in late 1995. It produced significant outcomes but also demonstrated several shortcomings. First, it failed to connect effectively activities carried out in the three main research spheres (universities, technological institutes and firms). Second, it had only a limited inducement power *vis-à-vis* the private sector; companies' innovation activities remained limited. Third, it failed to address the rapidly evolving needs of export industries which had to improve their competitiveness on increasingly dynamic and globalised markets, in order to derive more value added from the exploitation of Chile's natural resources.

Promoting what has been called a "second exporting stage" required policies to correct structural weaknesses in the industries concerned, notably the insufficient number of large, highly efficient world-class companies and the too large number of small and medium-sized enterprises (SMEs) that were not technologically oriented and unlikely to innovate.

4.1.2. First transition: institutional differentiation

During 1995-2000 various adjustments were made to R&D and innovation policy to improve its economic impact by increasing the participation of the private sector. Three goals were emphasised:

- To increase the involvement of private firms in research and innovation activities by: *i)* continuing to foster the emergence of a "critical mass" of innovative companies; and *ii)* articulating supply of and demand for innovation inputs by encouraging companies to become more active in co-operative activities, R&D contracts and purchase of technological services.
- To focus R&D on innovation, with three specific objectives: *i)* to encourage R&D projects that combine scientific excellence with economic relevance; *ii)* to promote pre-competitive R&D projects with a more immediate impact on productive sectors; *iii)* to support research with high spillovers, *i.e.* that would produce for economic players as well as for the public sector as a whole information that would be useful, reliable and up-to-date.
- To strengthen the national technology infrastructure by supporting the modernisation of public technological institutes, encouraging the creation of technological service companies, and promoting the formation of a network of public and private technological centres.

In line with the new objectives, the technological funds no longer took a purely horizontal approach. Competitive funding was organised by topic or sector in areas identified as particularly important for the country's development, such as underwater species, information and communication technologies (ICT), and biotechnology, among others.

One of the most important changes during this phase was the modification in 1996 of the criteria and mechanisms used to finance the public technological institutes run by CORFO. Such funding was made conditional on the achievement of specific goals ("performance contracts") and included a portion of self-financing. A new fund was created under CORFO, the Fondo Nacional de Interés Público (FONSIP, National Public Interest Fund), to implement these new principles. This fund later became the Fondo de Desarrollo e Innovación (FDI, Development and Innovation Fund) and was opened to other users, such as private technology institutes and companies, and later to universities. In 1997, two other technological institutes (INN and INFOR) ceased to receive core funding from the government and became mostly dependent on other sources of income, especially competitive funds and income from sale of services.[38]

The technology funds introduced new lines of financing aimed at improving the commercialisation of research results, including: the protection of industrial property, the development of business plans, product design, and marketing strategy in the case of FONDEF and the FDI's line of "entrepreneuriable" innovation projects.[39]

These efforts to increase the economic impact of public investment in R&D induced behavioural changes among beneficiaries, especially universities, which were encouraged to create or improve internal capabilities to manage research projects and to pay more attention to the economic value of research results, a dimension of academic research that had clearly been neglected.[40]

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38. They continued to receive some government funding through an instrument called a Performance Agreement.

39. This line of support was introduced to correct a "technological novelty and feasibility" bias in the criteria used to select projects, emphasising more the commercial prospects and the managerial and entrepreneurial skills required to bring new technology to the market.

40. One of the historical causes of the very low level of patenting in Chile (one a year for every million inhabitants) is the restrictions set by FONDECYT which, in addition to giving priority to the number and quality of scientific publications over patents, imposed an obligation to return the funds awarded to the project if any of the results were patented. This has left its mark on the university culture even to today.

Box 4.1. Sector-specific R&D and innovation funds

The Fundación para la Innovación Agraria (FIA, Agrarian Innovation Foundation), is a private foundation created by the Ministry of Agriculture. Its primary goal is to promote changes in the country's agriculture and rural economy. It stimulates the development of competitive advantages in the agricultural production system by modernising productive systems, developing and implementing new technologies and products, diversifying production, helping in the commercialisation of forestry and agriculture production on domestic and international markets, increasing product quality, and ensuring the sustainability of productive processes.

The mission of the Fondo de Investigación Minera (FIM, Mining Research Fund), created in 1996 under the Centro de Investigaciones Minero Metalúrgicas (CIMM, Mining Metallurgy Research Centre), is to finance scientific research on copper and its by-products. It is funded by both public and private mining companies.

The Fondo de Investigación Pesquera (FIP, Fishery Research Fund) was created in 1991 under the General Fishing and Aquaculture Law. Its purpose is to finance fishing and aquaculture research projects whose results will help in the management of fisheries and aquaculture businesses and the conservation of hydro-biological resources. It is funded from the national budget and from fishery and aquaculture licences.

Another important new development during this stage was the recognition of the regional dimension. Thus, in 2000, CONICYT launched a new financing mechanism, the Programa Regional de Desarrollo Científico y Tecnológico (the Regional Programme for Scientific and Technological Development) to create scientific and technological centres throughout the country in conjunction with regional governments, universities and private enterprise. Another aspect of the institutional differentiation which characterised this period was the consolidation and creation of sector-specific innovation funds and the launch of two programmes to concentrate scientific research efforts in areas in which Chile showed the greatest potential. Under CONICYT was created the Programas de Investigación Avanzada en Areas Prioritarias (FONDAP, Programmes for Advanced Research in Priority Areas), which gave birth to the Centros de Excelencia (Centres of Excellence). Surprisingly to foreign eyes, this programme was complemented by the Iniciativa Científica Milenio (Millennium Scientific Project), placed under the Ministry of Planning (MIDEPLAN), which had quite similar rationale and goals.

4.1.3. Second transition: rebalancing the policy mix through further institutional differentiation

In 2001, the new national economic development agenda, which aims to transform the country into a developed economy within ten years, identified the reinforcement of science, technology and innovation capabilities as one of six priorities and therefore stimulated to several new developments in innovation policy.

As a result, CORFO's FDI underwent a major transformation which, following a merger with FONTEC, gave rise to the Innova Chile programme which was established to provide support to private enterprise's efforts in a wide range of activities: *i)* pre-competitive and public interest innovation; *ii)* business innovation; *iii)* technology diffusion and transfer; and *iv)* entrepreneurship. In addition, Innova Chile set up interconnected departments with a sectoral focus on mining, biotechnology, food industry, tourism, infrastructure and energy, and ICTs, with a view to promoting a shared strategic vision among stakeholders, screen new opportunities for technological innovation and development, activate demand for new projects, and monitor the achievements of relevant programmes.

Another new initiative was the launch under CONYCIT of the Programa Bicentenario de Ciencia y Tecnología (PBCT, Bicentennial Science and Technology Programme) financed in part by a World Bank loan. The purpose of this programme is to assist in the transition to a knowledge-based economy and society by developing an effective innovation system. It has three components: *i)* improve Chile's science, technology and innovation system so that it has a major impact on the development of policies and creates an environment conducive to innovation in Chile; *ii)* strengthen the science base, including the research infrastructure and the ability to access new findings in other countries; and *iii)* promote relationships between the public and private sectors at the national and international levels.

In 2001, the Technological Innovation and Development Programme (PDIT or Chile Innova) (2001-06) was set up. Its mission was to help increase competitiveness and support innovation and technological development in strategic areas of the national economy, especially among SMEs that produce goods or services. The PDIT has contributed significantly to creating spaces for inter-institutional interaction and dialogue among the agents through which the programme has operated (CORFO, CONICYT, FIA, INN and Fundación Chile). In addition, it has helped to set priorities for S&T policies. The programme has also contributed to the modernisation of Chilean companies, especially SMEs (mainly through quality improvements, environmentally clean production and the introduction of information technologies).

A shift gradually took place in the overall policy mix and instrument toolkit to make government support more responsive to the requirements of activities and sectors of strategic importance. This involved some re-balancing between horizontal, non-discriminatory support, and more selective approaches to leverage comparative advantages through joint development of sector-specific technological capacities and the diffusion of enabling technologies such as biotechnology, ICTs, clean production and quality management. This also involved complementing financial support by measures to foster human resource development and innovation management.

As a result, a cluster-based approach to innovation policy began to take shape, following a path successfully pioneered by Fundación Chile. Policy makers realised that a bottom-up, project-based approach to the selection of priorities was at odds with the productive structure in which dynamic "clusters" had arisen, such as the aquaculture industry in general and salmon fish-farming in particular, and the wine and fruit industries, to name the most famous. The main ensuing challenge was two-fold: devise ways to facilitate collective action on the part of companies and provide customised support "packages" from several funds. Some of them, particularly FONDEF, FDI, and FIA, began to work together to finance technology consortium types of projects.

There was also greater recognition of the importance of some framework conditions for innovation other than macroeconomic stability and competition, especially specialised financial markets and intellectual property rights (IPR). Realising that conventional CORFO and CONYCIT funding could no longer be considered a satisfactory mechanism for boosting technology-based entrepreneurship, the government initiated new measures, inspired by international best practices, to address the shortage of seed and risk capital (see Box 3.2 in Chapter 3). Chile's Industrial Property Law was adapted in 2005 to meet the requirements of the Agreement on Trade-related Intellectual Property Rights (TRIPS agreement) and an Industrial Property Court was created.

4.1.4. Ongoing transition: moving from public support to innovation governance

In spite of the considerable progress made during the last decade there is a wide consensus among stakeholders that Chile's innovation system has not yet reached a satisfactory level of efficiency, although opinions vary regarding some aspects of the diagnosis. Another consensual idea is that the root of the problem is the absence of coherent overall governance of the innovation system, which creates a "silo effect" whereby multiple funds and instruments both overlap and leave certain needs unanswered, while at the same time many may not have in any case the size necessary to have a real impact. Creating a proper institutional framework to design an overall strategy and to co-ordinate, monitor and evaluate its implementation is now considered a priority objective.

4.2. Governance and policy mix

4.2.1. Governance

Chile has not so far had a formal mechanism for defining an explicit strategy, translating it into priorities and guiding its implementation. The priorities have been defined in a relatively decentralised manner by agencies such as CORFO in the Ministry of Economy, CONICYT in the Ministry of Education and FIA in the Ministry of Agriculture. Other ministries such as Health and Planning have played a comparatively minor role. Of course, some degree of co-ordination does exist at the programme level and to a lesser extent across agencies but this is not a good substitute for high-level steering of the system.[41] It may even have perverse effects since individual agencies have a natural tendency to appropriate what they perceive as the national policy agenda to serve their constituency at the expense of others.

For example, the Ministry of Economy has played an important role in the co-ordination of multifaceted governmental initiatives to promote innovation in the business sector by means of three programmes established under its auspices during the last 15 years: the PCT (the Science and Technology Programme) (1992-95), the PIT (the Technology Innovation Programme)[42] (1996-2000) and the PDIT (2001-06) (The Technological Innovation and Development Programme, known since 2003 as Innova Chile).[43] However, none of these programmes has been really successful in inducing more R&D-based innovation by firms, partly because CORFO's culture mirrors the dominant business culture and its responsiveness to its "clients", at least those able to articulate their needs, can lead to some conservatism. Another example is the PBCT[44] (2003-10) which has been launched under CONICYT with the very broad ambition to "guide the country in the process of transforming itself into a knowledge economy".

