NOTE BY THE SECRETARIAT

This document presents a review of the Chilean research centres programmes by the OECD that was requested by the Chilean authorities[1] with a view to providing input to the CSTP/TIP Knowledge Triangle project. The document benefits from a peer review discussion at the 45th meeting of the OECD Working Party on Innovation and Technology Policy on 17 June 2015. The peer review discussion was led by Delegates of the Czech Republic and Spain.

This version is submitted to the Chilean authorities as the final version of the Chilean case study for the Knowledge Triangle Project. The Secretariat acknowledges the voluntary contribution from Chile to support the OECD review team.

[1] The OECD team was comprised of Secretariat staff (Mario Cervantes and Giulia Ajmone Marsan of the OECD's Science and Technology Policy Division) and external experts (Wolfgang Polt, Joanneum Research Austria; Steven Wooding, RAND Europe, United Kingdom; Nicolas Vonortas, George Washington University, United States and Jean Guinet, Consultant, France).

Introduction

1. Chile is participating in OECD's "Knowledge Triangle" project carried out by the Committee for Scientific and Technological Policy 's Working Party on Innovation and Technology Policy –TIP. To this end, the Chilean National Council of Innovation for Development (CNID) invited an OECD Secretariat team to carry out a review of Chilean research centres, investigating their performance, governance and their linkages with universities and the business sector as input to the "Knowledge Triangle" project. This paper presents the findings from the OECD team visit to the Chilean research centres and will serve as evidence to support discussions in Chile with regard to the renewal of the funding for the more than 30 research centres that operate in different scientific domains; the natural, life and social sciences all of which were initially created with ten-year mandates. The findings are based on the evidence gathered during the fact-finding mission in Chile of April 2015 as well as desk research. During the fact-finding mission, the OECD team visited a number of centres selected by CNID. The selection was made to provide an overview of the broad range of research centres in Chile. However, not all dimensions of the landscape may have been represented in the selection of the centres visited by the OECD team.

The Chilean research and innovation system in context

2. Over 2008-2013, Chile's productivity growth exceeded that of most OECD economies. Nevertheless, the Chilean economy is now growing at its slowest pace in five years, as declining copper prices and lower global demand (in particular from China) have reduced the terms of trade and weakened business confidence and investment. Chile's economy is highly open to trade, yet its participation in global value chains is among the lowest in the OECD area (OECD, 2015a). Cross-country evidence suggests that the bulk of job creation and gains in aggregate productivity come from the rapid growth of young dynamic firms. Yet survival rates of young industrial firms in Chile are the lowest among OECD countries.

3. In global competitiveness ranking, Chile's economy has advanced to the stage of being among Latin Americas most competitive ones recently. In the IMD competitiveness Scoreboard 2014 it occupies rank 31, better than advanced economies like the Czech Republic (33), Spain (39), other Latin American countries like Mexico (41), Peru (50) and Colombia (51) but also some of the BRICS countries with India ranking 44th, South Africa 52nd and Brazil 54th. Chile's economic success can be attributed to a strategy of export-led growth against the background of fiscal and monetary stability, the establishment of sound financial markets and increased coverage of the education system[2].

4. However, the structure of production has remained concentrated on primary industries (most of all copper) and agriculture, forestry and fisheries which are by far the most important sectors of production. Manufacturing industries (especially high-tech ones) account for just a small share. This orientation towards resource-based sectors remained almost unchanged over time.

5. The annual budget of the public national innovation system has almost doubled from USD 455 million in 2006 to USD 998 million in 2014. Still, Chile spends comparably little on R&D, amounting to just 0.4% of GDP which is well below other countries that Chile surpasses in other dimensions of competitiveness. In the longer term, this level of investment is inadequate for bringing and sustaining a modern knowledge economy. As in most countries with overall low R&D intensity, the bulk of R&D is financed from public sources and performed in public research institutions. Hence, research and technological development are done by a rather small scientific community (in 2012 only 0.92 researchers per thousand workers as compared to an OECD average of 7.77 and between 6 and 10 in countries like

[2] The OECD team acknowledges input from Andrés Zahler, Head of Innovation Division of Ministery of Economy, concerning the history and challenges of the Chilean national innovation system that he presented during the fact-finding mission.

Estonia, Greece and Hungary; see OECD MSTI 2103) of which only a small part is working in the business enterprise sector.

6. Chile's business innovation performance is well below the OECD median (Figure 1), particularly among SMEs. Chile currently has a weak international technological presence as evidenced by triadic patent applications as a share of GDP (Figure 1f) (OECD 2014a). In this context, the research system of Chile can play an important role in developing the innovative and technological capacity of the business sector but also in promoting structural change and economic diversification.

7. Higher Education Institutions (HEIs), and in particular universities, are important actors in the national innovation system (NIS). Chile's public research system is small in comparison to other countries; few of its universities are among the world's leading institutions and there are few publications in top journals relative to GDP by OECD standards (Figure 1a, indicators a, b, and c). However, the amount of government expenditures in R&D performed by Higher Education Institutions – HEIs (35.3%) in 2012 was well above the OECD average (18.1%), illustrating the importance of HEIs in the innovation system. To capitalise on the returns from a rather limited science base, several initiatives to encourage and accelerate the commercialisation of public research were introduced during 2012-14 (see below) (OECD 2014).

8. Nearly 80% of all the researchers in the country are employed by universities or associated research centres. Therefore, the task of the HEIs is twofold: to train technicians, professionals, graduates and postgraduates, and to contribute to scientific and technological development. The extent to which they can indeed fulfill the role of core actors in innovation is, of course, questionable. The sector is currently under stress trying to balance academic excellence, on the one hand, and direct contribution to the industry and the economy at large, on the other.While not an unfamiliar phenomenon around the world, it is particularly relevant in a small economy, with few resources primarily based in universities, and a private sector still largely uninterested in research but more prone to acquisition of technologies from abroad.

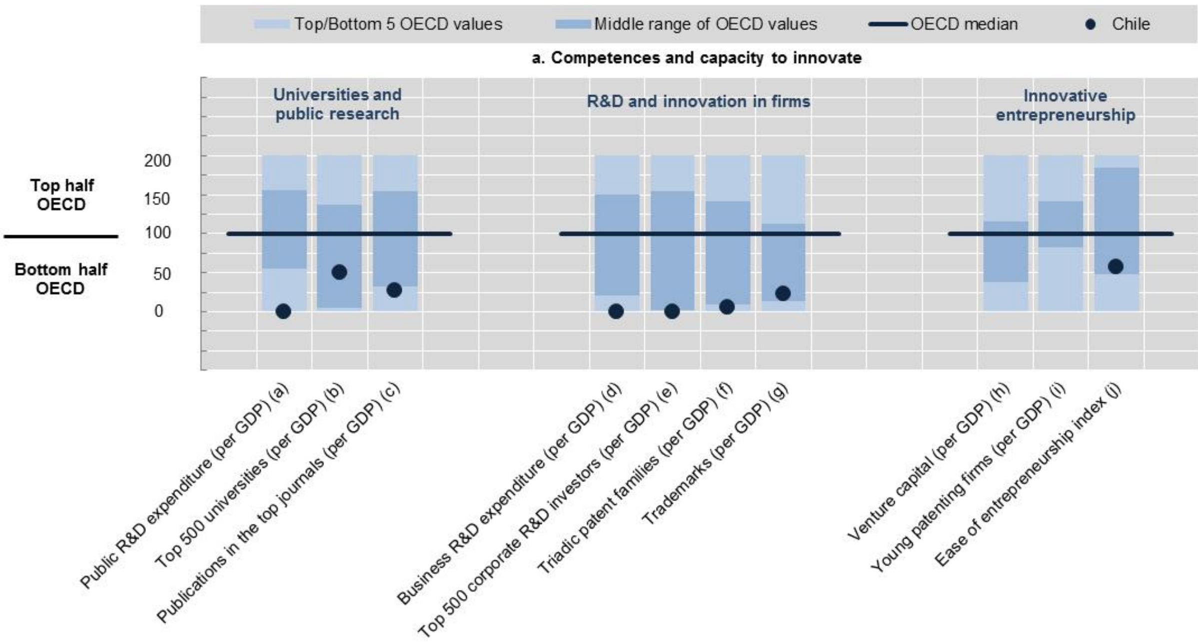
9. With respect to OECD indicators measuring the skill level of students, Chile is below the OECD average. PISA 2012 results indicate that Chilean students performed considerably below average in problem solving (they are positioned at the same place as Turkey or Brazil) and mathematics (they are positioned at the same place of non OECD economies such as Thailand and Malaysia). In addition, Chile attracts few international students from abroad. On the other hand, the country has invested heavily in training Chilean nationals abroad and encouraging their return through contractual fellowships (OECD 2014c, Education at a Glance, Highlights).

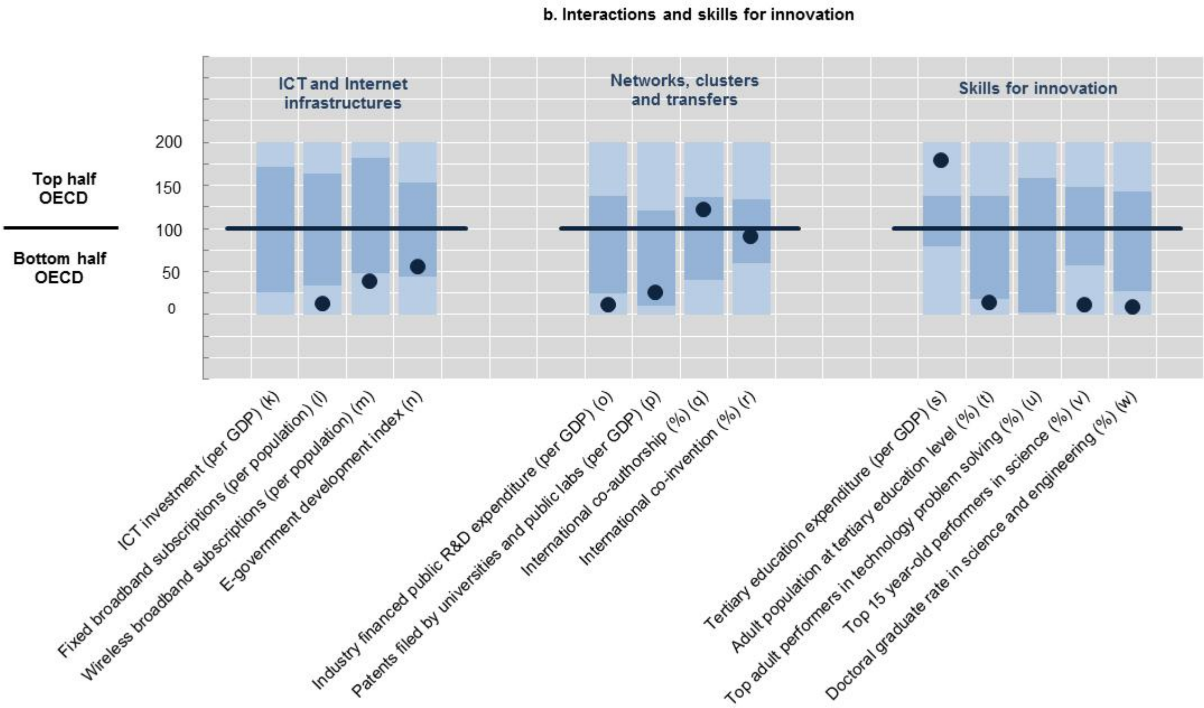
10. There are important differences in economic development across regions. Chile is characterised by a considerable concentration of economic activity in the Santiago Metropolitan region. At the beginning of 2000s, the Santiago region was contributing to half of the economic growth of the country (OECD 2013d, Urban Policy Reviews, Chile). A similar concentration is reflected by innovation related indicators: in 2010, half of R&D expenditure and R&D personnel were concentrated in the Santiago metropolitan region. PCT patent applications (an international patent application procedure) in Santiago account for 66% of total PCT patent applications (OECD Regional Database).

Table 1. Overview of economic, environmental and R&D expenditure indicators

Economic and environmental performance	CHL	OECD	*Gross domestic expenditure on R&D*	CHL	OECD
Labour productivity			**GERD**		
GDP per hour worked, USD PPP, 2013	26.7	47.7	Million USD PPP, 2012	1 312	1 107 398
(annual growth rate, 2008-13)	(+2.4)	(+0.8)	As a % of total OECD, 2012	0.1	100
Green productivity			**GERD intensity and growth**		
GDP per unit of CO_2 emitted, USD, 2011	3.4	3.0	As a % of GDP, 2012	0.35	2.40
(annual growth rate, 2007-11)	(-1.4)	(+1.8)	(annual growth rate, 2007-12)	(+6.4)	(+2.0)
Green demand			**GERD publicly financed**		
NNI per unit of CO_2 emitted, USD, 2011	4.4	3.0	As a % of GDP, 2011	0.16	0.77
(annual growth rate, 2007-11)	(+0.2)	(+1.6)	(annual growth rate, 2007-10)	(+8.4)	(+2.8)

Figure 1. Comparative performance of national science and innovation systems, 2014





Note: Normalised index of performance relative to the median values in the OECD area (Index median=100).
Source: OECD 2014, Science, Technology and Industry Outlook 2014, OECD Publishing.

11. The Chilean national innovation system faces several key challenges which require sustained investment in R&D and innovation capacities as well as the continued build-up and attraction of human capital. Among these challenges are the following:

- Securing and broadening the technology base and innovativeness of sectors in which the country is specialised;
- Fostering new areas with high growth potential;
- Creating the conditions for research and innovation that avoid dispersion of very limited resources and allows the build-up of critical masses in selected areas;
- Providing attractive research opportunities for the increasing number of home-grown graduates as well as for researchers from abroad;
- Fostering research of high quality and international visibility;
- Utilising the knowledge base created in public research institutions to foster innovation in the private sector, either through the provision of high-skilled labour or through joint projects;
- Utilising the knowledge base created in public research institutions to foster regional development and address societal challenges (e.g. climate change, environmental risks, etc.) most pertinent for the country.

Enhancing the quality and impact of the research in Chile: the role of the Chilean research centres

12. To upgrade the quality of the scientific base and meet some of the aforementioned challenges, the Chilean government, like other OECD countries, has created a number of funding streams to support the development of internationally competitive research centres (Figures 2 and 3). These funding streams are allocated by different ministries and, although designed for different purposes, in reality they tend to have very similar aims. In Chile, the total budget allocated to fund public research centres is approximately 70 million USD per year, which correspond to approximately 14% of the sum of higher education and government expenditure on R&D (HERD + GOVERD).[3]

6. Chile has invested a significant amount of public funds in fostering major research centres through various public programmes: "Iniciativa Científica Milenio" – (Scientific Millenium Initiative) of the Ministry of Economy, and "Fondap" and "Basal" funding programmes, both under the National Commission for Scientific and Technological Research (CONICYT), the main Chilean science funding agency of the Ministry of Education responsible for strengthening the scientific and technological base of the country and for promoting the formation of advanced human capital. InnovaChile, of the Chilean Economic Development Agency (CORFO) is attached to the Ministry of Economy and implements government policies to promote entrepreneurship and innovation. In addition, there are a significant number of "Regional" research centres. The research centre funding programmes have effectively produced critical mass and relatively long term research projects, some of them oriented by national or regional priorities (see Table 2 and sections below for a detailed description of these programmes).