41. The cross-presence of directors in the governing boards of various funds and other communication channels helps co-ordinate the operations of the various institutions.

42. Science and Technology Program.

43. The co-ordination scope of these programmes was reduced since they accounted for a small share (10% in the case of PDIT) of the funds assigned to CORFO and CONICYT.

44. Programa de Ciencia para la Economía del Conocimiento. Also known as Programa Bicentenario de Ciencia y Tecnología.

However, CONICYT is not necessarily well placed to implement the part of this agenda that requires serious participation by business firms, including the consortium component.

Box 4.2. The Science and Technology Policy Council of Finland

The Science and Technology Policy Council of Finland (STPC) was established in 1987 as "successor" to the Science Policy Council (established in 1963). It functions as a high-level political body for the formulation of Finnish science and technology policy guidelines and it is the main inter-ministerial body for co-ordinating and integrating science and technology activities. Its main tasks are to advise the government and the ministries, to prepare proposals and reviews for the Council of State and the ministries, to issue statements on the allocation of public funds to science and technology and to act as an expert body for questions relating to science and technology. Though it only participates in drafting science, technology and innovation policy and legislation by formulating guidelines and national strategies, as it formally has only an advisory capacity, the Council is mainly responsible for the strategic development of Finnish science, technology and innovation policy.

The members of the STPC, which is chaired by the Prime Minister, are the Minister of Education and Science, the Minister of Trade and Industry, the Minister of Finance, and up to four other ministers. Further, the membership includes ten other members with a stake in science, technology and innovation policy, including representatives from the Academy of Finland, the National Technology Agency of Finland, universities and industry as well as employers' and employees' organisations. They are appointed by the Council of State for three years. This corporatist structure is based on the Finnish tradition of decision making and consensus building and ensures broad-based discussion among stakeholders and thus support for policies, which not least ensures their smooth implementation. The STPC functions as a forum for discussion in which policy makers and main stakeholders develop a common political understanding and vision of the Finnish education and science, technology and innovation system. The STPC has two subcommittees with preparatory tasks: the science policy subcommittee, chaired by the Minister of Education and Science, and the technology policy subcommittee, chaired by the Minister of Trade and Industry. In addition the Council's subcommittees draw on the knowledge and the advice of two experts each.

The Council's strategic guidelines and issue statements are published in a science and technology policy review every three years. These policy papers analyse past developments, draw conclusions and make proposals for the future. For example, in its review of 1990 the STPC promoted the concept of a national innovation system, being understood as a complete set of public and private factors influencing the development and utilisation of new knowledge and know-how. Following several OECD recommendations, the concept of knowledge-based society was launched in 1996. In its review "Knowledge, Innovation and Internationalisation 2002" the Council stresses the importance of the rapidly internationalising innovation framework and the pressures for structural and operational change in Finland. Thus, the need for increased government R&D expenditures was urged. Public funding should increase faster than the estimated growth in GDP, which would mean an increase of EUR 300 million from the 2002 level until 2007. The money is to be allocated to promising Finnish research areas such as life sciences, environmental technologies, ICT and health and to knowledge-intensive service sectors.

Source: Berghell and Kiander (2003); European Commission (2004); Lemola (2002); SATW (2004); Seppälä (2002).

Devolving policy functions to funding agencies is not a good idea. Many OECD countries have struggled or are still struggling with the consequences of this confusion of roles. It is wise to rigorously separate policy from delivery. It is somewhat surprising that in Chile, where a strong economic culture is pervasive among public servants in charge of macroeconomic policy, thinking about innovation policy seems so far to have had little theoretical underpinning, such as agency theory, public choice theory and new public management concepts.

In this context, some recent decisions of the Chilean government are particularly opportune and in line with best international practices (see Box 4.2 for an example). At the end of 2005 a draft law was sent to Congress that creates two new components in the Chilean NIS: the Consejo Nacional de Innovación para la Competitividad (the National Innovation Council for Competitiveness) and the National Innovation Fund for Competitiveness. Pending Congress's approval, a temporary Innovation Council for Competitiveness was created by decree at the end of 2005.

The interim Council was given the mission to propose guidelines for a 12-year national innovation strategy for competitiveness; measures to strengthen the Chilean innovation system and the effectiveness of public policies or instruments; and some allocation criteria for resources in the 2006 budget that had not yet been allocated to specific expenses, notably the income from the mining tax (see Box 4.3). This mission was renewed in April 2006 by the new government.

Box 4.3. The mining tax

The law that establishes a specific tax on mining activities came in force on 1 January 2006. This tax is levied on mining companies whose sales are equal to or greater than the equivalent value of 12 000 metric tons of fine copper (MFT) in accordance with the following schedule.

Bracket of annual sales in MFT	Rate (%)
12 000 to 15 000	0.50
15 000 to 20 000	1
20 000 to 25 000	1.5
25 000 to 30 000	2
30 000 to 35 000	2.5
35 000 to 40 000	3
40 000 to 50 000	4.5
Over 50 000	5

MFT is determined according to London Metal Exchange Grade A copper cash quotation, which is published, in domestic currency, within the first 30 days of every year by the Chilean Copper Commission.

When officially established, the Council will be an advisory body to the President of the Republic for all aspects related to innovation policies, including science, the formation of specialised human resources and the development, transfer and diffusion of technology. It will also provide a forum for facilitating dialogue among key players.

The Council could be the catalyst of an accelerated maturation of Chile's innovation system (Figure 4.1), provided that it is properly composed, institutionally positioned and equipped. OECD countries' experience in this field suggests that:

- Its composition, in terms of the number and institutional affiliation of members, should balance representativity and efficacy, in order to avoid capture by vested interests and ensure productive deliberations. It should comprise representative of all "communities" (government, industry, financial sector, academia and technological institutes), but at least one-third of the members should not have any responsibility for the management of innovation policy. Among "independent" members at least one should be foreign or at least a Chilean expatriate with a proven record in science, technology or innovation.
- Its institutional positioning should maximise its policy impact and guarantees its reputation as an impartial body that acts in the public interest.
- Its mandate and mode of operation should safeguard against the "talking shop" syndrome and encourage evidence-based approaches to policy assessment and advice.
- It should be backed by an executive secretariat with sufficient resources, steered by a reduced-scale executive board with the skills and financial means to carry out or commission independent studies and evaluation and implement a permanent monitoring system.

Its role in evaluation should be two-fold: to set quality standards and a framework for the evaluation of individual institutions, programmes and measures and to carry out thematic evaluations from a systemic perspective. Regarding the latter, the following tasks stand out as particularly important:

- Assessing the role of technological institutes in the innovation system and their steering mechanisms. These have evolved over time, at different paces and according to variable motivations and guiding principles. It would be timely for the government to get a clearer overview of the current situation in order to decide whether reforms would be warranted to increase these institutes' contribution to national innovation performance.

- Assessing the combined efficiency of existing programmes and measures, including key framework conditions (*e.g.* IPR), to promote commercialisation of university research through mobility of researchers, patenting and licensing, research contracts and spin-offs.
- Assessing the supply of and demand for the specialised human resources needed for innovation, with a special focus on the role of engineering sciences, with a view in particular to determining a good model of more fruitful public-private co-operation in this area.
- Assessing the scope for a fully fledged cluster approach to innovation policies by: evaluating the current portfolio of programmes in order to promote consortia and firm networking; mapping existing and latent innovative clusters; extracting lessons from successful experience in Chile and abroad (Box 4.4); and determining how further decentralisation of innovation policy could be achieved.
- Assessing international linkages (from foreign direct investment to scholarships) to determine ways of intensifying those likely to make the greatest contribution to the whole innovation system.

A very important new tool for implementing a more coherent policy is the Innovation for Competitiveness Fund (FIC). In 2006 it received a very substantial CLP 43 432 million, which represents almost one-quarter of the total budget outlays for R&D four years earlier. Its budget for 2007 was increased to CLP 52 760 million (Table 4.1). This makes it possible to translate policy priorities into sizeable incremental changes in the allocation of funds among existing structures. More importantly, this fund has the potential to be an "agent of structural change" that could induce deeper, dynamic structural adjustments in the system, helping to provide the public support system a more strategic focus. To that purpose, one option might be for the FIC to absorb all public funds targeted at innovation. Another, which would preserve some degree of institutional differentiation, while taking advantage of experience accumulated by existing funding agencies in dealing with some stakeholders, would be to structure and manage FIC following the venture capital industry's model of a "Fund of Funds", with of course the adaptations required to comply with public finance regulations and to fulfil its public interest mission.

Box 4.4. Cluster-based innovation policy: some lessons from OECD countries' experience

Governments can nurture the development of innovative clusters primarily through regional and local policies and programmes to stimulate knowledge exchange, reduce information failures and strengthen co-operation among firms and between firms and knowledge institutions. More direct policy tools can be used at the national level to encourage cluster formation and development, such as public-private partnerships for R&D, public procurement and competition for government funding to provide incentives for firm networks to organise themselves on a regional basis. OECD work suggests that efficient cluster policies:

- Build a shared vision, based on a sound diagnosis of initial conditions, and ensure a vibrant dialogue between industry and government in defining and implementing the cluster development strategy.
- Catalyse rather than plan local development by bringing actors together and supplying enabling infrastructures and incentives.
- "Back and empower local leaders" instead of trying to "pick winners".
- Improve availability and access to key resources (skilled people, R&D, physical and "intangible" infrastructure, smart money).
- Avoid "high-technology" or "manufacturing" myopia by recognising the importance of knowledge-intensive services and of the technological upgrading of traditional industries for an innovation-led growth.
- Build on existing innovation networks, but keep incentive schemes open and attractive to outsiders, especially new firms.
- Customise policy approaches to fit the specific needs of different industry and technological fields. Depending on a cluster's characteristics, government plays a variable role in addressing the following problems: lack of interaction; information imperfections; mismatch between knowledge infrastructure and business needs; lack of demanding customers (see table below).
- Leverage regional resources through interregional co-operation and participation in national and international innovation initiatives.
- Allow experimentation and learning by doing in an area with a good deal of scope for improved international diffusion of good practices.

Box 4.4. Cluster-based innovation policy: some lessons from OECD countries' experience *(continued)*

A "customised" cluster policy in the Netherlands

Role of government / Projects[1]	Antheus	Twinning	ITS	Life sciences	Water cluster	Mass individualisation	EMVT	Construction	PDI	ECP.nl
Chairman	White	Grey	White	Grey	Dark grey	White	White	White	White	White
Catalyst/initiator	Dark grey	Dark grey	Grey	Grey	Dark grey	Dark grey	Grey	Grey	Grey	Grey
Process manager	Dark grey	Dark grey	Dark grey	Dark grey	Dark grey	Dark grey	Dark grey	Dark grey	Dark grey	Dark grey
Broker	Dark grey	Dark grey	Dark grey	Dark grey	Grey	Dark grey	Grey	Dark grey	Dark grey	Grey
Connecting networks	Dark grey	Dark grey	Dark grey	Dark grey	Grey	Grey	Grey	Grey	Grey	Grey
Finance	Grey	Dark grey	Pale grey	Grey	Pale grey	Pale grey	Grey	Pale grey	Pale grey	Pale grey

Note: White = no role; grey = role.