13. It is important to note that most of these centres have been created and have operated with direct support of one or more universities, as most of the researchers of the centres are part of the academic staff of the hosting university. As such the Centres have the following goals: to train the next generation of scientists and engineers, raise academic excellence, contribute to the development of and increase the uptake of new technologies by industry, leverage public resources in research, and transition the system towards the needs of the knowledge economy. In addition to the types of centres that the OECD reviewed, Chile has 14 public technological institutes under the management of different ministries. They are the oldest, established decades ago. They purport to provide advice and technical assistance to the managing ministries as well as to develop research to contribute to the delineation of regulations on specific topics and in some cases transfer technology to several productive sectors such as forestry, agriculture, fishing, energy, and defence. The OECD team visited one Centre of one such Institute (INIA) at La Serena.

14. The centres display very different characteristics irrespectively of the funding stream through which they were created. They vary considerably in their size and the type of research they carry out (basic vs. applied research). In many cases, centres are teams of researchers from different universities or research institutions joining a single lab to develop common research projects, often located within the university campus; others are more well-established research centres with *ad hoc* buildings and management offices or infrastructure.

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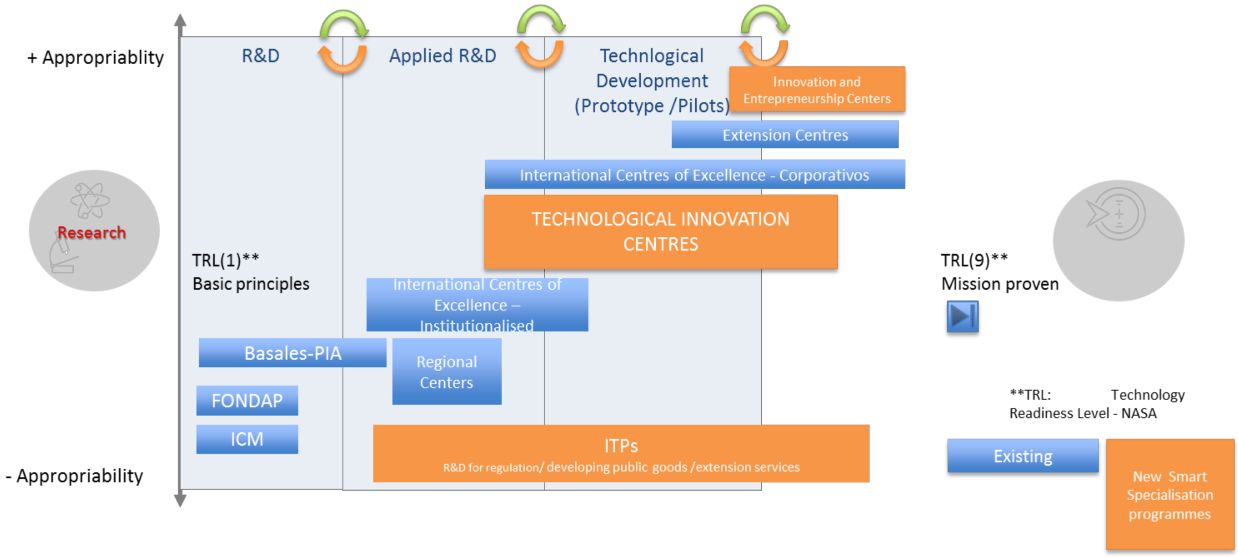
[3] This budget includes the funding programmes: Basal, FONDAP, Millennium Science Initiative and the Regional programme. Each centre can obtain additional sources of income from smaller public research grants, private organisations, local governments or funding from abroad.

Figure 2. Science and Technology Research Centres in Chilean National Innovation System



SOURCE: CORFO

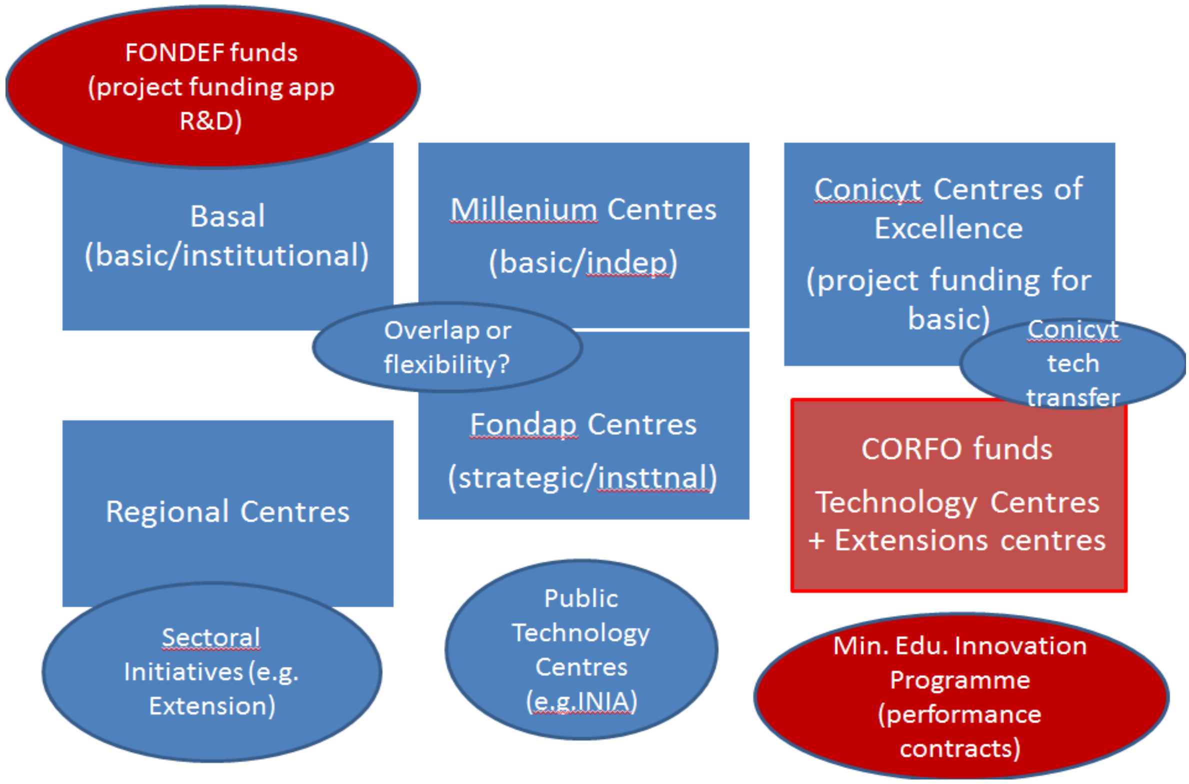
15. Most of the centres are funded through competitive calls for five years and can be renewed for additional five years. After having obtained funding for a maximum of ten years, the centres cannot be renewed through the same funding programme. Some centres have managed to survive after the ten-year period by applying and obtaining funding through a programme different from the one originally used. This highlights how in certain cases, programme beneficiaries do not distinguish different streams of funding according to different purposes, but instead they select the stream of funding in order to establish or renew the existence of a centre. This pattern, however, is not altogether unique in OECD countries. Many research centres funded on the basis of "excellence initiatives" use or combine funding from other sources (OECD 2014b).

16. The Ministry of Education and Research, through the National Council for Science and Technology (CONICYT) has developed three streams of funding to establish research centres:

- The *Research Centres in Priority Areas (FONDAP Programme):* CONICYT initiated FONDAP in 1997 to promote the creation or consolidation of research groups. FONDAP has had four calls for grants until now and has funded 18 centres, 7 of which have already completed their term. This programme funds research centres in selected priority areas, specified in the national call. Priority areas vary depending on the year of the call and can cover all fields of science: from geological science, to biomedicine, social sciences or engineering and technologies. FONDAP centres were created with the following missions: to carry out research at an international standard of quality, to engage in collaborative research, develop advanced human capital, to establish national and international research networks and dissemination of research results. Centres are funded for 5 years and following an evaluation can be renewed for additional five years. FONDAP centres can obtain a maximum funding of 1.5 million USD per year and the universities participating in the centres are required to contribute 10% of the total budget of the centre.

Figure 3. Funding landscape for the research centres

Basal, FONDAP, the Regional Centres and Millenium Centres receive together approximately 70 million USD per year: that is 8% of the national expenditure for STI in Chile



- The *Science and Technology Centres of Excellence (Associative Research Programme)*: CONICYT created in 2009 the Associative Research Program (PIA) by combining two previous programmes: the Bicentennial Program for Science and Technology and the Basal Funds for Scientific and Technological Centres. These 17 centres were created to develop scientific and technological research and develop human capital. These centres distinguish themselves from the ones created through the FONDAP Programme and the Millennium Institutes as they are required to develop activities leading to the application and/or transfer of research results to increase the competitiveness of the Chilean economy. As in the case of the other centres, they are funded for five years with a possible extension for additional 5 years. These centres can obtain a maximum funding of approximately two million USD per year. Additional sources of funding (which can in some cases even double the total grant) include other sources of competitive funding as well as financing coming other programmes such as FONDAP, the Millennium Scientific Initiative, and the Regional Centres programme. Additional funding can also come from national funding agencies such as FONDECYT, FONDEF or CORFO. Finally, the centres are required to raise 20% of the total budget from private and/or international organisations.

- The *Regional Centres of Scientific and Technological Research (Regional Programme*): The Regional Programme of CONICYT initiated in 2002 a funding programme for 13 R&D Centres to promote the development of capacities in science, technology and innovation in the 11 regions outside the Santiago metropolitan area. Regional R&D Centres are co-financed by the regional governments and CONICYT for a period of ten years. Currently this programme supports 13 regional centres located in 11 different regions of the country. Three additional centres have been discontinued. These centres are located in regions outside the Santiago metropolitan area and are created with the aim to promote the development of research, science technology and innovation programmes as well as skills and competencies in thematic areas that are important for the economic development of the regions. As with the other centres, regional centres are established for five years and can be renewed for additional five years. After a ten-year period, they may receive funding for additional three years under special conditions. . These centres may apply and compete for funding from the Basal programme.

17. The Ministry of Economy funds the *Millennium Science Initiative*: The Millennium Science Initiative (MSI) was established by the Ministry of Planning and Cooperation (MIDEPLAN) in 1999 and transferred to the Ministry of Economy in 2011 to promote the development of cutting edge scientific and technological research to contribute to the socio-economic development of the country. MSI funds research institutes on the basis of scientific merit through public grant calls. They also receive funding for two consecutive 5 year periods. The programme currently funds 9 institutes. The maximum funding they can receive is two million USD per year. Millennium Institutes are very similar in their objectives to FONDAP centres, but there is no pre-selection of priority areas. These centres may belong to the following two categories: natural and physical sciences and social sciences. These centres may apply and compete for funding from the Basal programme.

CORFO Centres

18. CORFO is the national economic development agency under the Ministry of Economy. It supports the establishment of International R+D Research Centres of Excellence. CORFO is currently developing a new scheme to fund technology transfer centres. These centres were not included in the analysis.

Public Technological Centres (Other Ministries)

19. Other ministries through special agencies and sectoral funds support Public Technological Institutes. These research centres are permanent centres conducting, in most cases, applied research serving the needs of the Ministry that is responsible for the centres. Some of them are currently under the control of CORFO. These centres were not included in the OECD analysis.

Table 2. Summary table of the funding programmes for research centres and their goals

Instrument /Agency-Program in charge	General Objectives	Expected Results
Basal Financing/ CONICYT-PIA	To promote the creation and/or consolidation of Centers that aim to the development of a) Activities of scientific and technological research of excellence, with an international scope and collaboration, and the training of advanced human capital of excellence to carry out these activities; b) Specific activities leading to the application and/or transfer of researchers results to actions that contribute to the increased competitiveness of the Chilean economy; c) Activities of dissemination and/or extension to other sectors of Chilean society.	- Scientific and technical research of excellence resulting in Incremental quantity of ISI and non-ISI publications and citations as well as participation in international exchange networks. - Human Capital Formation resulting in Master's, Ph.D. theses finished and Postdocs working at the Center. - Technology transfer and links to other economic sectors and Chilean society represented by Incremental quantity of national and international patents applied for or granted, licenses and/or technology transfer agreements, spin-offs and other initiatives with companies, Ph.D. and Postdocs inserted in industry, participation in public policy events, etc. - Support for other research groups. - Activities of dissemination and extension to other sectors of Chilean society.
FONDAP Centers of Excellence/CONICYT-FONDECYT	To promote the creation of Centers that aim to: a) Carry out research of international standards of excellence; b) Engage in collaborative research; c) Develop advanced human capital; d) Establish both national and international collaborative networks and; e) Disseminate the results to the scientific community and society.	• Center establishment, maintenance and expansion done with the contribution of the Funding and Associated Institutions • Implementation of actions conducive to collaboration among a group of researchers and their lines of research Qualitative and quantitative contribution to scientific production in the area • Contribution to the training of doctoral students • Effective transfer of knowledge to other institutions, professionals and specialists in other areas, elementary and high school education, and the community in general • Collaboration and exchange of knowledge with visiting scientists and other researchers. • Attraction, incorporation and retention of new researchers to the Center • Dissemination of results to national media
Regional Centers / CONICYT-Regional Program	To fund the installation of Regional Centers of Scientific and Technological development oriented to promote capabilities of research and formation of critical mass in specific disciplines and topics at regional level.	Centers that become national referents, within a reasonable time frame, due to their expertise in their thematic areas, by: • Focusing their research in relevant topics for the corresponding region. • Developing specific disciplines or areas in the region. • Promoting conjoint activities among participants that will led to reach levels of excellence. Inserting and retaining human resources able to lead research and development activities in the region.

The role of Public Research Institutions (PRIs) in national innovation systems

20. Public research institutions (PRIs) exist in a great variety in different national innovation systems: in some countries such as Germany, Austria and the Netherlands, the Czech Republic and even in France, they are a major pillar of the research and innovation system, in others such as Spain they occupy a smaller role, which could be equally important, e.g. to fill gaps and perform functions in a national innovation system that universities do not cover. Hence, the concrete function and role that PRIs can and should play depends very much on the historical state of development of the innovation system in general (whether it has an advanced, R&D intensive business sector or not, whether it is open to scientific progress and technological change from abroad, etc.) and its individual parts (e.g. the quality of its HEI sector) and the development of their linkages (e.g. the intensity of industry-science collaborations). Lessons from a recent OECD study on the subject matter (OECD 2011) point in the direction that to do so, one would have to respect the various historical trajectories and different levels of development of a national innovation system.

Centres of research excellence

21. Recently, a number of OECD countries have either introduced incentives for the transformation of research institutes to produce scientific output on a higher level of quality (e.g. the German 'Excellence Initiative), created new institutions rather detached from the universities (like the 'Institute for Science and Technology – ISTA' in Austria) or have set up schemes which should incentives research institutions and enterprises to set up joint centres (such as the Competence Centre programme in Austria, Finland and Sweden). In doing so, they have used mixes of permanent and temporary funding of institutions. Where they have developed permanent ones, they have introduced stringent evaluation and assessment criteria as well as performance based funding to ensure that centres remain agile.

22. The development of research "centres of excellence" in Chile has some similarities and differences with initiatives in other countries. As in the case of Chile, within the OECD many "research excellence initiatives" (REIs) that support independent research centres hosted at universities, public research institutes or even in some case, companies, aim to initiate change in the national research landscape. Some countries have established their REIs on a more permanent basis, in which case the term "programme" is more common, while other have clear sunset clauses (see Annex Table 1). Among the common goals are:

- The main objective of the REI to enhance the competitiveness of research.
- Focusing funding on a few institutions, selected on the basis of excellent performance and future potential.
- Selection panels tend to be internationally staffed.
- There is a variation in focus across countries; some centres target the development and training of young researchers; the building of research infrastructure; attracting international talent, and co-operating with industry.

23. The available evidence in OECD countries also suggests that REIs account for a small share of total government funding of public R&D (i.e. HERD plus GOVERD); accounting for more than 3.1% of total government funding of public R&D only in Estonia (Centre of Excellence), Portugal (Multi-year

funding programme), Slovenia (Centre of Excellence) and Ireland (Programme for Research in Third-Level Institutions –no. 4) (OECD, 2014b and Annex 1 at the end of this report).

24. The OECD has found that research excellence funding schemes that fund a relatively high number of centres/initiatives are comparatively less selective, but there are exceptions. Some REIs are more selective but account for relatively low shares of government R&D funding. The German Excellence Initiative is an exception; it is a highly selective funding instrument with a relatively high funding impact and a large amount of annual funding per research centre (OECD, 2014b). Chilean policy around research centres could learn from these experiences showing that a mixture (an 'ecosystem' of different types of institutes) should aim to develop institutions which play different roles, have different portfolios of activities and hence should be funded and assessed differently. A coherent governance structure is a key ingredient to facilitate the development of different types of research institutes.

Rationale and methods for assessing impacts of public sector research Chile[4]

Why should research be evaluated?

25. In comparison to the long history of science and research, the evaluation of such research is a relatively new phenomenon. The reasons why it can be useful to evaluate research can be summarised using the four As.[5] The first is **Advocacy**. Results from the evaluation of research can be used to make the case for science and to justify spending on research. By contrast, the evaluation of research also improves **Accountability**, the second A. In many developed countries substantial amounts of public funding are allocated to research which needs to be held accountable to stakeholders, such as the taxpayer and other donors. The evaluation of research can help to ensure that funding decisions and funding flows are transparent and fair. The third A is **Analysis** and refers more directly to the 'science of science', that is, the aim to identify what works in conducting research. Through the evaluation of research it is possible to get a sense of where research is having an impact and how this has been achieved. In turn, such evidence can inform funding decisions or **Allocation** of research funds, the fourth A. Here, evidence can be used as the basis of funding decisions, for example to highlight areas of research that may need structural improvement. To gather the evidence needed for research evaluation a number of methods are now available which together shed different lights on the performance of research.

Strengths and weaknesses of alternative ways to evaluate research

26. A review by RAND Europe of the different tools available for research evaluation shows that a substantial number of tools are used around the world to assess, review and evaluate research. The main methods of evaluation are summarised in Table 3 together with a brief assessment of their individual strengths and weaknesses.

Table 3. Tools to Assess, Review and Evaluate Research

Bibliometrics: the study of published material that uses quantitative techniques to assess among other things the volume, visibility, citations and collaborations of a particular research unit.
Strengths: widely applicable and comparable; high credibility and a good indicator of the quality of

[4] This section has been written by Dr Steven Wooding and Dr Joachim Krapels. RAND Quality Assurance was provided by Dr. Molly Morgan Jones.

[5] Morgan Jones, M., and J. Grant 'Making the Grade. Methodologies for Assessing and Evidencing Research Impact', in 7 Essays on Impact: DESCRIBE Project Report. Dean et al., eds., Exeter, UK: Exeter University Press, 2013. pp. 25–43

research output Weaknesses: bias against early career researchers; coverage is not global; indicators cannot be taken as direct reflections of 'quality' or 'excellence'
Surveys: includes a range of methods to provide a broad overview of the status of a programme or body of research. Strengths: comparable data across a population; reliable; relatively inexpensive; short turnaround time Weaknesses: limited depth of information; limited adaptability to context; inflexibility, the design cannot easily be changed without risking comparability
Logic models: graphical representation of the causal pathway by which a programme or body of research seeks to generate outputs and impacts. Strengths: shows how a process works; makes explicit links within programmes and projects Weaknesses: can be too linear; are not always applicable
Case studies: in-depth exploration to describe and explain a particular research activity or research outcome. Strengths: provide in-depth understanding of a pathway to an outcome or impact; can accommodate heterogeneous data Weaknesses: can be expensive and time consuming; cannot easily generalise the findings; more subjective than other methods; cannot generally be used to compare large numbers of researchers or research projects
Economic analysis (e.g. cost-benefit; cost-effectiveness; cost-utility): comparative analyses that examine the costs and outcomes of two or more policies, programmes or bodies of research. Strengths: provide clear and structured information for decision makers Weaknesses: data can be difficult to obtain as it needs to be comparable
Peer review: assessment of academic material by other academic reviewers. Strengths: credibility within and outside academia Weaknesses: can be expensive and time consuming; can bias against innovative approaches; potential lack of transparency
Data mining: the process of extracting data from existing databases to generate useful information. Strengths: a way to make sense of large amounts of data; reducing the burden of data collection on informants Weaknesses: highly dependent on the quality of the dataset; changes in data may require changes in data mining techniques; presentation of the results can be challenging
Interviews: method of in-depth data collection through direct interaction with research participant. Strengths: in-depth data; can take context into account; accommodates for heterogeneous data Weaknesses: can be time-consuming; can be difficult to generalise; cannot generally reach a large number of researchers
Data visualisation: tool for data summarisation through the visual representation of the data. Strengths: allows for intuitive exploration of data

Weaknesses: can be challenging to accurately portray data
Site visits: visits to research departments or institutions to provide direct interaction between evaluators and researchers. Strengths: opportunity to speak to all involved; interactive process that allows for multiple parties to contribute Weaknesses: can be expensive and time consuming; can be difficult to generalise
Document review: method to gain a broad overview of the material produced on a particular topic or issue. Strengths: easy to conduct; reducing the burden of data collection on informants Weaknesses: rarely sufficient on its own; limited by the data that has actually been printed

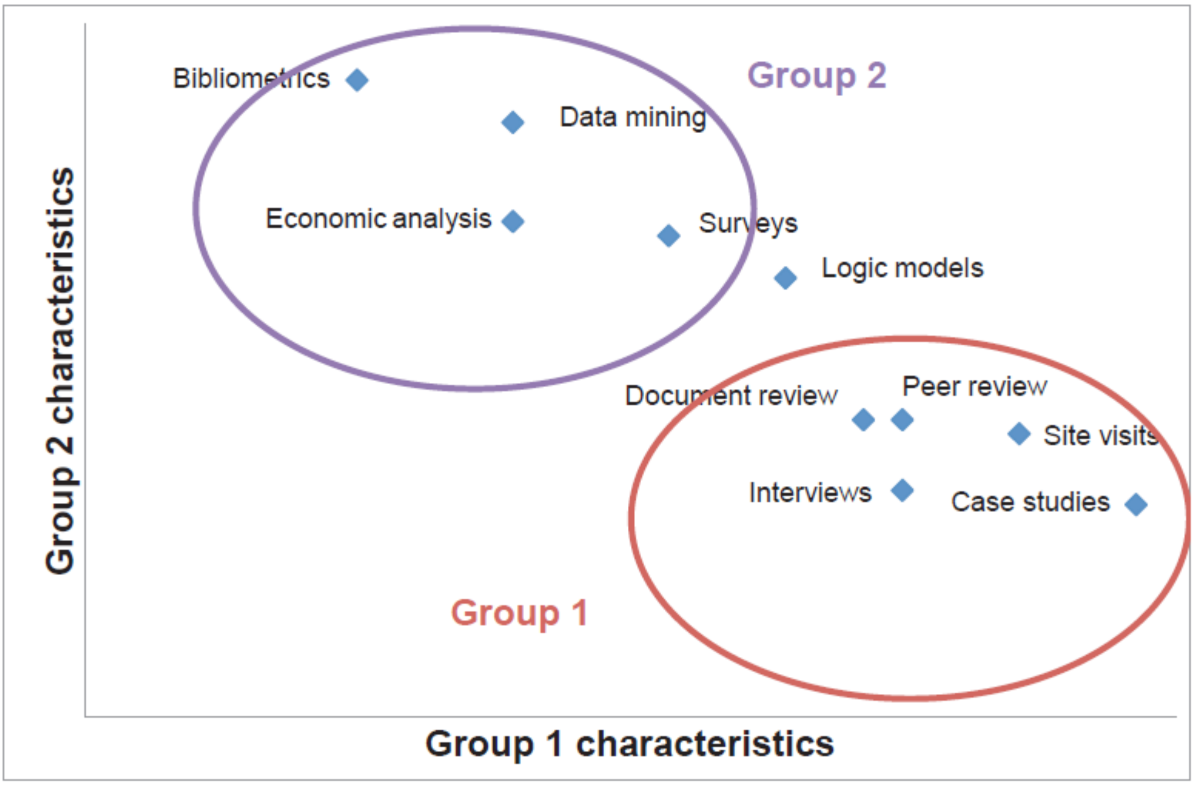
Through a scoring and ranking exercise of the characteristics of the different methods, Guthrie et al (2013)[6] show that the methods can roughly be divided into two groups. The first group consists of methods that are 'formative, flexible and able to deal with cross-disciplinary and multi-disciplinary assessment';[7] whereas the second group consists of methods that are 'scalable, free from judgment, quantitative, transparent, comparable and suitable for high frequency, longitudinal use.'[8] Although exact allocation of methods to groups can be tricky, as there is some variation in the way in which methods are used, Figure 4 shows a mapping of methods to group characteristics based on the scoring exercise.[9]

[6] Guthrie, S., Wamae, W., Diepeveen, S., Wooding, S., Grant, J. (2013) Measuring Research: A guide to research evaluation frameworks and tools. Cambridge: RAND Corporation

[7] Ibid

[8] Ibid

[9] A complete overview of the methodology underlying the mapping of the graph can be found in Appendix B of: Guthrie, S., Wamae, W., Diepeveen, S., Wooding, S., Grant, J. (2013) Measuring Research: A guide to research evaluation frameworks and tools. Cambridge: RAND Corporation



Source: Guthrie, S., Wamae, W., Diepeveen, S., Wooding, S., Grant, J. (2013) Measuring Research: A guide to research evaluation frameworks and tools. Cambridge: RAND Corporation

27. Generally, for the evaluation of research, a mix of methods is most likely to yield robust results and a comparison of existing evaluation frameworks shows that most rely on multiple methods. Some methods however, are more closely related to the reasons for evaluating research than others. Group 2 methods tend to be more effective for Allocation and Accountability, whereas Analysis will rely strongly on Group 1 methods, likely to be supplemented by Group 2 methods. Advocacy generally, can be done on the basis of all data collected.

The Scientific, Social and Economic Impacts of Chilean Research Centres

28. In order to have scientific, social and economic impacts there needs to be an effective research system – one way to judge that is through bibliometrics as outlined in the previous section. A bibliometric assessment of Chile from 2013[10] contains one chapter of data disaggregated by the research centres, but overall does not provide a substantive bibliometric assessment of the research centres. The amount of data that can be taken from this report is therefore limited. Still, the available data suggests that the research centres are some of the top performing research entities in the research system in terms of the level of citations their papers attract, and that the quality of centres is stable or rapidly increasing in recent years.

29. The normalised citation indicator shows that in recent years several centres have produced outputs with normalised citations scores above world average (Figure 5). This means that on average,

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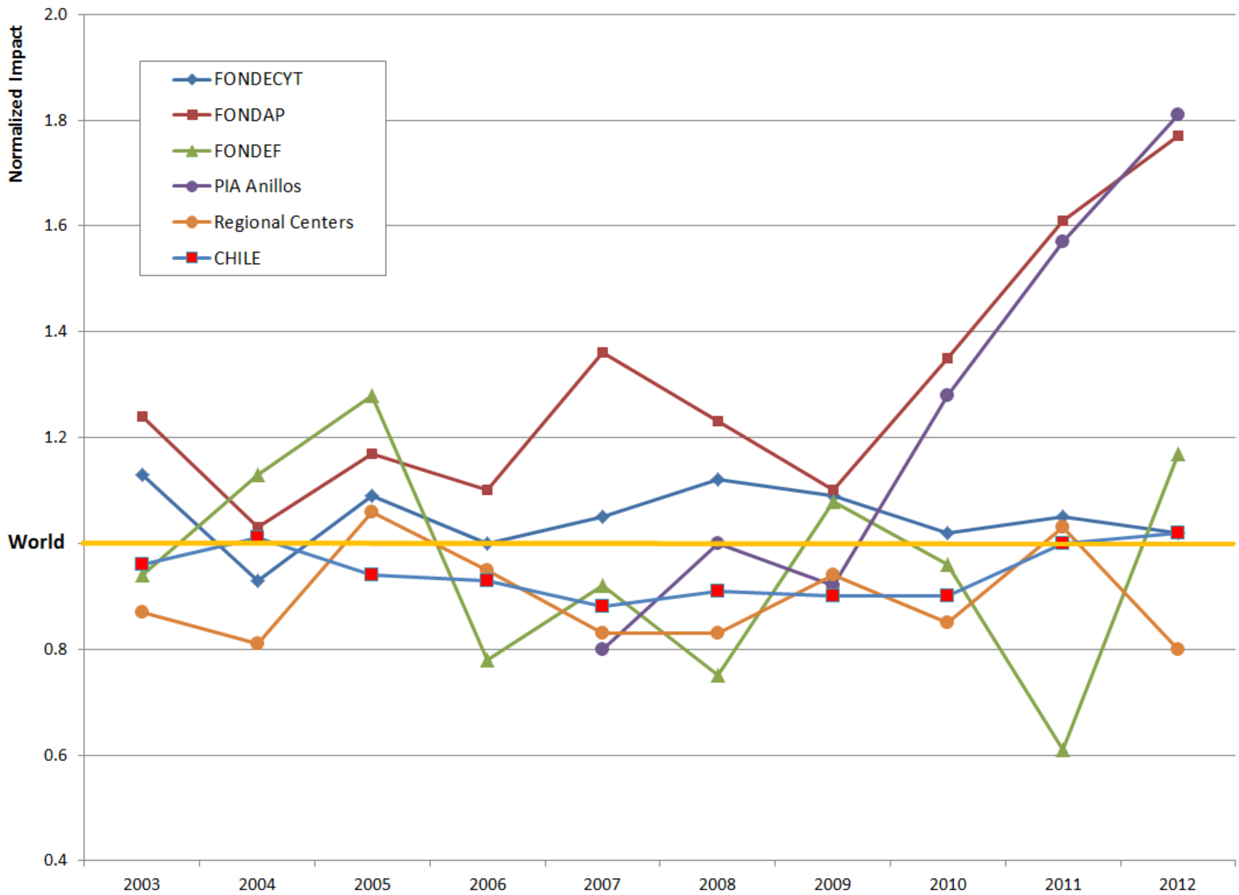
[10] Scimago Lab (2012) Principales indicadores cienciométricos de la actividad científica chilena 2012 - Informe 2014: una mirada a 10 años. Madrid: Scimago Lab

publications from the centres receive more citations than other publications in their respective fields globally. Highest normalised citation scores were recorded in 2012 for Anillos PIA and FONDAP. These score are generally higher than the scores reported by universities in Chile (data not shown), yet there may be some overlap between the papers included in the samples of the universities and the centres.