1. Antheus is a regional cluster project at the micro level, aimed at increasing co-operation between a large aluminium plant and the smaller (aluminium-using) firms surrounding it. ITS stands for Intelligent Transport Systems. EMVT is the Dutch abbreviation for Electro Magnetic Power Technology. PDI stands for Product Data Interchange, a project mainly aimed at supporting this technology in the chemicals cluster.

Source: Gilsing in OECD (2001b).

Table 4.1. FIC 2007 budget

Budget line	CLP millions	Percentage of total
Public interest innovation	8 390	16%
Formation of human capital	8 961	17%
Fostering science and technology	19 168	36%
Business innovation	10 085	19%
Internationalisation of innovation	2 571	5%
Raising awareness of innovation	2 699	5%
Other	885	2%
Total	52 759	100%

Source: Consejo Nacional de Innovación para la Competitividad.

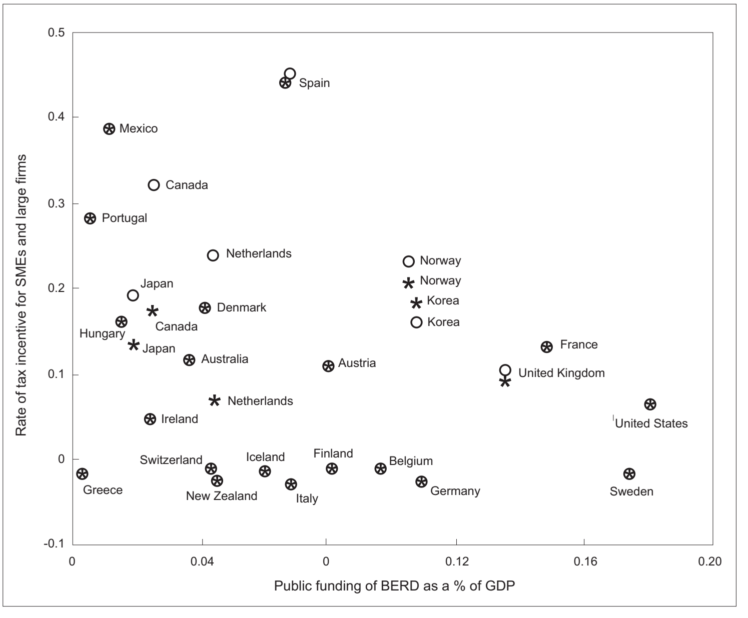
4.2.2. Policy mix

Chile's innovation policy mix shows quite strong disequilibria. These reflect structural features, notably the dominant role of universities in the performance of R&D, discussed in preceding chapters, but also policy choices regarding priority objectives and preferred instruments. Regarding the latter, two problematic features should be highlighted.

First, the emphasis has been on R&D rather than on knowledge diffusion and technology-based entrepreneurship, even if Innova Chile has recently been more active in these areas. Second, project-based schemes, as opposed to programme-based support, represent the lion's share of overall public expenditure for R&D. Third, compared to most OECD countries (Box 4.5) Chile's mix of instruments to promote business R&D in the business sector has been tilted towards direct government support. Currently R&D spending is deductible against corporate income tax liabilities, as is one-half of donations to universities. The bulk of public support takes the form of competitive grants through a multiplicity of funds (see section 4.3).

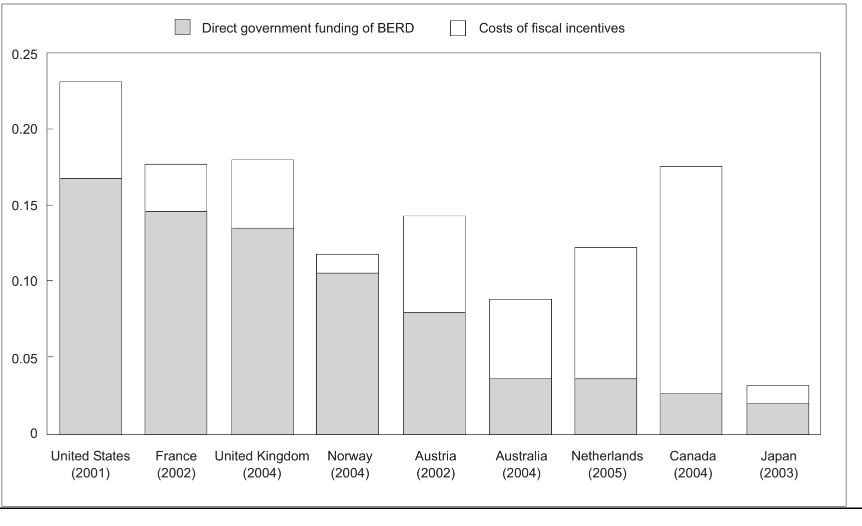
Box 4.5. OECD countries' policy mix to promote innovation in the business sector

Public financial support to firms' R&D, by instrument, 2004 or latest



Direct government funding of business R&D and tax incentives for R&D

As a % of GDP



Box 4.6. The new Chilean R&D tax incentive

The incentive consists of a corporate tax credit equal to 35% of the payments made to a "research centre" contracted to conduct R&D. The remaining 65% of the payment can be deducted as a cost for tax purposes. There is an upper limit to the size of the credit of 15% of the company's annual revenue. The incentive will be established for a period of ten years.

To obtain the tax benefit, CORFO, the Government's Development and Innovation Agency, has to certify the R&D contract. The certification will consist of a simplified process whereby CORFO only checks that the tasks in the contract are in fact R&D, as defined in the law, and that the research centre has the capability and resources to conduct the required activities.

Research centres may be part of a university, they may be part of a firm or they may also be private non-university stand-alone research centres. To conduct R&D subject to the tax benefit, the research centres must obtain an initial authorisation from CORFO. The tax benefit cannot be obtained by firms that contract with research centres that belong to them or to related parties. This restriction is established for two reasons: first, to avoid tax evasion, and second, to target the benefit to activities for which knowledge spillovers and externalities will be maximised.

The law requires biannual evaluations and a more complete one at the eighth year. These evaluations will provide information about the benefits and problems of the tax incentive so that it can be corrected, if necessary, and it will allow the government decide whether it should continue once the ten-year deadline has been reached.

This is about to change since, following a lengthy debate, the government has introduced a tax incentive for private R&D.

This decision, in its principle, conforms to practices in a majority of OECD countries. It sends a strong signal about government commitment to research and innovation to the business community since it implies overcoming the *Hacienda's* (Treasury) well-known reluctance to complicate further the overall tax system. The design of the proposed tax incentive (Box 4.6) is quite unusual by OECD country standard (Tables 4.2 and 4.3) and seems to reflect: *i)* a compromise between the "believers in tax credits" and the "sceptics" since the proposed scheme excludes own R&D and thus limits the possible extent of deadweight losses; *ii)* a willingness to promote interaction within the innovation system since the scheme supports R&D contracts; and *iii)* the immaturity of the business R&D culture since the scheme, in particular the certification procedure, is less straightforward than those applied in various OECD countries.

Table 4.2. Tax support to R&D – a decision tree

Policy choice		Practices (see Table 4.3)	Evaluation
Whether or not to use tax incentives for promoting R&D		Over two-thirds of total OECD business R&D expenditures benefit from tax incentives. Among the largest R&D performers, only Germany does not offer such incentives.	Tax incentives are cost-effective for increasing private R&D, but their inducement power is moderate and contingent on the level of corporate income tax. Their superiority over alternative uses of government resources is clear only with regard to non-selective subsidies. At an aggregate level the effectiveness of tax incentives tends to increase (decrease) with the decrease (increase) in R&D subsidies. For an R&D fiscal measure to induce substantial and worthwhile R&D at low cost to taxpayers, there must be high spillovers from the modest amount of induced R&D to generate net benefits. This is unlikely to be the case in countries where R&D activities are more concentrated in large firms operating in sectors where appropriability problems are less severe (*e.g.* oligopolistic industries).
If yes, choose between or combine	Volume-based scheme	Ten countries.	The most generous form of tax incentives. Appropriate as part of a catching-up strategy in terms of R&D intensity. But an effective inducement is achieved at high cost. The generosity of the scheme can be reduced as countries catch up. The generosity of support can be limited for large firms and eligible expenditure defined in a restrictive way (Netherlands). A switch to an incremental mechanism always needs to be given careful consideration.
	Incremental and mixed schemes	Ten countries.	More cost effective than volume-based schemes for increasing R&D. However, the effective rate of support varies considerably across industries and firms and the choice of the reference base for calculating eligible incremental R&D raises difficult problems. An incentive proportionate to the intensification of R&D efforts (as a % of turnover) is more cost-effective than one proportionate to the increase in R&D expenditure, unless the target is to favour fast-growing young SMEs.
Target or grant favourable treatment to certain types of research, sector or firm		Nine countries give preferential treatment to SMEs. Only a few offer specific tax incentives for basic research, "priority technology areas" or co-operative research.	Preferential treatment of SMEs might be justified on the grounds that small firms are more affected than large ones by liquidity constraints stemming from capital market failures. However, it is difficult to design a scheme which will meet the various needs of all types of SMEs, as demonstrated by a relatively low participation rate in some countries. The quality of the financial and infrastructural environment of SMEs varies greatly. R&D tax incentives can be seen as a transitory remedy which may become less effective as the business environment improves. Ceiling on benefits of general schemes can make them more generous to smaller firms. Superior targeted grant-based policy tools exist to provide capital to start-ups as well as to promote specific technologies or basic research.

Table 4.3. R&D tax incentives in OECD countries, 2005

	Large firms		Special treatment for SMEs	
	Tax credit	**Tax allowance**	**Tax credit**	**Tax allowance**
Volume	Canada (20%) Japan (8-10%) Mexico (20%) Netherlands (14%) **Norway** (18%)	Belgium (113.5%) Czech Republic (200%) Denmark (150%) **Poland** (130%)[1] **United Kingdom** (125%)	Canada (25%) Italy (30%) Japan (15%) Netherlands (42%) **Norway (20%)**	Belgium (118%) **Poland** (150%)* **United Kingdom** (150%)
Combination (volume/incremental)	France (5%-45%) Korea (7%-40%) Portugal (20%-50%) Spain (30%-50%)[1]	Australia (125%-175%) Austria (125%-135%) Hungary (100%-300%)	Korea (15%-50%)	
Incremental	Ireland (20%) United States (20%)			
None	Finland Iceland Switzerland Turkey	Germany Luxembourg Slovak Republic	Greece New Zealand (under consideration) Sweden	

Country in bold indicates incentive introduced after 2000.
1. Only for enterprises that obtain at least 50% of their income from the sale of their R&D results.