30. The scores of FONDECYT have remained relatively stable over time, which appears to be in accordance with other bibliometric research conducted on FONDECYT on earlier years which showed that while FONDECYT had been able to substantially increase the volume of publications, it had not (yet) had an effect on research quality as measured by citations.[11]

31. Within the centres there is substantial variation between programmes (Figure 5). Table 4 shows the proportion of research that is classified as belonging to the world's top 10% publications. Scores differ quite substantially between centres, between programmes within centres and between years. Part of this strong variation may be the result of limited number of papers underlying these statistics, as there seem to be years in which no papers were produced. The percentages are reduced when the sample is further limited to only include publications with a lead author from a Chilean institution (Table not shown).

Figure 5. Evolution of the Impact of Chilean Research Centres, normalised by funding programme and year.



Programme	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012

[11] Benavente J.M., Crespi G., Figal Garone L., Maffioli A. (2012) The impact of national research funds: A regression discontinuity approach to the Chilean FONDECYT, Research Policy, Vol.41:8, p.1461-1475

FONDECYT	1.13	0.93	1.09	1.00	1.05	1.12	1.09	1.02	1.05	1.02
FONDAP	1.24	1.03	1.17	1.10	1.36	1.23	1.10	1.35	1.61	1.77
FONDEF	0.94	1.13	1.28	0.78	0.92	0.75	1.08	0.96	0.61	1.17
PIA Anillos					0.80	1.00	0.92	1.28	1.57	1.81
Regional Centers	0.87	0.81	1.06	0.95	0.83	0.83	0.94	0.85	1.03	0.80
CHILE	0.96	1.01	0.94	0.93	0.88	0.91	0.90	0.90	1.00	1.02

Source: Scimago Lab (2012) Principales indicadores cienciométricos de la actividad científica chilena 2012 - Informe 2014: una mirada a 10 años. Madrid: Scimago Lab

Table 4. Evolution of the share of high impact articles by funding instrument and the median in Chile

FONDECYT	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
DOCTORADO	11.65	3.33	6.98	5.56						
INCENTIVO A LA COOPERACION	100		16.67		21.43	28.57	16.67	16.67	100	
INICIACION				33.33	12.50	9.00	10.22	9.88	10.96	8.27
LINEAS COMPLEMENTARIAS	28.13	12.50	5.56	22.22						
POSTDOCTORAD O	18.52	7.32	14.81	10.39	8.47	14.67	8.00	11.88	10.68	8.18
REGULAR	13.01	9.47	12.91	10.68	11.48	12.33	9.96	10.46	12.02	9.63

FONDAP

CASEB	17.86	14.75	18.31	18.03	19.18	11.96	8.27	15.96	14.13	
CEGA									33.33	
CEMC	11.11	10.53	4.17	30.00	13.64	25.93	17.86	20.83	38.46	
CENTRO ASTROFISICA	18.42	12.09	15.65	20.83	19.05	17.54	17.39	20.77	18.18	
CGR									19.05	25.00
CIMAT	16.67	2.44	10.20	3.85	17.24	10.71	17.65			
CMM	19.35	9.30	15.25	4.11	6.25	7.69	7.14	6.82		
COPAS		11.76	7.41	17.24	22.50	14.81	21.43	15.15	5.41	70.37
CRCP	9.09	9.09	13.33	11.11	14.29	45.45	15.38			
CENTROS DE EXCELENCIA									20.19	21.05

FONDEF

INVESTIGACION Y DESARROLLO	3.70	6.06	16.22	6.45	7.69	7.81	4.48	5.88	4.88	15.62

MAREA ROJA	100							100		
TRANSFERENCIA TECNOLOGICA	100						50.00			
TIC-EDU										66.67
Anillos PIA										
ANILLOS ANTARTICOS						33.33	50.00			
ANILLOS CIENCIA Y TECNOLOGIA				11.54	10.00	13.51	10.73	9.79	30.50	
BASAL									34.44	24.78
CENTROS BASALES									18.18	17.50
Centros Regionales										
CONTINUIDAD	0.56		0.22	0.06		0.16	1.10	0.36	1.12	0.99
CREACION	0.87	0.81	1.09	0.96	0.83	0.85	0.93	0.85	1.03	0.75
FORTALECIMIENTO									0.94	0.43
Chile	10.35	9.89	9.99	8.83	9.24	8.97	9.28	9.29	9.77	9.42

Source: Scimago Lab (2012) Principales indicadores cienciométricos de la actividad científica chilena 2012 - Informe 2014: una mirada a 10 años. Madrid: Scimago Lab

32. It is clear from the data provided that the research sector in Chile is small and that the centres make up only part of that. From the evidence gathered through the site visit it is impossible to provide an overall assessment of the social and economic impact of the centres but there were clear examples of entrepreneurial researchers producing wider impacts from their work.

Entrepreneurial examples

33. Assessing social and economic impacts depends on a much wider range of measures which are not currently captured or available for Chilean research centres. However, during the site visit the team saw various examples of research that was having a wider impact on society. Two examples are provided in Box 1.

Box 1. Example of entrepreneurial research centres in the Chilean research landscape

Next generation Wi-Fi antennas

With the rise of electric appliances making use of wireless connections (e.g. the 'internet of things') it is becoming increasingly busy on the traditional Wi-Fi bandwidths (2.4 GHz). To alleviate this problem, researchers at the Cerro Calán laboratory at the University of Chile have been working on a new type of antenna to support Wi-Fi connectivity at the 60 GHz bandwidth. A key problem of current 60 GHz connections is that antennas tend to be very directional. The antenna however, has been developed in such a way that it has an omnidirectional radiation pattern and thus can easily reach any device in a room. Furthermore, the antenna can be manufactured using existing technologies already available to manufacturers.

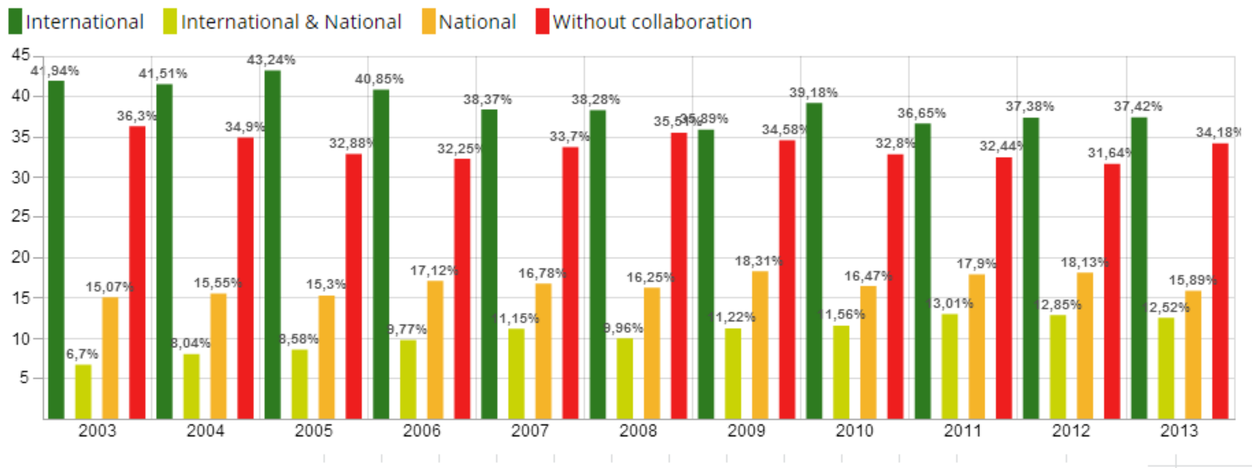
Local bio-fertilizers and bio-pesticides

Chemical fertilizers can damage the environment and harm human health, while imported bio-pesticides may not work in the specific context of Northern Chile. To provide agriculture with the next generation of tools researchers of the Centro de Estudios Avanzados en Zonas Áridas (CEAZA) have worked to develop environmentally friendly fertilizers and pesticides. To create bio-fertilizers researchers use locally-sourced bacteria from crop soil to replace traditional chemical fertilizers. The study of the bacteria has given rise to a regional bio-pesticide bank, which contains a collection of local bacteria that can serve to replace chemical pesticides.[12]

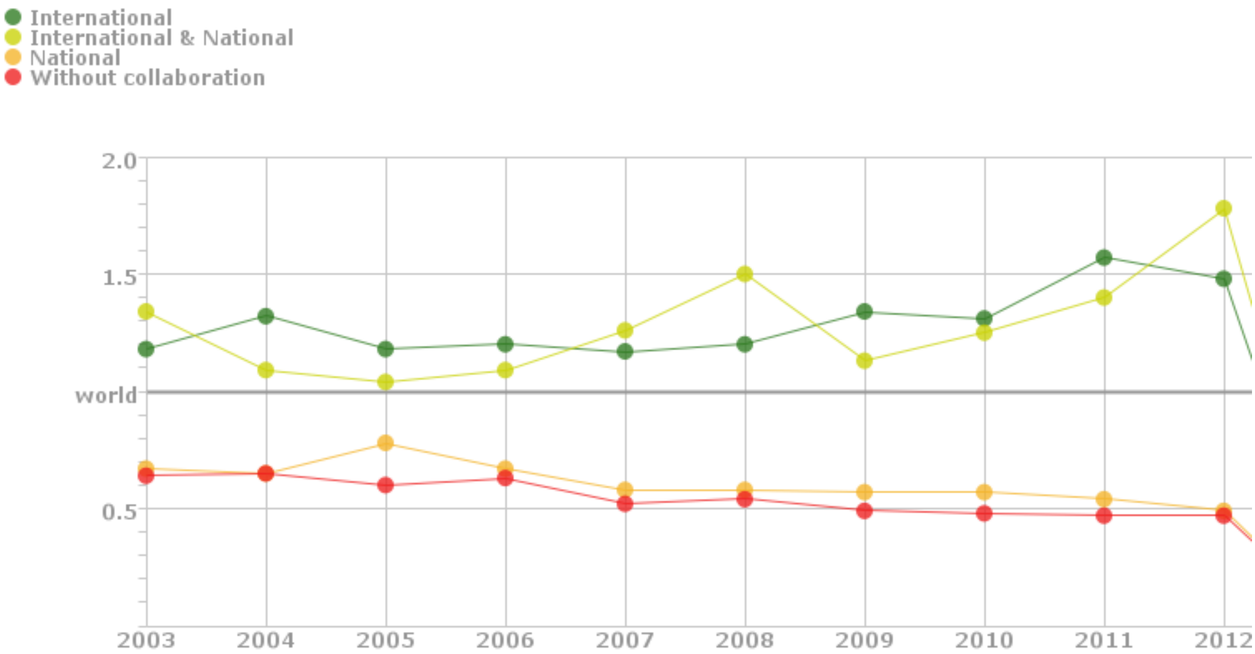
Collaboration by Chilean Research Centres

34. During fieldwork it was observed by Centres that they have explicitly addressed a need to promote collaboration between researchers, as an alternative to a university system that tends to emphasize individual grants and hence reduce the incentive for collaboration. Bibliometric data on collaborations is not available for the centres. Data on collaborations patterns (Figure 6) is confined to the figures for Chile in total. The data shows that most papers are either based on an international collaboration or without any collaboration. In terms of the average normalised citation scores for these papers, highest scores are reported for papers based including both a national and international collaboration, and for papers with just an international collaboration. Finally, during fieldwork there also appeared to be significant collaboration between centres as most centres mentioned collaborating with at least one other centre.

Figure 6. Patterns of scientific collaboration and international visibility by type of collaboration, 2003-2013



12 Information provided by CEAZA



Source: Scimago Lab (2012) Principales indicadores cienciométricos de la actividad científica chilena 2012 - Informe 2014: una mirada a 10 años. Madrid: Scimago Lab

35. There were examples where centres had demonstrated an ability to bring widely differing disciplinary approaches to tackle certain questions. For example, INCAR, the Interdisciplinary Center for Aquaculture Research (Box 2), brings together a wide range of disciplinary approaches to address the issues critical for the sustainable development of Chilean aquaculture. From genomic and epidemiological research on parasites of key food species; to investigations into the biochemistry of salmon diet; through to work on regulatory frameworks that would promote sustainability, and evaluations of the socio-economic impacts of aquaculture on coastal communities.

Box 2. Interdisciplinary Centre for Aquaculture Research (INCAR) model of collaboration

INCAR's Mission is to generate relevant scientific knowledge instrumental to the task of turning aquaculture into an ecological, economic, and social sustainable productive activity, in order to contribute to Chilean sustainable development. Scientific discovery, dissemination of scientific information and technology transfer are at the heart of everything INCAR does. Outreach adds value to the Centre's research activities by helping us build partnerships with stakeholders and policymakers, making INCAR's scientific capabilities and creative activities useful beyond the scope of academia. INCAR's outreach programme and technology transfer activities aims to inspire society and share the information generated by researchers at the Centre.

In order to fulfill its mission INCAR allocates important efforts in developing strong links with Local Governments, Regional Governments and the Central Government as well as with the aquaculture industry, small aquaculture producers and fishers unions. Several of the members of the Centre participate in commissions and committees highly relevant to the design and implementation of public policies. Emphasis is also given to the generation of knowledge by INCAR scientists directly relevant to the development or implementation of public policies. In addition, one of the main bodies of the Centre is the Advisory Panel. The role of this Panel is to link INCAR with key public and private organizations so that the actions of the centrr (research, educational, training, transference, outreach) remain relevant for the private and public stakeholders of Chilean Aquaculture. The Advisory Panel is composed of the following members: Head of the Marine Regional Programme of the Southern Cone of the World Wildlife Fund (WWF); National Deputy Director of Aquaculture of the Chilean National Fisheries Service (Servicio Nacional de Pesca; SERNAPESCA); President of the Association of Mussel Farmers of Chile (AMICHILE); General Manager of the Salmon Technological Institute (INTESAL; this institute is the research branch of the Association of the

Salmon Farming Industry of Chile); International Scientist (Dr. Doris Soto), Aquaculture Management and Conservation Service, Fisheries and Aquaculture Department, FAO; and Director of FONDAP programme, CONICYT.

Aquaculture research in Chile requires being connected with companies related to fish and mussel production, as well as companies that produce services for the aquaculture industry. The INCAR centre has developed formal interactions with relevant companies belonging to the salmon industry and mussel production, including Marine Harvest, Aquainnovo (AquaChile), Abalones Chile, EWOS Innovation and Pathovet. For instance, investigations in the sea lice Caligus are currently carried out between INCAR's researches and Marine Harvest in Puerto Montt (Southern Chile) and EWOS innovation Chile. Likewise, collaborative research related to the capacity of Atlantic salmon (*Salmo salar*) to confront infections of the ISA virus and *Piscirickettsia salmonis* are taking place between INCAR's researchers and technologists from companies such as Aquainnovo (AquaChile) and Pathovet.

INCAR's principles for technology transfer are: (i) Engagement of potential users/entrepeneurs at an early stage in the technological development process; (ii) Use of local knowledge and formal expertise of the potential users/entrepeneurs, (iii) Interdisciplinary Transfer of Technology teams are created ad hoc for each product at due time which includes researchers, user/entrepreneurs and financing expertise. The University of Concepcion (UDEC) has two specialized units in technological transfer: the Development and Innovation Directorate, and the Intellectual Property Rights Unit. Both of these units have vast experience with these issues and are key in INCAR's technology transfer programme. It is important to note that the UDEC is the university that has registered the highest number of invention patents in Chile since the year 2000. The other two Universities participating in INCAR (i.e. Austral University of Chile and Andres Bello University) also have specialized Units for technology transfer and are also an important part of the INCAR strategy on this issue. The interface between INCAR scientists and the technological transfer units of the Universities is done by the INCAR's Director.

Although the Regional Office in Coyhaique (Region of Aysén; where presently 55% of the salmon culture in terms of biomass is taking place in Chile) was only set up in July 2013, the administration has been very efficient in incorporating the centre into local society in the Region of Aysén. For instance, INCAR was awarded direct funding for research by the Regional Government of Aysén (approx. US$200.000 in 2013; US$ 240,000 in 2014). Furthermore, at the national level, INCAR has also been successful in levering additional external funding via concurrent grants both from the public and private sector (US$8.6 million).

INCAR is formally associated with several foreign institutions of excellence: the Observatoire Océanologique de Banyuls/Mer (CNRS, Université Pierre et Marie Curie, Sorbonnes Universites, France); the Bren School of Environmental Science & Management (University of California at Santa Barbara, USA); the GIGA Research Centre of Excellence (University of Liège, Belgium); the Institute for Sociology and Political Science (Norwegian University of Science and Technology, Norway); the Aquaculture Institute (University of Santiago de Compostela, Spain), and the Applied and Fundamental Fish Research Centre (AFFISH-RC) of the University of Liège (Belgium). As an example, during 2014, 13 international scientists visited INCAR for scientific collaboration purposes; they came from the following countries: Belgium, France, Mexico, Norway, Spain and Scotland (UK). In addition, 10 members of INCAR participated in scientific collaborative activities abroad in the following countries: Australia, Belgium, Canada, France, Germany, Mexico, Norway, Sweden and USA. In 2014, of a total of 74 ISI publications generated by INCAR, 23 were joint publications with scientists of international institutions with a total of 27 different international institutions.

Source: INCAR

Technology and Knowledge Transfer in Chile's Centres of Excellence

36. Technology and Knowledge Transfer have been – to a different degree - among the targets of the programmes. Yet any goals in this vein have to be formulated against the background of an industry that to this very day has little R&D capacities itself, relies very much on imported technology and primarily competes on price in mostly basic industries. As they have been quite competitive on this basis, there have not been very much incentives hitherto to switch to a more R&D and knowledge-intensive mode of production. As a consequence, expectations towards the programmes and goals in this respect should be measured by taking into consideration these characteristics of the system.

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37. The current picture on the role of technology and knowledge transfer in the Chilean research centres is a very scattered one: first, this type of activity was not thoroughly defined and recorded nor was it an important evaluation criterion (as these focused predominantly on scientific output) for all the centres. Hence, the team was not able to obtain sufficient empirical basis for a sound overall judgement. Here, the evidence available is almost exclusively anecdotal and gathered from the site visits and discussions. A major observation, pertinent also to other fields of activities of the centres is that they are often asked to perform a great variety of activities (from excellent (basic) research to applied research, education and training to technology and knowledge transfer), while quite often the assessment is primarily on the quality of scientific output. Even in programmes where centres have to earn a share of their income from industry contracts, the assessment and evaluation criteria were said not to fully capture the different types of interactions with industry nor the impact on the enterprise sector.

38. From this starting point, a major recommendation emerges already: define the different dimensions of technology transfer more precisely and make them part of the selection and assessment criteria where appropriate (it has to be tailored to the research area and the potential for industry-science linkage and does not have to be necessarily the same for all centres).

39. Technology and knowledge transfer were among the main goals of a number of centres, especially when there was a clear focus on applied research, as in the Basal centres or the Regional centres, but not confined to this type of centres. Also e.g. in some Millenium Centres there were examples of good interactions with industry (e.g. with pharma companies). When there was interaction with industry, it was mostly through direct contracts (which might be further encouraged by the recently enacted R&D tax measures for outsourced R&D), either with the centre or through funding of individual researchers. The OECD team also found examples of centres pursuing more applied types of research that were the spin-offs from more basic research-oriented ones. A few outstanding centres were reaping between 30 and 50 percent of their income from contracts with industry (e.g. in bio industries and aquaculture). Others receive in kind contributions from industry (e.g. the use of vessels and other infrastructures) to carry out research, the results of which are then shared with companies or made available to the wider public.

40. Some interviewees pointed to the fact that enterprises rarely wanted to engage into knowledge ‘co-creation’ (e.g. through real joint projects), but were rather interested in results from research projects with direct applicability. This was said to be the dominant pattern in sectors like agriculture, fisheries and especially in the interactions with SMEs. If this were a general pattern, in some cases it would be appropriate to assess the centres performance on the basis of income from contracts with industry rather than on the basis of their impact on/contribution to knowledge build-up in the business sector.

41. Some Basale Centres have taken actions to systematize their efforts in knowledge transfer, e.g. through the establishment of technology transfer units dealing, for instance, with IP questions. Others have opted for their IP questions being handled through the universities to which they are affiliated. Reported problems for technology transfer include too high expectations about short-term results (especially from policy side), whereas technology transfer needs sustained cooperation. To this goal, some of the centres involve industry prominently in their boards and advisory panels, which helps shape their research agenda in accordance with industries priorities. Sometimes they involve industry representatives also in the definition and selection of internally funded projects (ex-ante and ex-post) in order to better align the research agendas. These experiences offer some ground for mutual learning, therefore the exchange between the centres about (successful and unsuccessful) practices in technology transfer should further be encouraged and fostered.

42. In some instances, there were individual attempts to get into closer collaboration with industry which would have profited from the availability of a larger framework for collaboration (e.g. cluster initiatives in some regions or national programmes (e.g. for Big Data)), especially when these efforts were

in an early stage, dispersed or still rather remote from market applications (e.g. in the case of areas around radio astronomy and astrophysics).

43. It has to be mentioned that – due to the need to secure funding beyond the fixed life-span of a centre – sometime centres with a very basic research mission somewhat artificially add applied research and industry cooperation to their portfolio of activities even if this is quite remote from their main areas – just to fulfill the funding criteria of specific programmes. To avoid such (at least partially misguiding) incentive structure, funding opportunities should be designed in a more stable and long-term manner.

44. Another channel through which knowledge transfer happens is through training and mobility of personnel. As education and training is part of the mission of some centres, it could be assumed that through this channel knowledge transfer happens, but unfortunately it was impossible to further the analysis beyond the anecdotal evidence provided in the site-visits, as there was no systematic accounting and tracking of the persons trained and the professional career paths of individual researchers. Nevertheless, the personnel of some of the centres (e.g. in bio industries) regularly visit and conduct research with companies. The mining industry was also explicitly mentioned as a sector very interested in recruiting researchers from the centres. During some of the interviews, ad hoc mobility schemes were suggested in order to increase temporary exchange between the centres and industry. Indicators on these aspects of knowledge and technology transfer could also be included in future refinements of the assessment and evaluation criteria, again with different weights for different types of sectors and research areas.

45. Apart from promising examples observed at individual centres, the overall impression was that technology and knowledge transfer is still a major issue in the Chilean innovation system. This observation was corroborated by views from industry which characterized the Centres as still predominantly driven by concerns about scientific quality and output and only to a lesser extent by those of innovation and industry-science relation.

46. In this vein, the recent initiatives by CORFO to set up extension centres might be a promising step forward. Ten such centres have been developed so far and are not meant to have own R&D capacities, but to support technology transfer. Also, another programme is in the making by CORFO: the Technology Centres for innovation which are meant to provide infrastructures for prototyping and close to the market development. In these centres, industry will have a leading role. Topics of the centres will be developed in the context of a Smart Specialisation Strategy, inspired by similar initiatives in EU and OECD countries.

47. These initiatives towards improved knowledge and technology transfer and towards greater impact of the centres on innovation and application in industry, while valuable in themselves, could certainly benefit from a better coordination between the major stakeholders (ministries, regions, universities, industry). The drive towards knowledge and technology transfer activities should be designed without increasing the complexity of the system and with a close eye on the incentive structures for the different centres in order to avoid too much overlap of missions and portfolios of activities.

Impacts of knowledge transfer activities

48. There are many ways to measure technology transfer impacts. Measures of commercial impact include the number of research contracts or collaborations between a research centre and business organisations, the number of start-ups or spin-offs created by a centre, the number of patent applications, personnel exchanges between centres and companies, etc. (OECD 2013b). Societal impacts can, instead, refer to research findings that help address social challenges, such as environmental challenges, natural disaster and risks or ageing population. Other societal impacts can include the transfer of knowledge from

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research centres to students and citizens more in general. These impacts are often only asked for (and promised) on paper, while for the overwhelming majority of the centres, scientific output is the main goal.

49. If policy makers wish to increase these impacts significantly: (i) measures of these impacts should be established by which the performance of the centres should be assessed (which is not currently the case). These measures would have to take into account the specificities of the individual centres and their area of research, however; (ii) centres (or at least a specific type of centre) should be developing their research agenda with higher degrees of industry/society involvement. This holds true also for the centres with a specific regional focus. Their activities ought to become part of 'regional development plans'. In addition, for some very basic research areas, it is less appropriate to require the establishment of business university linkages. Instead other forms of collaboration could be encouraged. For example, many OECD countries have mathematics- in -industry institutes or programmes where mathematics academics engage with industry through workshops. This requires academics that can bridge the gap between the two communities.

50. This coordination should take place in the context of an overall, coherent strategy covering the whole of the PRI (including HEI) sector, as there are co-ordination issues spanning beyond the different types of Centres of Excellence. A broader, coherent strategy for the Chilean system would also include the definition of the role of the existing long-standing Public Technology Institutes (possibly with a closer alignment to governance, funding and evaluation procedures of the Centres of Excellence) as well as the universities. Especially 'younger' universities seem to be more inclined to adopt 'third-mission' policies (e.g. by developing platforms for technology transfer and innovation, but also the 'older' established universities are developing technology transfer offices. These efforts are quite recent and it is probably too early (and certainly beyond the scope of this report) to assess their impact.

Linkages between research centres and universities

51. The relationship between research centres and universities varies according to the different type of research centres. As already mentioned at the beginning of this paper, in many cases research centres have developed within universities and share most of research (and in some cases even administrative) personnel. These research centres have evolved as autonomous research groups within universities. The autonomy from traditional university faculties has allowed research centres to become more agile and responsive to research needs, the recruitment of research staff, the collaboration with other research organisations and, at least in some cases, the business sector. Given the small size of most research centres, being located within a university campus, sharing most of research staff and facilities help centres to acquire visibility and critical mass within the Chilean national innovation system and internationally. In addition, generally research centres gather researchers affiliated with many different universities or research organisations and promote inter-university collaboration.

52. Some research centres - often larger centres with a sufficient critical mass and a more applied research mission- have developed, instead, outside the university and offer, at least in some cases, applied research services to non-university organisations. As more research centres acquire critical mass and develop applied-research activities, it is likely that the number of university-detached centres will increase in the future. See Box 3 for an overview of university-research centres linkages in OECD countries.

Box 3. Linkages between PRIs and universities in selected OECD countries

In many OECD countries, PRIs are increasingly conducting joint research and innovation activities with universities (Technopolis, 2010). Co-operation between the two types of organisations benefits their research activities: universities bring to the table their expertise in fundamental research and education, while PRIs provide knowledge on applied research, technical know-how and infrastructure. Co-operation between PRIs and universities takes place in different ways depending on the different contexts and institutional settings. Personal relationships among researchers with different affiliations also play a role. Examples of linkages include the following:

- *Linkages driven by participation in* ***joint research projects***. Joint research projects between universities and PRIs are the most common and widespread means of co-operation. PRIs increasingly participate in national and international research projects involving one or more universities, which generally lead to joint scientific publications. For example, by the early 2000s more than half of the scientific publications produced by Norwegian PRIs were co-authored with universities; in 2008, Swedish PRIs spent approximately 21% of their core funding on joint projects with universities (Technopolis, 2010); VTT (the Technical Research Centre of Finland) regularly conducts joint research projects with Finnish universities; and the Fraunhofer Institute for Reliability and Microintegration (Fraunhofer IZM) has a long list of university research partners in many Germans cities, as well as in Italy, Spain, the Netherlands, Finland, Japan, Sweden and the United Kingdom (Fraunhofer IZM, 2014).

- *Linkages driven by* ***joint appointments of research staff***. Another factor fostering the establishment of knowledge linkages is the joint recruitment of human resources for science and research. For example, the directors of the Fraunhofer institutes also work as professors at a nearby university; not only does this foster joint project development, it also facilitates organising internships between Fraunhofer institutes and universities, and recruiting PhDs. The largest Norwegian research institute – the Foundation for Scientific and Industrial Research (SINTEF) – and the Norwegian University of Science and Technology share more than 500 R&D personnel (approximately 25% of SINTEF staff) (OECD, 2008). Joint affiliation of researchers at both universities and PRIs is also common practice in Italy and France.

- *Linkages driven by* ***joint supervision of PhD students or post-doctoral researchers***. In those areas where clear synergies and research overlaps exist, joint supervision of PhD students or young post-doctoral researchers is a way to strengthen joint co-operation and research linkages. For instance, students enrolled in PhD programmes at the Swiss Federal Institute of Technology Zurich (ETH Zurich) can carry out their doctoral thesis research either at ETH Zurich or at one of the research institutes in the ETH Domain. Joint PRI/university supervision of PhDs and post-doctoral researchers is also common practice in other OECD countries, such as Norway and Germany.

- *Linkages driven by* ***joint provision of education courses***, including higher education courses and lifelong learning. Germany offers interesting examples of these practices: Fraunhofer IZM supports teaching at the Technical University of Berlin by offering students additional seminars and the opportunity to participate in national and international research projects. The Fraunhofer Academy is the Fraunhofer Institutes' provider of lifelong learning and part-time training for specialists and managers. It offers classes and seminars in co-operation with universities. Fraunhofer Institutes contribute by providing practical experience and knowledge around applied research, while universities provide interdisciplinary knowledge.