It should be noted that the introduction of an R&D tax incentive is part of a broader effort to make the tax system more innovation-friendly. Chile has recently reduced the tax rate on some goods and services that increase the knowledge base. Income generated in Chile by foreign residents is subject to the "additional tax" (a withholding tax). Although the general "additional tax" rate is 35%, there are other tax rates for some specific activities. For instance, software imports were subject to an "additional tax" rate of 30% if the product was standardised and 20% if it was custom-made. Since 1 January 2007, in order to promote the diffusion and adoption of new technologies, the additional tax rate charged for knowledge-related services was reduced to a uniform 15%. Table 4.4 shows the previous and the new tax rates for the types of activities considered very important for the country's development since they involve technology transfer from abroad that directly benefits Chilean companies' productivity and competitiveness.

Table 4.4. Tax treatment of knowledge-related services

Category	Former tax rate	New tax rate
Patents	30%	15%
Utility models	30%	15%
Industrial designs	30%	15%
Integrated circuit designs	30%	15%
Vegetable varieties	30%	15%
Standardised software	30%	15%
Technical consulting	20%	15%
Engineering work	20%	15%
Custom-made software	20%	15%

4.3. Portfolio of instruments

4.3.1. Funding agencies, funds and programmes

As already mentioned, innovation policy in Chile is implemented through a number of generally small funds and programmes managed by a few essentially independent agencies, mainly CONYCIT, under the Ministry of Education, and CORFO, under the Ministry of Economy. Access to all funds and programmes is through public tenders. Projects are selected according to criteria which are specific to each fund/programme. When applicable, eligibility requires private-sector partnership. The main funds and programmes are listed in Table 4.5. Box 4.7 briefly describes other related policies.

Table 4.5. Main funds and programmes to support R&D and innovation in Chile[1]

	Created	Ministry	Mission
Funds			
Innova Chile	2005	Economy	Contribute to increase the competitiveness of the Chilean economy by promoting and facilitating innovation in firms, promoting entrepreneurship, and strengthening the national system of innovation.
FONDECYT	1981	Education	Support basic scientific and technological research in all areas of knowledge.
FONDEF	1991	Education	Encourage universities and technological institutes to co-operate with industry in R&D projects.
FIA	1981 (reactivated in 1994)	Agriculture	Promote science and innovation processes relevant for the agricultural sector.
FIP	1991	Economy and Energy	Support scientific research and technical work relevant to the management of fishing resources.
INNOVA Bío-Bío	2002	Economy and Interior	Promote innovation and transfer of technology in the Bío-Bío region.
Science and technology programmes			
Technological Development and Innovation Programme	2001	Economy (with Education and Agriculture)	Increase competitiveness of SMEs by supporting innovation in ICT, biotechnology and new technologies. It aims to articulate and co-ordinate the various public innovation support mechanisms used by different institutions (CORFO, CONICYT, FIA, INN and Fundación Chile). It ended in 2005.
FONDAP	1997	Education	Support groups of researchers in centres of excellence with a view to achieving critical mass in some areas (seven ongoing centres)
Millennium Scientific Initiative	1999	Planning	Support scientific institutes and nuclei of excellence in various disciplines and areas (there are currently three institutes and 12 nuclei). Objectives very similar to FONDAP.
Science for the Knowledge Economy (PBCT)	2003	Education	Encourage interaction between public and private innovators and develop human capital directed at science and technology (supported by the World Bank).
Explora	1995	Education	Disseminate scientific and technological developments among children and youth.
Scholarships (CONICYT, President of the Republic,[2] and MECESUP)	..	Education and Planning[2]	Promote the development of Master's and PhD programmes. Foster specialisations abroad for Master's, PhD and specialisation studies for civil servants, academics and recent graduates of universities or professional institutes.

1. The newly created National Innovation Fund for Competitiveness (FIC) is not included, since its institutional positioning and precise mandate is not yet clear.

2. It is likely that the President of the Republic scholarships will be soon transferred to the Ministry of Education (CONICYT).

Box 4.7. Other innovation-related policies

Clean production policy

Clean production is a production and environmental strategy which has the double objective of increasing the competitiveness of companies and preventing emissions that can harm people's health and the environment. In 1997 the government announced a Clean Production Promotion Policy. A year later, the Ministry of Economy established a committee, composed of over 40 representatives from the public, private, academic and non-government sectors, which took part in the creation of the Clean Production Policy 2001-05. Chile thus took the lead in institutionalising clean production in Latin America. This policy is implemented within the framework of the Clean Production Programme of Chile Innova (PDIT) which promotes institutional strengthening, application of clean technologies within firms, and diffusion of good practices.

Biotechnology policy

Chile faces the challenge of advancing from traditional technology to modern uses of biotechnology: genetic engineering, bio-information technology and molecular biology, including with a view to creating new opportunities for production diversification and adding value in resource-based, export-oriented, industries.

The National Commission for Biotechnology Development was set up in June 2002. For ten months, over 200 players – public authorities, members of parliament, scientists and private-sector representatives – worked on defining the measures to be implemented to allow biotechnology to take off as a tool for production and social development. In addition, the ethical implications of transgenics and cloning were discussed, and the need to establish regulations was agreed. The Commission's report presented a complete diagnosis and a policy proposal which included a range of concrete initiatives.

On that basis, the government advanced a National Policy for Biotechnology Development. Its objective is to foster the development and application of biotechnology in Chile, especially in production sectors based on natural resources, with the goal of increasing the well-being and quality of life of citizens, contributing to the creation of wealth in the country, and ensuring the protection of health and environmental sustainability. During the two first years (2004-05) the focus was on structuring a sectoral innovation system tightly linking companies with universities to give the country leadership in certain niches of biotechnology in the medium term.

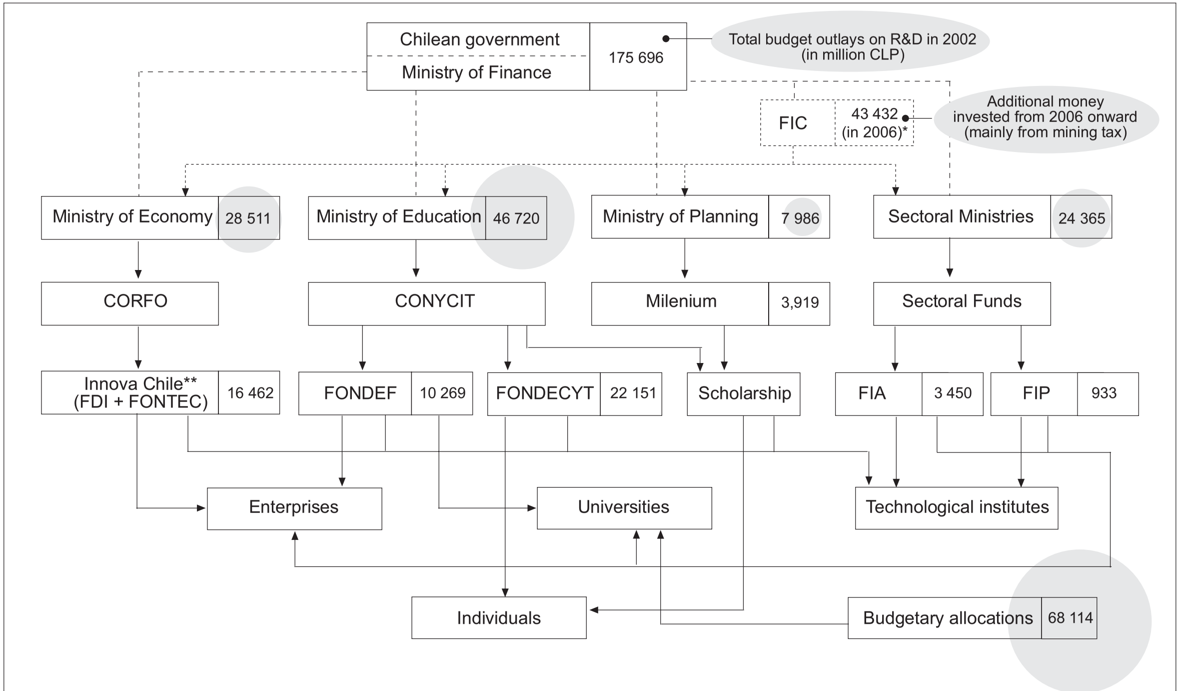
Digital Agenda (2004-06)

As a bicentennial objective, the government has stated its ambition to make Chile the Latin American leader in the use of ICTs for driving development. The connectivity figures for Chile were in this regard promising: at the end of 2003, 500 000 homes and 100 000 companies were connected to the Internet, as were almost the whole educational system and all of government, from La Moneda down to the municipalities.

At the beginning of 2003, representatives from the government, private and academic sectors formed the Digital Action Group to design proposals to reduce the poverty gap and promote the efficient use of ICTs in SMEs (Digital Action Group, 2004).

Today, Chile leads in digital development in Latin America. According to Harvard University's Networked Readiness Index (NRI), it rose at the global level from position 35 in 2005 to position 29 in 2006.

Figure 4.2. The institutional profile of Chile's innovation policy making



* FIC 2007 budget is 52 760. ** FDI and FONTEC were merged into *Innova Chile* in 2005.

Source: OECD, based on Ministry of Economy and CONICYT.

4.3.2. Agency co-ordination failures

Agency co-ordination, especially between CONICYT and CORFO, is a longstanding problem which has so far not received a satisfactory solution. It poses major challenges given that:

- Many funds and programmes are insufficiently differentiated in their objectives, rationale and desired types of outcomes. In fact, the tendency has been for each major agency to develop its own responses to all problems, resulting in a poor division of labour in the public support system.
- This existing division of labour is almost entirely based on the type of beneficiaries and does not reflect policy objectives and rationale.
- The form of incentives, rate of subsidisation and eligibility criteria are determined separately by each fund and their differences are often not justified on economic grounds.
- The internal capabilities, management style and culture are specific to each agency/fund.

Co-ordination through cross-cutting programmes, most notably the Technological Development and Innovation Programme, has largely failed. In fact, it has been limited to such functional aspects as systemising exchange of information on activities and projects, joint promotion of programmes, and sharing of information on results. Such an approach cannot by itself address all aspects of the problem.

Direct inter-agency co-ordination has also produced disappointing results:

- Top-down co-ordination through cross-participation in agency boards has not proven very effective.
- There are no established mechanisms for co-operation in designing programmes and mutual learning of best practices in their management; co-ordination remains spontaneous, voluntary and lacking in accountability.
- Funding mechanisms do not play their role in co-ordination since they are allocated through separate "pipelines".

Such shortcomings in inter-agency co-ordination are partly the result of the lack of a clear overall national innovation policy strategy, but they have also aggravated the consequences by creating various disequilibria in the policy instrument mix.

4.3.3. Fragmented, unbalanced and unfocused instrument mix

4.3.3.1. Lack of critical mass, duplication and blind spots

Public spending for R&D and innovation in Chile is important in relative terms, when compared to the level of private efforts, but limited in absolute terms. The multiplication of instruments unavoidably spreads resources too thin in every area of support, but particularly in the promotion of business innovation since a large fraction of public money for R&D is earmarked for basic research.

This fragmentation has been also encouraged by too hasty learning from good practices in advanced countries which encouraged the introduction of many measures in an institutional and policy context not entirely prepared to cope with the ensuing accelerated institutional differentiation. The period 1997-2005 was particularly "fertile" in new initiatives by the two main funding agencies (see Figure 4.1). The need to achieve critical mass in government support has consequently been neglected. This explains why many measures, evaluated positively in terms of individual projects' cost-benefit ratio, have had no significant impact on the competitiveness of firms, sectors or territories.

The problem has been compounded by duplication of effort owing to an uncertain division of labour among funding agencies. There are many cases of duplication, or at least unnecessary overlaps, such as the pre-competitive projects promoted in FONDEF (CONICYT) and FDI (now absorbed by CORFO's Innova Chile), or the promotion of centres of excellence in scientific research by the Millennium Initiative and FONDAP, to cite just two examples.

At the same time some of the most basic needs of numerous economic actors have largely not been met, as their satisfaction would have required actions which are: *i)* more difficult to articulate because they require inter-agency co-ordination, such as cluster-based policies; and/or *ii)* are less visible politically and less in demand by the usual clientele of funding agencies, such as measures to help the "silent majority" of SMEs to take the first step towards innovation; and/or *iii)* are less easy to handle by existing public agencies given their skills and "corporate culture".

Overall, one of the main problematic features of the current mix of instruments is that it offers uneven support to the different phases of innovation projects in different types of firms. The public system remains focused on the research stage of innovation in well-prepared companies. The early stage of capacity building in "could-be" innovative firms, and the obstacles encountered by "would-be" innovative firms in stages such as concept-to-prototype, industrialisation, and commercialisation are not sufficiently addressed.

4.3.3.2. Deficient articulation with sector-specific demand

Chile has a legacy of horizontal innovation policy approaches (see section 4.1.1 above), which was appropriate at a certain juncture in the development of its innovation system but may have been unduly prolonged under the influence of neo-classical economic thinking (the dissuasive "picking the winners" argument), and because of the limited ability of the current governance structure to devise and manage programmes with multiple objectives and stakeholders and involving different levels of government.

The question for Chile is not whether innovation policy should target some clusters of activities or firms' network, but rather how it can formulate and implement "clever selectivity" in practice. This does not of course preclude horizontal policies to capitalise on serendipity, to help firms from all sectors build on externalities from dynamic cluster developments and to upgrade innovation capabilities throughout the economy.

The connection between the innovation support system and the competitive development of productive sectors has been too weak for too long, even if institutions like Fundación Chile demonstrated quite early the feasibility of a cluster-based approach to the promotion of innovation, and even if public policy has been tilting in this direction in recent years: CORFO, CONICYT, the Ministry of Economy's efforts to identify strategic areas and the Programas Territoriales Integrados (Integrated Territorial Programmes). Such efforts are, and will remain for some time, constrained by the fact that regions are not well-equipped to play the role they should in the definition and implementation of relevant policies.

4.3.4. Evaluation and institutional learning

An evaluation culture is not lacking in Chile, but evaluation frameworks are underdeveloped and questions arise regarding the approach that should be taken to systemic evaluation.

Table 4.6. Evaluation of innovation policy instruments in the last decade

1997	Science and technology programme	Functioning of support funds
1998	CONICYT FDI FIA	FIP FONDECYT Scholarships of MIDEPLAN
1999	FDI	System of technological funds
2000	Millennium Initiatives	Technological Institutes
2001	Millennium	
2002	Explora of CONICYT	
2003	Millennium	Technological Innovation and Development Programme (mid-term evaluation)
2004	FDI FIP	High-technology Investment Programme of CORFO Institutes and nuclei of Millennium
2005	Chile Innova, sub-programme TIC FONTEC	Innova Bio Bio

Over the last ten years, a number of *ad hoc* evaluations have been carried out by national and foreign entities (Table 4.6). They analysed either the operation and effectiveness of public financing tools or the national innovation system as a whole. In general, they concluded that public funding has functioned properly in terms of quality of management, transparency and strictness of follow-up, and that it has yielded tangible benefits for the beneficiaries and for society as a whole. They also generally noted that public support to R&D and innovation has helped bring the research community and the productive sector into closer association, and more generally has increased awareness in Chile of the importance of science and technology. Some of these evaluations clearly pointed to the need for institutional reform in order to strengthen the government's ability to formulate and enforce a coherent national policy that would stimulate and guide science, technology, and innovation efforts more effectively towards the areas of greatest public interest.

Until now there has been no official permanent organisation in charge of monitoring and evaluating Chile's innovation policy, which is able to provide an overview of the system and assess progress towards increasing its overall consistency. Today, however, there is a consensus that such an evaluation body should be attached to the newly established National Council for Innovation for Competitiveness. The main question now is:

What approach should this future body take? The main observation to be made is that the evaluation of an innovation system still under construction, such as that of Chile, should not be carried out using simple international benchmarking methodologies since, from an evolutionary perspective, evolving institutional capabilities are a vitally important parameter. The level of such capabilities, in both the public and private spheres, determines at each point in time what can be expected from public policy and what cannot and, consequently, how to direct the search for international best practices. Dynamic learning processes increase these capabilities. The drivers of such processes should receive great attention (OECD, 2002).

4.3.4.1. Government agencies' capabilities

Chile is fortunate to have competent, dedicated and honest public servants. This social capital is a considerable asset which allows confidence about the responsibilities that can be entrusted to government bodies and the degree of sophistication with which these bodies can fulfil their tasks. There is only a small number of human resources with high-level technical expertise, experience and leadership but they are very mobile within the bureaucratic and political systems and they therefore act as efficient "learning vectors". Given this, while the capabilities of Chile's public organisations in charge of innovation policies lag behind those of many of their peers in OECD countries, they have in many respects reached a level of quality that others may envy.

Taking funding agencies as an example, one can highlight the following positive outcomes of successful learning:

- Good mastery of the basics of a transparent grant allocation process (project application, evaluation, selection, monitoring, follow-up and closure).
- A good record in achieving planned objectives and in fulfilling budget commitments.
- Relatively low administration costs.
- Increasing ability to reach deeper into the innovation system, notably to increase the participation of SMEs.

There are also limitations. In particular, evaluation of the financial aspects of projects remains problematic owing to a lack of skills. The procedures for processing and selecting applications are still slow and heavy. Responsiveness to feedback from beneficiaries is low. A bureaucratic culture, not only regulations, prevents outsourcing even when own competencies are limited.

4.3.4.2. Capacity building in the innovation system

Capacity building, as facilitated by public support, is heterogeneous. Its pace and content varies depending on players, economic sectors and regions (see Box 4.8 for an example). These discrepancies reduce the efficiency of the innovation system. It is therefore important for government to identify "capability gaps", to see what progress has been made towards eliminating them and what the contribution of public policy has been. Table 4.7 presents a few examples of the potential value of monitoring learning processes in different institutions.

Box 4.8. Successful publicly supported firm-level capacity building: the case of CINTAC

CINTAC S.A. is a company that manufactures steel profiles, tubes and pipes. It was founded in 1956 and has enjoyed a leadership position in Chile. It is a medium-sized company (392 employees) with subsidiaries in Argentina and Peru.

Overwhelmed by growing competition from PVC pipes and aluminium profiles, the company developed an innovative construction solution using steel. It hired an external expert and applied for help from FONTEC. The success of the project led the company to establish a new department, the Innovation Management Office, under the expert hired. CINTAC has subsequently continued to innovate. In 2001, 20% of its sales were products with the company's own technology and brand, and these sales have grown at a rate of nearly 50% since they went on the market in 1998.

CINTAC's Innovation Management Office consists of only one person, as products are developed by subcontracting different experts for each project. CINTAC has not returned to FONTEC for backing, since innovation is now an integral part of its business strategy.

Source: Rivas (2004).

Table 4.7. Progress and shortcomings in capacity building in different institutions

Institution	Progress	Shortcomings	Impact of public policies
Universities	Consolidation of traditional areas of strength in scientific research. Initial accumulation of new capabilities in promising research areas, such as biotechnology.	Low competencies and weak infrastructure for delivering technology-based services. Low capability for managing innovation (from formulating projects to commercialising results). Insufficient business-relevant engineering skills.	Project-based support does not encourage universities to take a strategic approach to relationships with industry and thus does not help the development of relevant capabilities. The centre of excellence approach has had a good effect on basic research capabilities.
Firms	Greater awareness of and experience in searching for external sources of knowledge and technology. Small-scale, still generally patchy inclusion of innovative processes and products into business processes. Some progress in collective action, *e.g.* sector-wide strategic vision and technology road mapping.	The number of truly innovation-oriented companies is still very low. Lack of human resources with appropriate skills limits firms' absorptive capacity. Managerial capabilities are generally insufficient to sustain active in-house innovation.	Given the average competency profile of Chilean companies some crowding out of private effort (subsidy redundancy) is likely for companies the participate recurrently in support schemes. Despite some success stories (Box 4.7), the capacity building power of the overall support system has been insufficient.
Technological Institutes (ITPs)	Growing heterogeneity of demonstrated capabilities. Improvement and broadening of capacities in some areas (*e.g.* mission-oriented R&D) and institutes (*e.g.* Fundación Chile).	Investment in building exclusive capabilities has been often insufficient. Ageing human resources. Low ability to develop and diffuse sector-specific strategic technologies.	Steering and funding modes have encouraged many ITPs to adopt short-sighted strategies regarding the provision of technological services while, at the same time, overlapping with universities in R&D activities.

continued…

Table 4.7. Progress and shortcomings in capacity building in different institutions *(continued)*

Institution	Progress	Shortcomings	Impact of public policies
Knowledge-intensive services	Emergence of a critical mass of actors in some areas.	Still underdeveloped in many others (IPR, innovation management, business angels, etc.). Shortage of engineers with both a solid scientific background and business flair.	Low inducement of firms' demand for market-based services. Limited impact of recent initiatives (e.g. CORFO's promotion of seed capital). No perceptible "labellisation effect" (government-sponsored projects have no easier access to private financing).
Regions	Some regionally concentrated clusters are taking shape, with all the necessary ingredients. A model of regional-national co-operation in innovation policy is being experimented for the first time (Bio-Bio). A regional technological infrastructure is developing (CONICYT regional centres)	Lagging regions remains deprived of both private and public investment in innovation. Most regional governments show no interest in and no institutional capacity to develop their own innovation strategy.	The lack of co-ordination among agencies and government services complicates decentralisation. New conflicts of interest arise (it is more difficult at the regional level to distinguish clearly between beneficiaries and policy makers when allocating public support).

4.4. Strategic tasks of innovation policy: a functional assessment

As analysed so far, innovation is not yet a core element of the growth model. However, over the past 15 years different institutional approaches have been tried, several programmes have been implemented in diverse areas and a variety of policy instruments have been applied. As a result, Chile has accumulated a great deal of valuable experience and institutional learning regarding innovation activities and policies.

One example of this learning process is the acknowledgement that public funds committed to promoting innovation activities were not enough, followed by the decision to create an earmarked new tax levied on mining activity to provide more resources for promoting innovation. As a result, from 2006 the public budget allocation for innovation has risen considerably. Another example is the recent creation of the National Council of Innovation for Competitiveness to overcome the many co-ordination failures and overlapping initiatives of different players, as well as the perceived lack of a strategic leadership to set the main goals and priorities of the innovation process.

While these initiatives are quite recent and it is too early to measure their impact, they certainly indicate the government's commitment to strengthening and streamlining Chile's innovation system so that it can become one of the most effective springboards for sustained and sustainable growth in the not so distant future.