- *Linkages driven by* ***joint use of research facilities*** *or the creation of joint research labs*. Some institutions have created joint research campuses and laboratories where researchers affiliated with universities or PRIs can use research equipment, run experiments and generally work together on joint research activities. These are located within the university campus or PRI; alternatively, they are part of larger science and technology parks or innovation clusters. In Norway, the SINTEF headquarters are located on the campus of the Norwegian University of Science and Technology (NTNU) in Trondheim, with the two organisations sharing many research facilities. SINTEF has also strengthened its linkages with the University of Oslo by setting up three joint research centres, on applied mathematics, materials technologies and nanotechnologies. In Finland, VTT and the University of Oulu, together with partners in the business sector, are currently building a 5G Test Network to advance research in the field of wireless communications. In other cases, VTT researchers are hosted by Finnish universities. For instance, the VTT research group on Separation Technology will be located within the Department of Chemistry of the Lappeenranta University of Technology. In Switzerland, competence centres to promote cross-disciplinary research between the ETH Federal Institutes of Technology (ETH Zurich and EPFL Lausanne) and the ETH Domain research institutes have been established.

- *Linkages driven by* ***shared governing mechanisms***. Shared institutional mechanisms that formally govern co-ordination between PRIs and universities are less common. In Switzerland, ETH Zurich and EPFL Lausanne and four associated research institutes are part of the so-called ETH Domain (ETH Domain, 2014). The ETH Board, which brings together individuals from politics, industry and society, steers and provides strategic management of the ETH Domain as a whole. This translates into common strategic objectives across ETH Domain organisations, including providing education to students and permanent lifelong learning to citizens; conducting joint research; providing scientific and technical services; and promoting international co-operation. Other examples of governing mechanisms to steer strategic co-operation between PRIs and universities can be found at the institutional level. In 2005, the boards of NTNU and SINTEF defined a long-term common strategy around several areas, including internationalisation; research and industrial policy; research equipment and infrastructure; and academic priorities.

Source: OECD (2015c), OECD Reviews of Innovation Policy; Luxembourg 2015

The measurement of the impact of Chilean research centres

Assessment of current measurement practices

53. The current measurement of research centres is based on a number of practices. International reviewers are used effectively to evaluate the quality of centres and the review process is serious and shows a level of maturity in that, on occasion, centres are ended because of low performance. In addition, there is an emphasis on the measurement of academic quality through counting the publications in ISI journals or looking at the Impact Factor of these journals. Operationally there seems to be a distinction that basic research is that which can be published in ISI journals and applied research is that which cannot. It should be noted however, that this probably does not provide a useful policy based distinction as much research with clear application is published in ISI journals.

54. The criteria and evaluations are not significantly differentiated in practice between the schemes, such as FONDECYT, FONDAP and BASAL – although they may be in the policy documents which lay out the different priorities of centres. For centres undergoing evaluations, the emphasis placed on different evaluation criteria is often not evident and there appears to be a tendency to collect lots of granular data, for example lists of engagement activities, that may not help an overall assessment of impact, yet is a significant burden on the centres.

55. Whether feedback is provided depends on the scheme. On occasions there is no transparent link between what the performance has been assessed and the outcome – it is not clear how the different activities being carried out by the centres are weighted. For example, a centre may be asked to do three things: academically excellent research, translation of research findings and public outreach. The assessment asks about all three areas, but there is only an overall results, renewal or not, or high level feedback, rather than feedback about each of the three areas.

How to improve the assessment of Chilean research centres

56. A number of recommendations can be made to improve the assessment of Chilean research centres. These recommendations are based on the site visits, previous research and the authors experience of good practice in research centres:

- Ensure that indicators are appropriate to the mission of each funding scheme. If a scheme aims to produce applied research ensure that it is assessed on its success in doing this; conversely, if academic excellence is the intention ensure this is evaluated, or explicitly allow a portfolio approach where centres are rewarded for having a combination of excellent research and research with wider societal impact. It is generally not productive to insist that research has to excel in both basic and applied areas.

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- With regard to research excellence, a continuation of measurement through a combination of international peer review of centres informed by tracking centres publication outputs is recommended. The exact sciences should be assessed using normalised citation metrics rather than impact factors or whether the journal is included in ISI. Previous studies have shown that a concentration on number of publications tends to promote the production of a larger number of lower quality papers [Butler, 2003, Aagaard, 2015, Hodder et al, 2010, Anderson et al 2014]. Ideally information on publications should be collated centrally based on a list of document identifiers (e.g. DOI) provided by the centres.

- Social and economic impact is best measured through a combination of structured case studies of success allied with a set of metrics specific to each centre. A set of structured case studies would also provide an overview of impacts across the programmes and could provide a resource for learning how to promote and support researchers in generating social return. This approach has a long history in small scale evaluations and the large scale Research Excellence Framework assessment of the impact the research in UK universities (Yin, 1988; Manville 2015a, Manville 2015b).

- Given the diversity of centres it is likely to be impossible to develop a common set of metrics for social and economic impact. Furthermore, the development of impact indicators is not easy and there is little agreement within the field on what might constitute appropriate indicators.[13] Still, it might be possible to take the approach of using a systematic collection tool to allow impacts to be collected in an incremental fashion across a wide range of research areas. Examples of such systematic collection tools are ResearchFish[14] and ImpactFinder[15], which are used for example among institutes funded by the Medical Research Council in the UK as outlined below.

- Provide feedback on all evaluations with suggestions on areas of achievement and areas for development. Ideally provide indications of the weighting of different criteria or whether they are applied as thresholds or scales.

57. Across the world research funders evaluate the performance of research centres and not infrequently funding decisions are based on the outcomes. Two particular instances of centre or institute evaluation can be highlighted, from the UK and from The Netherlands, as the frameworks used explicitly incorporate attention to areas of evaluation other than research output (Box 4).

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Box 4. Evaluating research centres: looking beyond publications

UK: Medical Research Council Institutes and Units

Institutes and units funded through the Medical Research Council (MRC) in the UK undergo a substantial review every five years, the quinquennial review (QQR), on the basis of which future funding decisions are based. The reviews include assessments of the 'overall quality, impact and productivity' of the centres, but also assess the institutes and units on knowledge translation, social and economic benefit, training and capacity building and public engagement. The areas on which the institutes and units are reviewed are therefore much broader than just publications. Data to inform the review is taken from the submission by the centre and from Researchfish, an online system that is used by various research funders in the UK to collect information wider outcomes and impacts of funded research. Through a

[13] Morgan Jones, M., and J. Grant 'Making the Grade. Methodologies for Assessing and Evidencing Research Impact', in 7 Essays on Impact: DESCRIBE Project Report. Dean et al., eds., Exeter, UK: Exeter University Press, 2013. pp. 25–43

[14] www.researchfish.com

[15] http://www.rand.org/randeurope/research/projects/impactfinder.html

large number of questions on a wide range of social, economic, policy and other impacts, data is collected on the wider impact of the research. Examples of impacts (Table 5) are:

Table 5. Examples of research impacts		
Policy impact	**Economic impact**	**Engagement Activities**
Citation in clinical guidelines	Patent applications and patents granted	Participation in an open day or visit at my research institution
Influenced training of practitioners or researchers	Spin-outs/new businesses created	A press release, press conference or response to a media enquiry
Participation in an advisory committee	Income from intellectual property	A formal working group, expert panel or similar

Note: examples for policy impact and engagement activities are taken from the *Outputs, outcomes and impact of MRC research: 2013/14 report*, examples of economic activities are taken from the *Economic Impact Report 2013/14*. Both reports apply to the MRC in its entirety, rather than just the institutes and units.

Data is collected from all funded researchers, including the researchers at the institutes and units. In addition and simultaneous to the QQR, the institutes and units are required to develop five-year Public Engagement and Communication Strategies which outline overall communication objectives, target audiences and planned activities related to dissemination.[16] Apart from overviews of activities undertaken, progress towards the objectives is also informed by data from Researchfish.

The Netherlands: Institutes of the Royal Netherlands Academy of Arts and Sciences

The sixteen research institutes funded through the Royal Netherlands Academy of Arts and Sciences (KNAW) are assessed every six years with the use of the Standard Evaluation Protocol. This is a research evaluation framework designed in the Netherlands with the aim to 'reveal and confirm the quality and the relevance of the research to society and to improve these where necessary.'[17] The assessment involves both a self-assessment as well as site-visits by a review committee and is focused on three criteria: (1) research quality; (2) relevance to society; and (3) viability. Research quality relates to the institutes' contribution to scientific knowledge, for example through publications. Relevance to society is defined as 'the quality, scale and relevance of contributions targeting specific economic, social or cultural target groups, of advisory reports for policy, of contributions to public debates, and so on.' Finally, viability refers to the sustainability of the plans for the future.

For the criteria research quality and relevance to society institutes have to select indicators themselves which are in accordance with their strategy and which fit predefined requirements. Evidence to support progress towards these indicators can be qualitative or quantitative, or a combination of both. Examples of indicators of relevance to society provided in the guidance include: Outreach activities, for example lectures for general audiences and exhibitions; Patents/licences; Membership of civil society advisory bodies.

In addition, institutes are required to provide a narrative case study to support the evidence on relevance to society. The narrative should describe the following: (1) the precise work or research projects involved; (2) the individuals involved and their roles; (3) the nature of the research unit's relevance to or; (4) impact on society and the scope of that relevance or impact; (5) how the unit achieved this; (6) whether revenue has been generated.

[16] http://www.mrc.ac.uk/public-engagement/opportunities-for-researchers/templates-and-resources/mrc-qqr-public-engagement-and-communication-planning-amp-assessment-guidance/

[17] https://www.knaw.nl/shared/resources/actueel/publicaties/pdf/standard-evaluation-protocol-2015-2013-2021

How to improve the social and economic impact of research centres

RAND research over the last decade allows for some observations to be made on how impact resulting from research can be increased.[18] These observations mainly arise from studies of medical research[19], however, some of the lessons might be generalised to other areas of research. First, researchers with skills over and beyond strictly academic skills, such as entrepreneurial attitude and strategic thinking, tend to be more successful at the translation of research results into practice. Second, medical researchers focusing on clinical research have a greater chance of impact on patient care within 10-20 years than researchers focusing on basic research. Third, and not wholly surprising but worth mentioning, is that researchers who actively work towards social and economic impacts, rather than just academic excellence, are more likely to have an impact.

With regard to Chilean research centres today, there sometimes appears to be a lack of alignment between the incentives of university affiliated researchers, who often have an almost exclusive focus on the production of papers, and the priorities of the research centres for applied research in order to increase impact. The extent of the problem this causes varied depending on the exact relationship of the centres and the universities and during the field visit the team was told by universities that some were working to change their internal assessments of researchers.

In addition, the necessity for centres to 're-target' themselves to be eligible for different streams of funding leads to centres having to 're-brand' themselves through changing their research emphasis. This can be valuable as it can push basic researchers to develop applied ideas and push applied researchers to address more fundamental questions. It may not be the best mechanism however, to allow institutes to take strategic decisions on how to build on their strengths, while providing incentives for them to diversify and broaden their strengths. For example, centres that are excellent in basic research may reach the end of ten years and will then need to apply to a scheme that has more emphasis on applied research to continue, so they are forced to present their activities to appeal to a new set of more applied criteria. That has the value of making them think more about how to apply their research and that can work well, but it may distract them from doing more excellent basic research.

58. Finally, to illustrate how indicators might be used for the measurement of research activities, output and impact, Table 6 is an example version of a measurement framework or 'dashboard'. The dashboard is structured according to a logic model, one of the measurement tools outlined above, and has four rows with examples of indicators assigned to one of four possible objectives. Indicators have been taken from the example of other research centres and from the wider literature of research measurement indicators.[20]

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59. In the case of researcher centres, **inputs** are likely to refer to the resources that contribute to research and innovation, such as money invested or number of researchers employed. **Processes** are the

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[18] Guthrie, S., Garrod, B., Kirtley, A., Pollitt, A., Grant, J., Wooding, S. (Forthcoming) A 'DECISIVE' strategy for research funding: Lessons from three studies. Cambridge, RAND Europe

[19] Wooding et al (2005) Payback arising from research funding: an evaluation of the Arthritis Research Campaign. Rheumatology 44:1145–1156.

Wooding et al (2011) Project Retrosight. Understanding the returns from cardiovascular and stroke research: Policy Report (MG-1079-RS). Cambridge, RAND Europe.

Wooding et al (2013) Mental Health Retrosight. Understanding the returns from research (lessons from schizophrenia): Policy Report (RR-325-GBF). Cambridge, RAND Europe.

[20] The authors would like to acknowledge the support of Prof Dr Wolfgang Polt, who provided extensive examples of indicators used in research centres across Europe.

activities undertaken to produce the outputs, such as the funding of PhD students and contracting with the public sector. **Outputs** are the direct products produced by the centres. **Impacts** are the consequences on academia, society and the economy of the outputs produced by the centres.

60. The indicators provided are purely illustrative and do not serve as a blueprint or definitive list of indicators for research centres. They can however, serve as the starting point for debates and discussions about indicators for the measurement of research and research impact.

Table 6 : Example of indicators for the measurement of research activities and research impact.

Objective	**Input**	**Process**	**Output**	**Impact**
General development	Total amount of funding available	Proportion of grant applications that were successful	Total number of publications	Proportion of projects that have had a social, economic or policy impact[A]
Capacity building	Number of PIs from Chile	Proportion of PhD applications receiving funding	Number of PhD students trained	Number of PhD students who continue to work in research
Research excellence	Total number of researchers	Proportion of project with national/international collaboration	Normalized citation impact of publications	Number of publications in the global top-10%
Applied research and innovation	Level of access for private sector to research groups	Number of contracts with private/public sector	Number of patents applied for; number of patents granted	Number of spin-offs

Note: A = can be measured using for example ResearchFish[21] or ImpactFinder[22]

[21] www.researchfish.com

[22] http://www.rand.org/randeurope/research/projects/impactfinder.html

Governance of the research centres

61. The OECD team was unable to discern clear governance structures for the centres, specific to individual funding programmes. The research centres reported the use of external governing boards and some managerial structure – some very well defined, using professional expertise (e.g., IMII, UDT) and others relying to various extend on university faculty and other personnel.

62. Reflecting the predominant role of HEI – especially the public universities – in the national innovation system[23], many interviewed Centres are affiliated one way or another with (public) research-intensive universities located primarily in the two largest cities of Chile: Santiago and Concepcion.[24] Exceptions (in terms of affiliation) include INIA[25] and CIAE[26]. While most interviewed Centres are closely associated with universities and operate from within the university grounds, two of them (MIII and UDT) seem to be fairly autonomous fielding their own management and operating in a similar way to private companies. UDT is independent but engages faculty and students from the University of Concepcion extensively. In between the extremes are variations such as INCAR which while based in a university locates most of its people in the field across various smaller offices close to the principal targeted client industry user (aquaculture).