Previous sections have provided some elements of answers to such questions as:

- Is the strategic guidance of innovation policy adequate?
- Are institutions well positioned in the system to fulfil their tasks efficiently?
- Is the overall policy mix and portfolio of instruments adequately balanced?
- Are instruments well adapted to their objectives?
- Does the approach to innovation policy encourage "clever selectivity"?
- How developed are the learning capabilities of the NIS institutions?

Keeping these questions in mind, this final section undertakes a synthetic assessment of public support by adopting a functional perspective: how effective have innovation-related policies been collectively in performing the following tasks?

- Providing the business sector the right incentives for increased R&D and innovation.
- Promoting the emergence and consolidation of a critical mass of scientists that fulfils the criteria of excellence and relevance in their research work.
- Fostering synergy among the different players and institutions within the system.
- Providing the basic infrastructure needed for efficient diffusion of knowledge, know-how and technology.
- Securing the supply of qualified human resources.
- Keeping the Chilean national innovation system (NIS) well connected to dynamic global innovation networks.

4.4.1. Providing the business sector the right incentives for increased R&D and innovation efforts

In spite of significant public efforts, in terms of both financial and institutional resources, to improve the performance of the business component of the NIS, aggregate results have been rather poor. Table 4.8 shows some indicators taken from three of the four innovation surveys made so far in Chile.[45]

45. The results of the last one, conducted in 2005, were not yet fully available at the time of the OECD review. Preliminary results point to the possibility of an underestimation of private R&D efforts in former innovation surveys.

Table 4.8. Selected innovation indicators at firm level

	1995	1998	2002
Number of firms investing in R&D	1235	497	697
R&D per worker (thousand CLP)	80.6	54.4	103.6
R&D per worker in firms investing in R&D (thousand CLP)	293.3	420.3	518.5
Public support to R&D (as % of total financing)	1.04	0.38	2.93
Firms with product innovations (%)	65.1	53.3	59.3
Firms with process innovations (%)	70.8	54.2	56.0

Source: based on Benavente (2004).

These figures show a sharp decline in almost every indicator between 1995 and 1998 and, notwithstanding the recovery in 2002, they remain far below initial levels. This shows the influence of the economic cycle and is an indication that innovation activities are not deeply rooted in firms' strategies (Benavente, 2005).

A first observation is therefore that, although public support to R&D has grown in importance as a source of financing for Chilean firms, it has not had a significant impact on performance indicators, if one considers that more than 1 000 Chilean companies regularly carry out innovation activities. A second important observation is that companies that have received public funding have subsequently increased their own spending on R&D, have introduced more process innovations, and have increased their productivity in comparison with companies that have not benefited from public support.

This is only an apparent paradox. The explanation is probably that individual innovation policy instruments have been reasonably[46] efficient in stimulating innovation-related investment in "prepared" firms but, taken together, have failed to induce more widespread changes in the behaviour of the vast majority of firms.

Since the beginning of the 1990s the cornerstone of public policy has been the system of technological funds. The diagnosis that led to the creation of these funds was, rightly so, that excessive emphasis had been put

46. For example, Benavente (2002) estimated, based on the results of a survey of 450 firms, that every public dollar invested through FONTEC induced a private investment in R&D projects of $1.3. This is not bad, especially since FONTEC mainly supported adoption rather than development of technology. More recent empirical studies produced more ambiguous results (Benavente, 2007).

on the supply side (financing universities and research centres, mainly through FONDECYT), without enough connection to the needs of firms and of society at large. The idea has been to devise instruments – notably FDI, FONDEF, FONTEC and sectoral funds like FIA – that could strengthen that connection and, at the same time, increase private companies' investment in R&D.

These funds were based on a rigorous policy rationale (clearly identified market failures). They were operated following good practices and in a transparent manner: open calls for proposals and selection based on criteria in line with the mission of each fund. A strong horizontal, bottom-up approach to the selection of beneficiaries ensured against the risk of capture by specific groups, although lately some elements of top-down selectivity were introduced by some funds to the benefit of priority areas, such as ICTs and biotechnology, with a view to increasing economic impacts through spillovers.

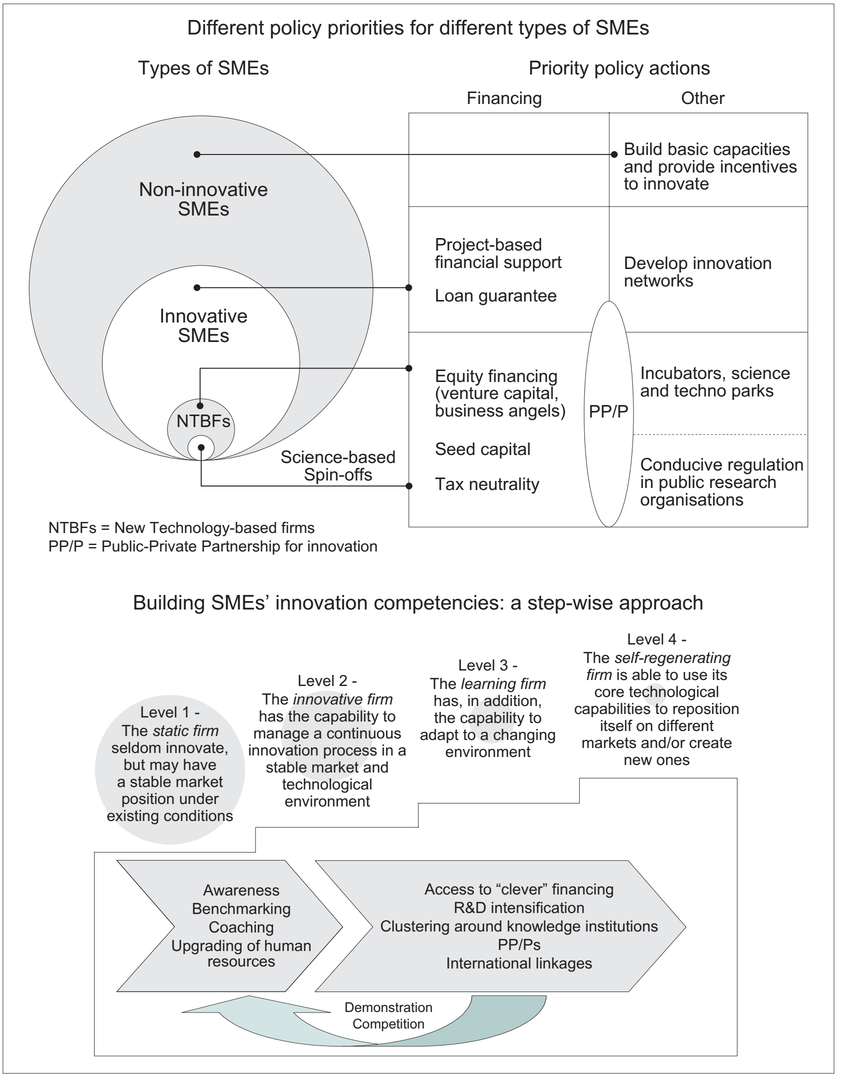
A reasonable hypothesis is that the fund-based approach did not bring about the desired results for two main reasons. First, it addressed piecemeal a series of market failures but failed to address underlying system failures, such as obstacles to the commercialisation and diffusion of new technologies, bottlenecks in the human resource "pipeline", lack of supportive public infrastructures, etc. Second, the portfolio of instruments (funds) did not sufficiently address "capability gaps". Chile should in particular take a more comprehensive but differentiated approach to the promotion of innovation in SMEs, following international best practices (Figure 4.3, Box 4.9).

In particular, for years the emphasis has been on technological innovation, rather than on diffusion, and on technological projects rather than technological entrepreneurship. However, a number of initiatives have tried more or less recently to correct this bias, for example:

- The Business Innovation programme of Innova Chile now supports more strongly business management schemes that foster company competitiveness.
- Innova Chile provides companies with co-funding for technology missions or internships abroad, to hire international level experts or specialised consultancy services, among others.
- The "entrepreneurship line" of Innova Chile helps companies introduce innovative results or products to the market.
- The Bicentennial Science and Technology Programme (PBCT) of CONICYT, through the co-operative research consortia, supports the recruitment of young scientists in industry.

- FIA supports initiatives and projects to commercialise innovation in the areas of agriculture, forestry and water.
- Recently, both CORFO and CONICYT have introduced instruments to encourage patenting by alleviating the cost of the local and international patenting process.

Figure 4.3. Promoting innovation in SMEs: the need for a comprehensive but differentiated approach



Box 4.9. Promoting innovation in SMEs: OECD countries' experience

When placing greater emphasis on innovation in their SME policies, governments face two challenges. First, given the variety of factors that influence firms' capabilities and incentives to innovate, they need to co-ordinate their actions in a variety of areas of government policy on the basis of a clear-cut strategy. Second, the heterogeneity of the population of small firms precludes any "one-size-fits-all" approach. In some sectors the bulk of innovations are due to new entrants or start-ups that challenge incumbents' market shares. But in most industries, SMEs contribute to the innovative process in a very different way. They operate in medium- to low-technology environments and innovate without engaging in formal R&D activities. They focus on improving production processes through the use of codified knowledge embedded in up-to-date equipment and on improving product design and marketing techniques through the use of tacit knowledge embedded in human resources.

OECD countries' experience demonstrates the importance of finding the right balance between measures addressing generic problems related to firms' size or newness and more targeted actions to solve problems that are specific to particular types of firms. Best practice policies include the following main components:

- *Conducive framework conditions*. The first responsibility of government is to provide a favourable climate in which entrepreneurs can easily create firms, have incentives to innovate and grow, and can access the necessary resources at a reasonable and predictable cost.
- *Measures to build innovation capacities.* Up to the early 1990s government promotion of innovation in SMEs was almost equated with support to technology diffusion. It focused on supply-led technology transfer and was biased in favour of manufacturing. However, mixed experience with supply-driven programmes, improved understanding of the role of new firms in increasingly interactive innovation processes, as well as growing evidence that the obstacles to innovation in most SMEs were internal to the firm and stemmed from deficiencies in labour skills and in organisational and managerial capacities prompted the emergence of a new generation of policies that put more emphasis on: *i)* fostering an entrepreneurial culture; *ii)* building the "innovative and absorptive capacity" of firms through skills development and improved management; and *iii)* promoting e-business and developing other business infrastructure for small innovative firms.
- *Measures to facilitate financing of innovation*. Insufficient access to financing is a persistent obstacle to the creation, survival and growth of innovative SMEs. Policies to reduce financing gaps broadly fall into three categories: *i)* subsidised loans and loan guarantees; *ii)* provision of seed financing and support for the development of venture capital; and *iii)* tax incentives and/or grants to correct market failures that lead to under-investment in R&D.
- *Measures to promote networking and partnerships.* Even more than larger firms, SMEs depend on external sources of information, knowledge, know-how and technologies in order to build their own innovative capability and to reach their markets. For complementary knowledge and know-how, innovative firms increasingly rely on collaborative arrangements in addition to market-mediated relations (*e.g.* purchase of equipment, licensing of technology). Inter-firm collaboration within networks is now by far the most important channel for the sharing and exchange of knowledge. Interactions are also intensifying between firms and a number of other institutions involved in the innovation process: universities and other institutions of higher education, private and public research labs, providers of consultancy and technical services, regulatory bodies, etc. In OECD countries, public programmes and initiatives that explicitly address networking are a rather new phenomenon. They address market failures at different stages of the networking process through SME-specific or less targeted measures (see the table below): *i)* raising awareness of networking opportunities and helping search for partners; *ii)* organising, financing and operating networks; *iii)* interfacing scientific and innovation networks through public-private partnerships (PP/Ps); and *iv)* creating international linkages and building global networks.

These trends do not solve all problems, and they raise new ones, particularly because they make the support system more complex, blurring further the division of labour among institutions. The system of funds cannot create by itself all the conditions for its efficiency; this is obviously even truer for any individual fund. For example, the public-partnership approach, which is being tested in the framework of PBCT, has a great potential for helping to close an institutional gap in the innovation system. However, as the experience of OECD countries suggests (OECD, 2007b), realising this potential may require more than additional "lines" in existing funds' portfolios (see also section 4.4.3).

Existing funds should probably continue to carry out the tasks for which they are best equipped. This raises the issue of the type of complementary actions needed to ensure better "behavioural and not only resource additionality" (Box 4.10) in beneficiary firms and to extend the pool of the latter at a minimum cost to the budget.

Box 4.10. Measuring behavioural additionality:
A new focus of OECD countries' evaluation of public support to business R&D

Do recipient firms pursue different types of R&D, or collaborate more with others? Do they improve their R&D management capabilities and introduce enduring changes in their R&D strategy and performance? Such issues are not typically addressed in traditional evaluations, and there have been relatively few efforts to explicitly measure changes in the ways firms conduct R&D as a result of government policy, the so-called "behavioural additionality" effects.

This OECD has explored the concept of behavioural additionality and promoted a multinational effort to develop better ways of measuring it. A recent publication summarises the results of a series of studies undertaken in Australia, Austria, Belgium, Finland, Germany, Ireland, Japan, Korea, Norway, the United Kingdom, the United States and the European Union. These studies reveal a number of qualitative changes in the types of R&D conducted by firms and the way in which they carry out R&D as a result of their participation in government R&D funding programmes.

Source: OECD (2006c).

The question of the tax treatment of R&D arises in this context. Unlike the majority of OECD countries, Chile has not yet used such an instrument. Recently, however, the government decided to take a first step in this direction by proposing some tax relief on some business R&D expenditures. As pointed out in section 4.2.2, which describes the proposed scheme, its main merit will be to send a powerful signal about the public sector's commitment to innovation and to boost the market for contract R&D. It is doubtful that it will fundamentally change the average Chilean firm's propensity to innovate.

4.4.2. Ensuring critical mass, excellence and relevance in scientific research

A vibrant innovation system requires a strong science base which is able to perform three vitally important functions: *i)* increase the quality of training in higher education and ensure that a minimum number of highly skilled personnel have research experience before entering the labour market; *ii)* provide a platform for ambitious science-based innovation; and *iii)* monitor worldwide progress in scientific knowledge and help domestic actors access relevant new knowledge produced in other countries.

In the last two decades Chile has made great efforts to gain a critical mass of highly skilled human resources and excellent scientific research institutions. It has been less successful in the admittedly more difficult task of making its science system more responsive to evolving economic and social needs, largely because of the absence of mechanisms to articulate and translate these needs into a scientific agenda.

In addition to direct funding of universities, Chile now uses a whole set of instruments to fund scientific research projects on a competitive basis. The diversification of this policy toolkit over the last decade reflects a political will to concentrate more resources in areas of excellence and to encourage links between academia and industry.

Over the last 25 years FONDECYT has consistently supported scientific researchers and small research groups in all areas of knowledge. It has been very well evaluated in terms of the transparency and independence with which it performs its mission. Established more recently, FONDAP has promoted with undeniable success the establishment of centres of excellence in advanced research and has sought to better articulate the work of research groups in areas in which Chilean science has reached a sufficient level of development and a critical mass of researchers with accredited productivity. The Millennium Science Initiative has created a number of institutes and nuclei of excellence in various disciplines and areas. The obvious overlap between this initiative and FONDAP is another example of a Chilean institutional disease: fragmentation instead of warranted differentiation.

Other programmes have also played a role in increasing Chile's capabilities in scientific research in connection with foreign partners, notably several scholarship programmes. In addition one component of the PBCT programme is aimed at strengthening the scientific base of Chile through the increase in manpower for scientific and technological research, in research infrastructure and in the ability to acquire knowledge produced in other countries in a timely manner. Although the "Higher Education Quality and Equity Improvement Program (MECESUP)" is not specifically targeted at improving universities' research capabilities, the issue has been tackled indirectly through actions that improve the universities' capabilities and the quality of their education programmes, especially at doctorate levels.

In the absence of significant demand from industry and of any, if only soft, top-down guidelines regarding research priorities, the Chilean science system is, as in many other countries, strongly path-dependent in terms of the allocation of resources among disciplines, and shaped by bottom-up demand from researchers, in terms of the allocation of resources among projects within disciplines. The only focusing devices, FONDAP and the Millennium Science Initiative, have a qualitatively important but quantitatively limited impact since their combined budget is less than one-sixth of the direct budget allocation to university R&D by FONDECYT, and they do not use economic relevance as a criterion to support research groups.

4.4.3. Strengthening the knowledge infrastructure through appropriate steering of technological institutes

Technological institutes (ITPs) were created to be the backbone of Chile's infrastructure for technology diffusion. As discussed in Chapter 3 many of those in fields of relevance to the private sector have had difficulties adjusting to the changing economic environment. Their contribution to the innovation system has been is a subject of debate for some time.

The way they are steered through funding has changed in the last decade. Initially, ITP funding derived almost exclusively from the public budget. In 1995 a dedicated competitive fund was set up to induce ITPs to respond better to the requirements of the productive sector. In addition, some ITPs also signed "performance contracts" with various ministries by virtue of which, in exchange for specific commitments, they received funding to invest in capacity building. The funds transferred through these performance agreements have rarely exceeded 10% of the total ITP budget.

The direct funding of ITPs has therefore been progressively reduced and has now been eliminated for the majority. A notable exception is the National Institute of Agricultural Research (INIA), the largest of the ITPs, which still receives significant direct funding from the public budget.

In 2000 an international evaluation of a group of ITPs was carried out. Its terms of reference were to assess their organisation and the relevance of their lines of activity, as well as to recommend adjustments – in light of international experience – which could improve their contribution to the innovation system. As a result some reforms have been implemented. In particular, there have been regulatory changes to give the ITPs more flexibility and a rationalisation that has involved the fusion of two institutes, with INTEC (which had belonged to CORFO) becoming an integral part of Fundación Chile.

However, there is not yet an overall coherent policy for the ITP sector. Its formulation would require an assessment of the performance and capabilities of all ITPs, from a truly systemic perspective, in order to reaffirm or redefine missions, operating modes, technological focus, etc., without excluding any option, reorganisation, merger, privatisation or closure.

4.4.4. Promoting industry-science relationships

The weakness of the linkages between public research and business innovation is acknowledged by all stakeholders in Chile. Initiatives to remedy this situation have recently been taken.

4.4.4.1. Public-private partnerships

FONDEF was created precisely to promote relationships between companies and research institutions, especially universities. It supports R&D projects in universities and research centres that have a clear application in production activities. Matching resources from at least one company is a pre-condition for project approval. This programme helps to encourage research interest in companies' problems, but its project-based approach has inherent limitations, as it is unlikely to generate projects with sizeable economic impact. It should be seen as a networking tool and be managed in that spirit.

A few true public-private research partnerships have appeared in Chile in the last decade, but until recently they were dispersed bottom-up entrepreneurial initiatives in which policy had a minor role. For example, Fundación Chile promoted several focused co-operative technological undertakings. In 2002, under the auspices of the Genoma-Chile Programme, BioSigma S.A. was created as a public-private partnership between Codelco and Nippon Mining & Metals Co. to incorporate the latest developments in biotechnology in the processes of biomining.

The first structured public initiative in this area is the recent creation of 19 technological research business consortia, a joint initiative between CONICYT (through PBCT), CORFO and FIA. This is the largest government effort to date to generate leading-edge scientific and technological knowledge by bringing together various players of a single value chain, include participation by potential business end users. These consortia have been established in a variety of areas, most of them within resource-based industries: applied biotechnology for new varieties of fruit; improved wood production through the use of forestry genomics; development of new technologies in fisheries; development of a cluster or alliance between producers and milk researchers in the Los Lagos region; strengthening of the wine industry through new technologies; development of new products with added value based on waste from traditional export industries; technological innovation in cancer research; launch of an aeronautical technology programme; and creation of a development pole around applied biomedicine.

It should also be noted that under the CONICYT's Regional Programme, co-operative research and development consortia have recently been established in all regions of the country.

4.4.4.2. Innovative clusters

CORFO's Integrated Territorial Programme (PTI) is aimed at fostering the development and improving the economy of a given territory or geographic zone. Its objective goes beyond technological development and innovation. It funds a range of activities, for example to improve company management, especially in SMEs. Recently, the PTI channelled additional resources to consolidate the development of the salmon cluster in the regions of Los Lagos and Aysén. This public-private programme promotes research and innovation as part of an overall development plan. Earlier initiatives to foster innovative clusters include: the mining cluster in the region of Antofagasta and the Colchagua Tierra Premium, for the wine industry, in the Region of O'Higgins. The latter initiative included the creation of the Colchagua Technological Management Centre as an R&D platform for the region's wine industry.

Overall, despite these successful or promising initiatives, Chile has not implemented a fully articulated cluster-based approach to innovation policy. This is surprising given that such an approach would have the potential to help achieve several of the government's priority objectives: *i)* better articulation between public research efforts and market dynamics; *ii)* rationalisation of the public knowledge infrastructure; and *iii)* acceleration of economic diversification by building around or creating bridges between poles of strength. However, there are new initiatives in this area. The Consejo de Innovación is currently undertaking a cluster analysis to be carried out by the Boston Consulting Group. So far eight clusters have been prioritised and policy instruments to promote their development are being designed. The clusters are: offshoring, fish farming, tourism, copper mining and sub-products, pork and chicken farming, processed food for human consumption, primary fruit industry and financial services.

4.4.4.3. Mobility of researchers, patenting and spin-offs

As pointed out in Chapter 2 there is very low researcher mobility in Chile, although mobility is an important vector of knowledge transfer and dissemination, including between public research and the business sector.

There have recently been specific initiatives to reduce this important bottleneck, especially through Chile Innova and the PBCT. Chile Innova funds scholarships for doctoral candidates in ICT and biotechnology and internships in world-class companies and research centres. One component of the PBCT (Researchers in Industry) seeks to expand the stock of high-quality research personnel in Chilean industry by awarding scholarships to doctoral students who undertake a substantial part of their thesis work in industry. A staff member of the company functions as the student's associate supervisor and the company is required to contribute a small supplement to the scholarship. It also awards partial scholarships to post-doctoral or other researchers early in their careers who undertake research in industry. These scholarships are temporary and their amount diminishes over time, with the company paying for an increasing share of the researchers' salary.