63. However, one is often confronted with the reality that the personalities and interests of the champions of the university-related Centres largely determine what these Centres do and how they behave. An excellent case in point is the comparison between Copas Sur Austral and INCAR. These are two centres of the same university (Concepcion) in the same general industry (marine science and aquaculture) funded by different programmes but seemingly functioning differently from what one would expect by looking at the funding source. Copas Sur Austral is supported by Basal funding but reminds very much of a FONDAP or Millenium centre. INCAR is supported by FONDAP but it operates very much as a Basal centre. As the system matures and grows, sole reliance on the enthusiasm and capabilities of a limited number of individuals is insufficient to scale up the impact of the research centres.

[23] See General Background section.

[24] Twelve without INIA (beyond our scope). CECS is based in Valdivia. Also, the interviewed Regional Centres are, by definition, located in the regions.

[25] By definition, and also an outsider of the examined set of Centres.

[26] A special case, the only centre funded by the specific programme.

Impact of funding on governance

64. The basic principles of the various funding programmes together with the Centres' competencies, determine the prioritisation of the Centers'research and the integration with education. There is quite wide variation in terms of integrating research and innovation not only across but even within individual funding programmes.

65. In research-intensive universities there seemed to be relative harmony between the Centres and the departments, something that has proven to be complex and rather not automatic around the world and, thus, commendable for the Chilean Centres.

66. A major reported weakness was in terms of recruitment: the existence of a drop-dead date (10 years maximum) makes recruitment and retainment of good research personnel difficult, especially as this deadline gets closer.

67. It was the view of the OECD team that the current operational rules are, in the majority of cases, more appropriate for academic research excellence than for commercialisation. There is wide variation of attention to commercialization across Centres, and it does not have to do primarily with the field of concentration or the funding instrument. There were striking differences in this respect even within the same disciplines (e.g., astronomy, marine science and aquaculture). The OECD team is of the view that that the basic differentiating factor is with the leading individuals and their perception of the core mission of the Centre.

Organizational structure and functions

68. Mostly lead researchers serve as centre managers. For most Centres relatively small size and attachment to university faculties makes this practice somewhat innocuous regarding their internal day-to-day operations. It does, however, create serious problems in their relationship with industry. Industry leaders reportedly perceive the Centres as distant from industry's interests, aloof, concentrating on academic research, and unable to address industry's technology needs. While one should not take the expressed concerns of industry at face value[27], the fact remains that centre-industry dialogue seems to be difficult.

69. There were exceptions, of course. Two of the centres visited were much larger than the average (more than 100 employees each) and in different areas (biomedical, chemistry). They are led by professional managers dealing with industry customers directly. Interestingly, both enjoyed an extensive degree of autonomy from universities, even though one of them (IMII) was connected to several universities and the other (UDT) was linked strongly to the local research university but in a manner that maintained its managerial and functional independence. The team also met with a few university-based Centres led by charismatic professors who kept them very much focused not only on high quality research but also on industry and customer needs – e.g., one was based at the Engineering School of the University of Chile (AMTC) and dealt principally with the mining sector and the other was based at the University of Concepcion and dealt with aquaculture (INCAR).

70. Several interviewees expressed satisfaction with the increased flexibility provided by the research centre's sense of autonomy from university faculties in terms of hiring and firing employees. When asked, all interviewees mentioned formal or informal procedures in place for frequent employee performance

[27] Industry's complaints concerning the usefulness of university research and the quality of university education is nothing new all over the world. While it is a view to be respected, the literature has advanced various reasons that moderate the significance of these concerns from the public policy point of view.

evaluation. Unfortunately, there was not much detailed information provided about reward systems, promotion and mobility of research staff.

Priority setting in research centres

71. From the interviews and information collected, it appears formal foresight exercises are completely missing in the setting of strategic priorities. Centres take advantage (with different intensity and rates of success) of evaluation cycles to reconsider their function and research foci. A major weakness of the system is considered to be the lack of consistent formal written response from the funding authorities to the annual Centre reports which creates a lacuna of potentially very useful feedback. This adds to the feature of the system as less mature (in a behavioural sense), depending excessively on the skills and motivation of individuals for success. While a surprising number of such individuals were met despite the small size of the Chilean research system, in a prospective relaxation of the 10-year limit, this feature can be the cause of significant instability.

72. The involvement with industry varies tremendously. This variation could in principle correspond to the differences among the funding schemes supporting the Centres. Surprisingly, however, evidence gathered per interviews did not indicate this as the main reason for very wide variance across Centres in this respect. Instead, the variance seems to basically reflect the convictions and tendencies of the leading Centre personalities. Interviewed FONDAP centers, for instance, could easily be more industry oriented than Basal institutes.[28]

Overall assessment by the OECD review team

73. Research centres have achieved (i) a level of collaboration between Chilean research institutions that was not present before (though sometimes only between universities and not necessarily with other types of research actors) (ii) in some instances they have reached a critical mass in the field they are operating in (though this is not true in all cases that were visited) (iii) flexibilities in terms of career path and skills development that universities found hard to offer. As such they seem to have gained weight in the Chilean research system and raised the quality of its scientific output and visibility.

74. Some centres have purposes and missions that are much more long-term than the current funding period allows for (e.g. because they provide and produce knowledge that will have to be produced on a public basis for the Chilean Research and Innovation System for a foreseeable future, like Oceanographic, astronomy or research on climate change to name just a few examples). Those centres could be transformed into permanent institutions, but should be subject to periodical strategic in-depth assessments. This is not necessarily true for all centres, as some of them might find different topics as the field of science evolve or the development of technological change takes new turns. For these centres, the system of limited time frames (which could be the same as it is now or an extended one for example to (6+6) 12 years) maybe a more appropriate solution to maintain dynamism and competition.

75. Researchers tend to adopt an opportunistic behaviour in their search for funds: they frequently apply where funds are available addressing their area(s) of concentration where they believe they can have an impact. The specific characteristics of the funding instrument occasionally appeared to be an afterthought. Researchers cannot be blamed for such practice, of course, since (a) the small size of the system "forces" them to behave opportunistically in some ways and (b) the drop-dead feature of the system creates incentives for team reshuffling in order to continue research activities beyond the 10-year period under a different hat.

[28] Case in point the differences among the three centres interviewed in Concepcion.

76. Chile suffers from a geographical overconcentration of research and economic activity in the Santiago area, with only few natural-resource-based industries spread around in other parts of the country in significant volumes (mining, agriculture, aquaculture). Three of the four types of Centres that were examined tend to grow organically (FONDAP, Basales, Millennium) while the fourth is explicitly designated for the regions (Regional). It is thus not surprising that research Centres tend to gravitate around the geographical areas of the main research-intensive universities and/or industry, namely Santiago by and large and Concepcion a distant second.

Policy Implications for the Chilean research system

- The eleven national strategic (sectoral) programmes of Chile[29] are not necessarily represented in the existing research centres. This is simply a reflection of the fact that the centres in the examined programmes grew organically on the basis of research strengths in the Chilean universities. Combined to the current overall paucity of resources spent on R&D (0.4% of GDP) in the country, this may invite a closer look by policy decision-makers to misalignments in terms of allocating future resources.

- Significant uncertainty was expressed by all regional centre representatives about their future prospects. They basically felt that they are falling between the cracks in a system that calls for collaboration between national agencies based in Santiago and regional governments facing a much different reality as well as exhibiting lesser awareness of the need for scientific research. The absence of strong research universities in the surroundings of regional centres only compounds the problem. They feel they are underfunded and strongly recommend to be evaluated on significantly different criteria than the rest three types of centres.

- Not new to the Chilean policy decision makers, the centralisation around Santiago creates a "black hole" of sorts sucking the vast majority of research expertise and resources. This is a chicken-and-egg problem which, until solved, points at the necessity of regional research centres in order to create a culture of research in the local governments and industries and thus a pool for more substantial operations in the regions.

- The system is very new and still relatively immature. Nonetheless, there was consensus among interviewees from all sides that the research centre funding scheme has worked overall in terms of raising academic excellence, improving scientific training, and setting the foundations of a deeper scientific culture.

- Young as it is, and based largely on the only sector of traditional research strength in the Chilean economy (universities), the system has yet to establish a convincing link between public research and business organisations. The vast majority of firms operate in mature technology sectors and do not "pull" domestic innovations.To the extent that they have technical needs, these are very specific – characteristically, the representative of a major international mining company mentioned that their needs are so specific as to differ even between individual mining sites – and are thus bound to not be addressed adequately by academically-based research teams.

- Still, several (at least four) of the interviewed centres showed acute awareness of market needs and willingness and ability to address them. Operational and managerial autonomy from affiliated

[29] Andres Zahler "Research and Innovation: Challenges for Chilean Innovation Policy", Ministry of Trade and Industry, 2015.

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universities in the case of one Basal (UTD) and one Millenium case (IMII) seems to be related to this. One or more exceptional personalities in the leadership of a FONDAP case (INCAR) is probably a very significant factor in the third. A well-established industry base and positioning in the most reputable engineering school in the country probably have much to do with a fourth case (AMTC). All four cases are on the upper range in terms of size.

- A number of issues raised in the academic literature in relation to the internal governance and research management of university-based cooperative research centres is quite relevant to the Chilean research centres. In particular, analysts have anticipated significant interdependence between the characteristics of the research undertaken by a Centre on the Centre's governance and structural dynamics. The relationship between the two is multidimensional and requires significant attention both in setting up and in evaluating the Centres' performance.

Recommendations from the review team

77. Based on the observations of the field visit and drawing on previous research, a number of policy recommendations can be made with regard to the future of the research centres. Elimina

- *Rationalise or differentiate the funding schemes for centres*, possibly allow multiple awards to be held in parallel. If the schemes were rationalised a single scheme could be set up that funded centres carrying out different missions from blue skies research to application and allowed them freedom to balance the portfolio of their research. Alternatively, a series of schemes with clearly different priorities and evaluations could be set up but centres could be allowed to combine funding from those different schemes to manage their portfolio of research.

- *Diversify the strategic objectives in the different funding streams and reflect the diversification in the design of evaluation metrics*. Many of the existing programmes to fund research centres have very similar aims, and even if the criteria are differentiated on paper, this does not appear to be reflected in practice. Many research teams having established research centres are little aware of the different requirements of funding streams and select specific programmes on the basis of which one has open calls when the funding is needed. After a period of experimentation, now the system is ready to consolidate and differentiate the various funding streams, for example by introducing clear criteria to fund basic vs. applied research. The evaluations of the centres should then be linked to the objectives of the selected funding stream (for examples: basic vs. applied research; regional impact vs. scientific excellence; knowledge transfer activities, etc.). In addition, centres in different thematic areas may behave differently and this needs to be reflected in evaluations: centres active in very theoretical areas are less likely to attract the same level of private funding or to develop spin-offs or patents than those centres active in applied research areas where business/research linkages are much easier to establish.

- *Extend the ten-year funding period only to those centres that satisfy excellence criteria after a rigorous round of evaluation.* The 5+5 funding period has been a good mechanism to develop research centres and critical mass around specific areas in the Chilean innovation system. However, temporary funding does not allow a long-term strategic development of research centres. Moreover, the 5+ 5 limit does not seem to stop centres from continuing their activities. At least in some cases, the 5+5 limit obliges research teams to look for other possible funding streams after the ten-year period in order the maintain the centres operational. However, not all centres have necessarily to become permanentstable. The decision of making a centre permanent continuous needs to happen after a rigorous evaluation of the centre activities. Centres active in strategic scientific fields for the Chilean national innovation system or centres demonstrating a clear impact on the Chilean economy and society are good candidate to become permanent, but the same is not true for centres active in less strategic thematic areas.

- *Insisting on the linkages between centres and the private sector is important but a broader vision of valorisation should be adopted*. Linkages between research actors and the business sector do not seem to be widespread in Chile. Developing further funding programmes to strengthen those linkages is certainly recommended however the design of those schemes should adopt a broad vision of valorisation: business/science linkages primarily happen through people and skill development and cannot be measured only by the number of spin-offs and patents. A discussion with business sector stakeholders as well as those centres that have successfully developed well-established cooperation with the business sector can provide suggestions on how to structure and implement these programmes.

- *Allow longer-term established centres to develop teams offering managerial support.* The long-term strategic development of research centres may require a better structured division of labour between researchers and professional research managers.

- *Preserve the seriousness of evaluation and willingness to act on the findings*. Both to improve the performance of centres through feedback and ensure resources are focussed on the most valuable and high performing areas of research.

- *Reduce the burden of assessment.* The burden of data collection can be substantial for centres and it will be good to ensure that the data collected is collated in ways that make analysis easy and provide comparability over time.

ANNEX 1.

Annex Table 1. Research Excellence Initiatives/Programmes in other OECD countries, selected examples

Country	Name of REI	Official acronym / short form	Start date	Maximum funding period for individual research unit
Australia	ARC Centres of Excellence		2003	7 years
Austria	Competence Centres for Excellent Technologies	COMET	2008	K1: 7 years K2: 10 years[1]
Canada	·Canada Excellence Research Chairs	CERC	2008	7 years
Denmark	Investment Capital for University Research	UNIK	2009	5 years
	Danish National Research Foundation Centers of Excellence	DNRF Centers	1993 (several rounds of applications)	5 to 6 years
Estonia	Development of Centres of Excellence in Research		2001	7 years
France	Initiatives d'excellence ("Excellence Initiatives")	n/a	2009	n/a
Finland	Centres of Excellence	CoE	1995	6 years
Germany	Excellence Initiative (Programme of the German Federal and State Governments to Promote Top-level Research at Universities)	n/a	2006	5 years
Germany-Hesse	State Initiative for the Development of Scientific and Economic Excellence	LOEWE	2008	6 years
Germany-Saxony-Anhalt	Networks of scientific excellence	n/a	2005	5 years
Germany-Thuringia	Thuringian Agenda for Supporting Excellent Research "ProExcellence"	ProExcellence	2008	5 years

Country	Name of REI	Official acronym / short form	Start date	Maximum funding period for individual research unit
Ireland	Programme for Research in Third-Level Institutions	PRTLI	1998	6 years, 5 years after 2010
	Centres for Science, Engineering and Technology	CSET	2003	10 years
Japan	Global Centres of Excellence Programme	Global COE	2007	5 years
	World Premier International Research Centre Initiative	WPI	2007	15 years
Korea	Brain Korea 21 Programme	BK 21	1999	7 years
	World Class University Programme	WCU	2009	5 years
Netherlands	Bonus Incentive Scheme	BIS	1998	No maximum set (will change in future)
New Zealand	New Zealand Centres of Research Excellence	CoRE	2002	6 years
Norway	Norwegian Centres of Excellence	CoE (SFF)	2002	10 years
	Centres for Research-based Innovation	CRI (SFI)	2007	8 years
	Centres for environment-friendly energy research	CEER (FME)	2009	8 years
Poland	Leading National Scientific Centres	KNOW	2012	5 years
Portugal	Multi-Year Funding Programme		1996	5 years
Russian Federation	National Research University initiative	NRU	2008	10 years
Slovenia	Centres of Excellence		2009	4 years
Spain	Severo Ochoa Centres of Excellence		2011	4 years
Sweden	Strategic Research Areas	SRA	2010	5 years
	Linnaeus Grants		2006	10 years
	Berzelii Centres		2006	10 years
United States	Science and Technology Centres	STC	1989	5 years

Note: 1. The COMET scheme is divided into funding lines, The line “K1” has a slightly different structure than the line “K2”.
Source: OECD (2014*b*) based on an OECD/RIHR questionnaire to government ministries.