Another initiative, which can help increase the flows of highly skilled personnel within the innovation system, is Innova Chile's Programme for the Hiring of International Level Experts or Consultancy. This programme co-funds the hiring of experts in technology and highly specialised production processes for companies that require it. Finally, some national universities have placement programmes for their graduates in the private sector, through joint agreements with companies interested in receiving the new professionals.

So far the impact of these initiatives has been quite modest, but it is too soon to jump to conclusions. If demand-side complementary measures succeed, notably those aimed at increasing R&D and innovation activities in the private sector, they can play a significant role in helping increase researcher mobility.

Patenting and licensing is another channel of knowledge transfer from public research to the business sector which has increased in importance in the OECD area, with many countries, following the example of the United States, implementing policies to encourage their universities to adopt a more strategic approach to the management of their intellectual assets. This has usually involved a combination of regulatory reforms (*e.g.* in the field of IPR) and institutional innovations (*e.g.* establishment of technology licensing offices), together with the provision of incentives that can gradually change the academic research culture. The results have been uneven, and many countries are still struggling with the problem. Chile obviously belongs to the group of countries in which universities have a very low propensity to patent for cultural reasons and because of their modest production of patentable work, but also because of the underdevelopment of the domestic market for knowledge.

The same basic reasons, plus the lack of seed and risk capital, explain the very small number of spin-offs in Chile. Promotion of this type of venture is very recent and faces cultural barriers that can only be removed with an appropriate combination of incentives for researchers and the institutions that house them, and the encouragement of networking among researchers, entrepreneurs and sources of finance (seed and venture capital). The experience of Innova Chile's seed capital programme, although small in scale and not exclusively oriented towards science-based spin-offs, seems to be a good first step. However it is too early to evaluate its impact.

In countries like Chile, where the knowledge market is very immature, it may be important to promote the development of knowledge brokers/ translators that can create a bridge between communities with different values, visions, objectives and languages. As in other countries, most SMEs do not have full-time researchers in house or even highly skilled engineers. In contrast with the situation in most OECD countries, however, if a Chilean SME wants to buy research it most often must turn to universities, which are practically the only institutions able to provide this type of service. However, communication between them is not good. They work at such different paces and with such different perspectives that they have difficulties adapting to each other's needs.

Intermediaries can help mitigate this problem. They can either be individuals (as technological brokers or technological counsellors) or institutions (even specialised departments of universities or research centres), with clear mandates and an understanding of business. They might well become business entities themselves as the system reaches sufficient maturity. The mere existence of financing mechanisms has proven not to be enough to promote industry-science relationships. Organisational innovation and institution building may be necessary to lift them to the level required for innovation-led growth.

4.4.5. Securing the supply of qualified human resources

Chile's huge effort in terms of public investment in education in the last decades has led to a significant increase in the system's coverage. Despite these achievements in terms of coverage, public discussion has been dominated in the last years by a growing concern about the quality of education (Eyzaguirre *et al.*, 2005).

This concern has arisen, among other reasons, from an analysis of the standardised international tests in which Chile participates: the International Study of Tendencies in Mathematics and Sciences (TIMSS), and the Programme for the International Evaluation of Students (STEPS). In both, Chilean students ranked among the lowest in the respective samples. Chile is surpassed by countries with a higher level of development, in particular the most innovative ones. However, Chilean students have even poorer results than would be expected for a country with Chile's level of spending per student, when controlled for its level of development.[47] To improve the quality of its education, it is critical to identify the main problems and to clearly focus efforts on resolving them.

To meet the challenge of the knowledge economy, quality, coverage and equal access to higher education matter a lot. In these areas, Chile lags the most innovative countries. However, demand for higher education is expected to rise in the coming years. This will help reduce the shortage of technicians and professionals in the Chilean labour market. It may also help diminish the shortage of professionals with doctorates in the active population.[48]

The main source of concern regarding higher education is inequity in terms of access. Although the share of the poorest 40% of the population benefiting from higher education has tripled since 1990,[49] the access gap between this group and the richest 20% has not decreased. In light of the high private profitability of education, this means that the development of the higher education system is not improving social equity.

As regards doctoral programmes, the supply has expanded notably, with a total of 91 in 2003. At the same time, there is a growing flow of graduates to doctoral programmes abroad, particularly in the United States and Europe. However, there are some weaknesses in this area. Each doctoral programme generates on average only 1.3 PhDs a year. This is not only quite low by international standards, it is also a sub-optimal use of resources given the financial and qualified human resources that are diverted from other uses to run these programmes. Moreover, there is probably an

47. Additionally, the OECD's International Adult Literacy Survey (IALS) showed that only 20% of the adult Chilean population has the minimum level of reading comprehension necessary for self management in a modern society.

48. Tokman and Zahler (2004) show that in the period 1996-99 Chile only incorporated three science PhDs per million inhabitants in the labour force, while Sweden and Finland incorporated 197 and 177, respectively.

49. It has passed from 4.4% to 14.5% in the first quintile of revenues and of 7.8% to 21.2% in the second.

excessive thematic diversity and very little co-operation among the different institutions.

While the number of graduate research scholarships has increased dramatically in recent years, the actual funding of advanced training is still insufficient. No more than 500 PhD scholarships are awarded each year, a number that should be at least 1 000 given the population and the need to renew staff levels in the higher education sector and in other institutions and companies. One of CONICYT's new priorities is to significantly increase specialised training; this organisation needs to become a central source for this type of funding since the Ministry of Education and the Ministry of Planning also have scholarship programmes, and this dispersal results in inefficiencies.

At the same time, however, certain limitations in the graduate education system need to be addressed, as the problems will become more acute if not corrected given the increased numbers of students entering Master's and PhD programmes and the short-term expansion plans. One of the problems students face is the difficulty of completing their theses owing to the lack of well-equipped laboratories and of teams of active researchers to ensure the quality of this level of education.

To improve quality and relevance it would be necessary to balance the PhD-Master's programme mix, to focus on some strategic areas and concentrate scarce resources on them, and to develop incentives to achieve more co-operation among institutions in the design and implementation of joint programmes. Recruiting foreign PhDs and post-doctorates in Chilean universities, which would help strengthen the accumulation of qualified human resources, is not easy for various reasons, and should be facilitated by means of regulatory reforms and additional financial support.

The lack of focus in graduate degree programmes, which are frequently ill-adapted to the needs of companies, explains why businesses are reluctant to hire scientists on a permanent basis. In fact, fewer than 6% of scientists working in R&D in Chile work in businesses, compared with over 30% in Finland. This situation potentially poses problems for the country since the ever higher number of students finishing PhD programmes will not all be able to work in the university system. With this in mind and as indicated earlier, CONICYT through its Programa Bicentenario de Ciencia y Tecnología (Bicentennial Science and Technology Programme) recently created an instrument to subsidise the hiring of PhDs in industry for well-identified innovation projects. While it is too soon to evaluate this instrument, early indications are that companies currently show limited interest in using it to hire highly qualified personnel.

4.4.6. Keeping the Chilean NIS well connected to global innovation networks

Chile lags significantly behind comparable countries in terms of the number of foreign students received and of Chilean students who study abroad. In other words, there is little internationalisation of the educational process.

The postgraduate programmes available abroad include the DAAD/CONICYT Agreement, the Fulbright/CONICYT Agreement, the ECOS/CONICYT Agreement (France), the Virginia University of Wellington/CONICYT Agreement, the President of the Republic Scholarship of the Ministry of Planning, and the International Master and Doctorate Scholarships of MECESUP of the Ministry of Education. Doctoral and postdoctoral scholarship financing lines have also been included in recent and ongoing support programmes, such as Chile Innova and PBCT.

The Technology Transfer Programme of the Innova Chile Committee of CORFO is dedicated to fostering initiatives for prospecting, dissemination, procurement and adaptation of management or production technologies to Chilean firms. It uses a range of mechanisms to allow regional and national firms to gain access to technologies in more developed countries. These mechanisms include bringing international experts to Chile, sending Chilean businessmen on technology trade missions abroad, sending local company experts to study in technology centres abroad, organising technology transfer centres and technology dissemination programmes with research centres and universities.

Chile has signed many science and technology co-operation agreements with OECD countries, including Germany, the United States, Spain, France, the United Kingdom, Italy, Japan, Mexico and Portugal. However, not all have been equally productive. According to the National Academy of Sciences, Chile has not in most cases committed the resources needed to become a "real counterpart" in those agreements. The agreement with France, which has so far been the most productive in terms of new projects, is aimed at researcher mobility based on submitting joint projects by both countries.

Acronyms and Abbreviations

BERD	Business enterprise expenditure on research and development
CCHEN	Chilean Nuclear Energy Commission
Codelco	Corporación Nacional del Cobre (National Copper Corporation)
CONICYT	National Commission for Scientific and Technological Research)
CORFO	Foundation for Promoting Development)
CIREN	Natural Resources Research Centre
CIMM	Mining and Metallurgy Research Centre
CIS	Community Innovation Survey
CLP	Chilean peso
CRUCH	Council of University Rectors
DEEM	Design, engineering, entrepreneurial and management
EFTA	European Free Trade Association
ESO	European Southern Observatory
EU	European Union
FDI	Foreign direct investment
FDI	Development and Innovation Fund
FONDAP	Fund for Advanced Research in Priority Areas
FIA	Agrarian Innovation Foundation
FIC	Innovation for Competitiveness Fund
FIDES	Investment Fund for Enterprise Development
FIP	Fisheries Research Fund
FONDECYT	National Fund for Scientific and Technological Development
FONDEF	Scientific and Technological Development Promotion Fund
FONSIP	National Public Interest Fund
FONTEC	National Fund for Technological Development
FTE	Full-time equivalent
GDP	Gross domestic product
GERD	Gross domestic expenditure on research and development
HRST	Human resources in science and technology
ICM	Millennium Science Initiative Programme
IDB	Inter-American Development Bank

IFOP	Institute for Fishing Development
IGM	Military Geographic Institute
INACH	Chilean Antarctic Institute
INFOR	Forestry Institute
INIA	Agriculture and Livestock Research Institute
INN	National Institute for Standardization
IP	Intellectual property
IPRs	Intellectual property rights
ISI	Institute for Scientific Information
ISRs	Industry-science relationships
ITPs	Technological institutes
MECESUP	Higher Education Quality and Equity Improvement Programme
MIDEPLAN	Ministry of Planning
MNE	Multinational enterprise
NIS	National innovation system
NTBFs	New technology-based firms
PAA	Academic aptitude test
PBCT	Bicentennial Science and Technology Programme
PCT	Science and Technology Programme
PDIT	Technological Innovation and Development Programme
PIT	Technological Innovation Programme
PPP	Purchasing power parity
PSU	University admission exam
R&D	Research and development
SERNAGEOMÍN	National Geology and Mining Service
SENCE	National Training and Employment Service
SHOA	Hydrography and Oceanography Service of the Chilean Navy
SMEs	Small and medium-sized enterprises
TFP	Total factor productivity
WTO	World Trade Organisation

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