ANNEX II. ASSESSMENT CRITERIA FOR PUBLIC RESEARCH INSTITUTIONS (PRIS) IN NATIONAL INNOVATION SYSTEMS – EXAMPLES FROM EUROPEAN COUNTRIES

78. Table 2 in this Annex II presents assessment criteria for the performance of PRIs are presented, based on recent evaluations and programme designs. As these examples are primarily focussing on centres (and programmes) which have as one main mission technology transfer and science-industry co-operations, they might provide a good ground for the further development of the assessment and evaluation criteria of the Chilean centres in this respect.

79. The programmes and centres scrutinized include examples from from Austria, Finland and Germany – countries with a considerable track record in funding industry-science relations and respective evaluations. They include:

- The Austrian Competence centres programmes: Kplus und Kind/net and their successor programme COMET. For the former, the results of an ex-post evaluation is publically available, for the latter a monitoring exercise is concurrnent.
- In addition, specific (additional) KPIs for an individual centre in the above mentioned programme, namely the Austrian Centre of Industrial Biotechnology (ACIB) are described
- Another major programme which was aimed at fostering collaboration between academia and business was 'Take OFF', the programme for Aeronautics in Austria, which can serve as a good example for the evaluation of links between programme goals and the indicators chosen to measure impact
- The study on the Research Studios Austria (a network of centres aimed to spur technology transfer) is remarkable insofar as it tries to position the RSA in the whole 'eco-system' of centres in Austria and elaborates the performance indicators with a view to benchmarking the RSA with other institutions
- The 'Leading-Edge Cluster' competition Germany and its evaluation also combines assessment and indicator design on the level of the programme with that on the level of individual centres. Insofar it is a good example of co-development and assessment of both level.
- The same holds true for the evaluation of the SHOK (Strategic Centres for Science, Technology and Innovation) programme and centres in Finland: assessment criteria had to be developed both for the individual centres (paying due respect to their differences) as well as overall indicators for the programme.

80. The table below provides not only the different types of impact indicators (economic, social) used, but also for which type of evaluations they were used and the source of the data (e.g. whether they were gathered from programme participants, secondary sources and the like). Links to programme descriptions as well as evaluation reports are provided in the table.

81. Main observation related to development of indicators to capture technology transfer, intensity of science-industry collaboration and economic/societal impact include:

- Indicators should be designed right at the outset of the programme – also those against which centres and programme will be evaluated ex-post
- They should be made transparent to all stakeholders
- They should include a mix of qualitative and quantitative assessment tools and criteria, e.g. expert/peer panels alongside indicators which should be designed in a way as to be useful also for the current management of the centres and the governance of the programme

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- When it comes to impact assessment on economy and society, a variety of techniques have to be employed (control-group approaches, social cost-benefit analysis etc.) for which provision in budgeting of evaluations have to be made.

Annex Table 2: Indicators for Impact Assessment of PRIs

Programme /Centre	Impact indicators				Used for … evaluation			Source of tl
	economic	*Description of the indicator*	*social*	*Description of the indicator*	*ex-ante*	*interim*	*ex-post*	
Austrian Centre of Industrial Biotechnology ACIB			H-Index	The h-index is an index to quantify an individual's scientific research output. A researcher's h-index can be calculated manually by locating citation counts for all published papers and ranking them numercially by the number of times cited. However, Web of Science, Scopus and Google Scholar can also be used to calculate an h-index.		x		Web of Scie and Google
http://home.acibhome.at/			Trend H-Index	Emphasizes recent citations, identifying researchers who are 'hot' now, even if their articles were are old.		x		Web of Scie and Google
	Average number of inventions per year	The indicator measures the innovation activity of the centre.				x		Data provic center.
Take Off (Austrian Programm for Collaborative Research in Aeronautics)	Interdependencies between value added and components of final use	The input–output model is used to represent the macroeconomic effects of changes and final use in one or more sectors.					x	Statistical (
http://www.kmuforschung.ac.at/images/stories/Forschungsberichte/2015/EVAL_TakeOff_final.pdf	Number of product innovations and products new to the market	This indicator measures innovative capabilities within the sector and the center itself.					x	Data provic center; Cor Innovation
https://www.ffg.at/take-off	R&D expenditures	As research funding is increasing R&D expenditure, the indicator additionaly measures the impact of effects on production and employment.					x	Data provic center.
	Use of technological results created out of research projects.	The indicator measures the technology transfer between and within the sector.					x	Data provic center.
			Transfer of research results into practice	Demonstrates the pan-European and international visibility of the centre.			x	Survey
			Successfull participation in national, regional and EU frameworkprogrammes.	Demonstrates the pan-European and international visibility of the centre.			x	Data provic center.
			Number of junior employees remaining at the centre.				x	
Competence centre Kplus und Kind/net	R&D expenditures	Measures the effect of the intensity of R&D expenditures.					x	Statistical (
http://www.bmvit.gv.at/innovation/strukturprogramme/downloadsstruktur/kprogramme_eval_endbericht.pdf	Number of FTE; Number of researchers	Measures the R&D personnel intensity					x	Statistical (
	Effects of the programme/ce	Difference-in-Differences Estimation of the effects of the programme/center					x	Statistical (

Programme /Centre	Impact indicators				Used for ... evaluation			Source of
	economic	*Description of the indicator*	*social*	*Description of the indicator*	*ex-ante*	*interim*	*ex-post*	
Research Studios Austria RSA	Number of employees	Positioning and visibility of the centre within the national institutional landscape.				x		Data provi center.
http://www.researchstudio.at/en	Financial mix (share of public institutional funding, public targeted funding, public competitive R&D, public fees for services, public contract income, private contract income, other income, income from IPR)	Positioning and visibility of the centre within the national institutional landscape.				x		Data provi center.
	Number of cooperation projects	Demonstrates continuity at financing and partnership.				x		
	Recruitment of business partners (for universities)	Positioning and visibility of the centre within the national institutional landscape.						
	Proximity and access to business partners	Positioning and visibility of the centre within the national institutional landscape.						
	Innovation activities of SMEs	Positioning and visibility of the centre within the national institutional landscape.						
COMET			Number of scientific publications in peer-reviewed journals	Demonstrates the pan-European and international visibility of the centre.		x		Data provi center.
https://www.ffg.at/en			Number of scientific publications in other journals	Demonstrates the pan-European and international visibility of the centre.		x		Data provi center.
			Number of publications for the general public	Demonstrates the pan-European and international visibility of the centre.		x		Data provi center.
			Number of PhD graduates	This indicators measures the impact of the centres funding.		x		Data provi center.
			Number of bachelor or master theses	This indicators measures the impact of the centres funding.		x		Data provi center.
	Number of patent applications	Measures innovative output				x		Data provi center.
	Number of new methods and testing procedures.	Measures innovative output				x		Data provi center.
	New norms and standards and market-leading concepts	Measures innovative output				x		Data provi center.
	Pilot applications and prototypes	Measures innovative output				x		Data provi center.
	Number of spin-off companies					x		Data provi center.
	Number of follow up projects with business partners					x		Data provi center.
	Number of new or significantly improved products or processes, organisational and marketing innovation	Measures innovative capabilities within the sector and the center itself.				x		Survey
	Share of turnover from product innovations (as a % of total turnover)	Measures innovative output				x		Survey
	Several questions with regard to the motivation and expectation from the companies participating in the programme, see SHOK.	Measures organisation/ firm's expectations from participation in the programm						Survey

Programme /Centre	Impact indicators				Used for ... evaluation			Source of t
	economic	*Description of the indicator*	*social*	*Description of the indicator*	*ex-ante*	*interim*	*ex-post*	
Leading-Edge Cluster competition Germany			Number of employees in the cluster management (no. of part time employees)	This indicators presents the organizational structures of the cluster.		x		Expert inte surveys co of the accc evaluation the Stifter Wissensch Stifterverb communit advocating improvem German ec research la Mannheim Panel - the Innovation
http://www.bmbf.de/en/20741.php ?hilite=leading+edge			Management structures: new, continued or reorganised activity	This indicators presents the organizational structures of the cluster.		x		
			Precursor initiatives: same/ different technology fields	This indicators presents the organizational structures of the cluster.		x		
			Development of research stuff in cluster-specific R&D-activties	This indicators measures the already noticeably impact of the leading -edge cluster competition.		x		
			Number the actors collaborating with others (% of actors)	This indicator measures the degree to which actors are involved in innovation co-operation. Complex innovations, in particular in ICT, often depend on the ability to draw on diverse sources of information and knowledge, or to collaborate on the development of an innovation.		x		
			Size of R&D cooperation networks	Networks of companies who significantly increased their R&D cooperation activities through the participation in the LECC.		x		
			Recruiting of highly qualified personnel	Measures the impact of the leading -edge cluster competition in terms of attractiveness of the region and the cluster itself.		x		
			Number of medium skilled workers	Importance of the regional labour market can be explained by differences in the composition of actors or differences in the technological focus.		x		
			Number of employmees in knowledge-intensive activities (% of total employment)	Knowledge-intensive activities provide services directly to consumers, such as telecommunications, and provide inputs to the innovative activities of other firms in all sectors of the economy.		x		
			Number of bachelor or master theses within the cluster	This indicators measures the impact of funding by the LECC on Project level.		x		
			Number of dissertations within the cluster	The indicator is a measure of the supply of new second-stage tertiary graduates in all fields of training. This indicators measures the impact of funding by the LECC on Project level.		x		
			Number of public-private co-authored research publications within the clusters	This indicator captures public-private research linkages and active collaboration activities between business sector researchers and public sector researchers resulting in academic publications.		x		
			Number of international publications within the cluster	International scientific co-publications are a proxy for the quality of scientific research as collaboration increases scientific productivity. This indicators measures the impact of funding by the LECC on Project level.		x		

			Local supply of highly skilled employees	This indicators measures the impact of funding by the LECC on Project level.		x		
	Development of (growth rate) R&D expenditure in the business sector (% of GDP)	The indicator captures the formal creation of new knowledge within firms.				x		
	Development of (growth rate) R&D expenditure of the actors (%turnover)	Improved R&D activity by the actors is an already noticeably impact of leading -edge cluster competition.				x		
	Sales from new products generated by innovation activities in the clusters					x		
	Number of spinoffs of technology-oriented companies	This indicator measures the degree of research-based spin-off companies in the clusterspecific technology field.				x		
	Growth rate of the technology transfers between RTOs and companies					x		
	Number of founders and tenders by selected comparable programmes	This indicator shows comparable cluster organisation in Europe by itsstructure of funding organisation, funding period, total funding, definition of goals, Policy-Mix, terms of refernce, institutional setting, target group, eligible costs.				x		
	Number of patent applications	This indicators measures the impact of funding by the LECC on Project level.				x		
	Number of patent applications	This indicators measures the impact of funding by the LECC on Project level.				x		
	Inventions directly reflected by the patent application					x		
	Product- and Process innovations, which are clearly assigned to the respective cluster	This indicators measures the impact of funding by the LECC on Project level.				x		
	Number of companies introducing product or process innovations	Technological innovation, as measured by the introduction of new products (goods or services) and processes, is a key ingredient to innovation in manufacturing activities. Higher shares of technological innovators should reflect a higher level of innovation activities.				x		
	Number of actors/ companies innovating in the region (% of SMEs)	This indicator measures the degree to which companies, that have introduced any new or significantly improved product or production process, have innovated in-house.				x		
	Generated inventions from LECC Projects	This indicators measures thei impact of funding by the LECC on Project level.				x		
	Visibility of the region	Measures the impact of the leading -edge cluster competition in terms of attractiveness of the region and the cluster itself.				x		
	R&D activity in the region	Measures the impact of the leading -edge cluster competition in terms of attractiveness of the region and the cluster itself.				x		
	Amount of venture capital (% of GDP)	The amount of venture capital is a proxy for the relative dynamism of new business creation.				x		

Programme /Centre	Impact indicators				Used for ... evaluation			Source of t
	economic	*Description of the indicator*	*social*	*Description of the indicator*	*ex-ante*	*interim*	*ex-post*	
SHOK	Increased international visibility and reputation of the organization as an R&D service provider	Organisation/ firm's expectations from participation in the programm.					x	An online s undertaker explore the perception experience SHOK instr the compa research or involved. The data us evaluation documenta annual rep data, onlin other relav addition of documenta interviews undertaker centers and on strategi
http://www.shok.fi/en/shok-in-english/	Commercialization of research findings in form of patents/ licenses and other IPRs	Organisation/ firm's expectations from participation in the programm.					x	
http://www.tekes.fi/globalassets/julkaisut/licence_to_shok.pdf	Commercialization of research findings in form of entrepreneurial and spin-o activities	Organisation/ firm's expectations from participation in the programm.					x	
	Increased access to specific know-how (e.g. technology, market)	Organisation/ firm's expectations from participation in the programm.					x	
	Development of new products and services for new or existing national & international markets	Organisation/ firm's expectations from participation in the programm.					x	
	Re-orientation of the product portfolio of the firm	Organisation/ firm's expectations from participation in the programm.					x	
	Growth in the research capacities for programm related topics	Organisation/ firm's expectations from participation in the programm.						
	Increased recruitment of qualified national/international personnel (e.g. academic, from industry)	Organisation/ firm's expectations from participation in the programm.					x	
	Improvement of knowledge and qualification of the research personnel	Organisation/ firm's expectations from participation in the programm.					x	
	Access to new research infrastructure (laboratory, testing facility etc.)	Assessment of the relevance and availability of services from the Center-organization/manage					x	
	Deepening core-competences (technology, knowledge) (firm-level)	Organisation/ firm's expectations from participation in the programm.					x	
	Developing of new fields of R&D competences (firm-level)	Organisation/ firm's expectations from participation in the programm.					x	
	Improving existing scientific competencies (increase number of peer reviewed publication and conferences)	Organisation/ firm's expectations from participation in the programm.					x	
	Developing of new fields of scientific competencies	Organisation/ firm's expectations from participation in the programm.					x	
	Strengthening knowledge and technology exchange with different stakeholders	Organisation/ firm's expectations from participation in the programm.					x	
	Increased number of joint PhD supervision (industry-university)	Organisation/ firm's expectations from participation in the programm.					x	
	Increased funding opportunities (industry & academia)	Organisation/ firm's expectations from participation in the programm.					x	
	Improved quality of the training of employees	Organisation/ firm's expectations from participation in the programm.					x	
	Increased collaborations with national/international firms	Organisation/ firm's expectations from participation in the programm.					x	
	Increased collaborations with national/international research organizations	Organisation/ firm's expectations from participation in the programm.					x	
	Increased development of prototypes, demonstration activities and pilots	Organisation/ firm's expectations from participation in the programm.					x	

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