Chapter 3

Transforming industries: Perspectives on solar energy, mining and agro-food in Chile

The shifting global geopolitical and technological landscape coupled with changes in consumers' preferences is opening up a window of opportunity for Chile. The country could transform its economy, enlarge its knowledge base and increase productivity by leveraging on its natural assets in new, more innovative ways. However, the world is moving fast and opportunities will not be permanently available. To tap into them, a strategic approach and a shared vision between government, business and society is needed. Chile has started to do so through strategic initiatives that identify future opportunities and clarify gaps to be addressed. This chapter presents the Chilean experience in solar energy, mining and agro-food; in each case it presents a snapshot of key trends and future scenarios, developed through multi-stakeholder consultations, it describes the current policy approach and it identifies reforms to move forward.

Unleashing the potential of solar energy in Chile

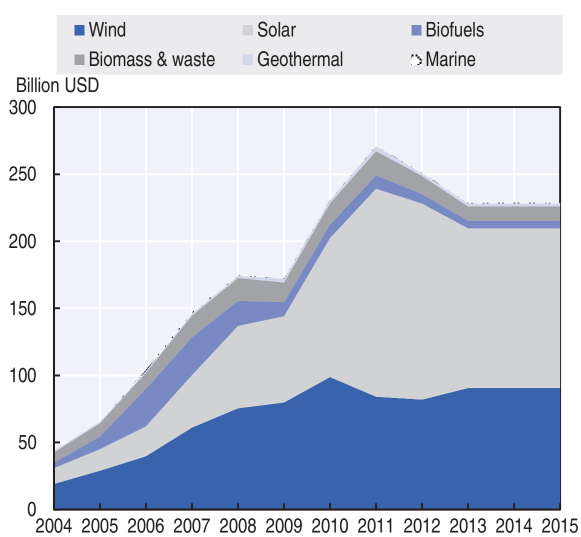
This section presents a snapshot of the rise of solar energy in the country and summarises the results of public-private consultations on the opportunities presented by solar for Chile. It describes the current policy approach and it identifies reforms to move forward.

Solar energy is gaining ground in Chile

Solar energy is becoming globally competitive thanks to falling prices. Investment in the development of renewable energies globally is surpassing investment in fossil fuel technologies (OECD, 2018; IEA, 2016). Of these, investment in solar has increased the most since 2010. Global investment in the installation of solar technologies accounted for half of all investments in renewables in 2016 (Figure 3.1). High investment by the People's Republic of China in solar photovoltaic (PV), and the consequent reduction in module prices, have contributed to the substantial reduction in the cost of generating energy from the sun (Mathews, 2017). Solar energy has experienced the biggest price decline of all renewables, with the levelised cost of electricity (LCOE) for PV falling by 67% between 2010 and 2016 (Figure 3.2). Prices, of course, vary by location: China and India have the cheapest energy from solar PV (with a weighted average LCOE of utility-scale solar PV at USD 0.09 per kWh in 2016, down 68% from 2010). In OECD countries the average cost is USD 0.14 per kilowatt-hour (kWh), which has fallen by 61% since 2010. In the rest of the world the average cost is USD 0.17 per kWh. In 2016, the cheapest prices for PV were awarded through public bids in Abu Dhabi (USD 0.024 per kWh), Mexico (USD 0.026 per kWh) and Chile (USD 0.029 per kWh). The global record of USD 0.017 per kWh was registered in the second quarter of 2017 in Dubai (IEA, 2017b).

Figure 3.1. **Solar is capturing the lion's share of global investment in renewables**

Global investment by renewable energy technology, 2004-15

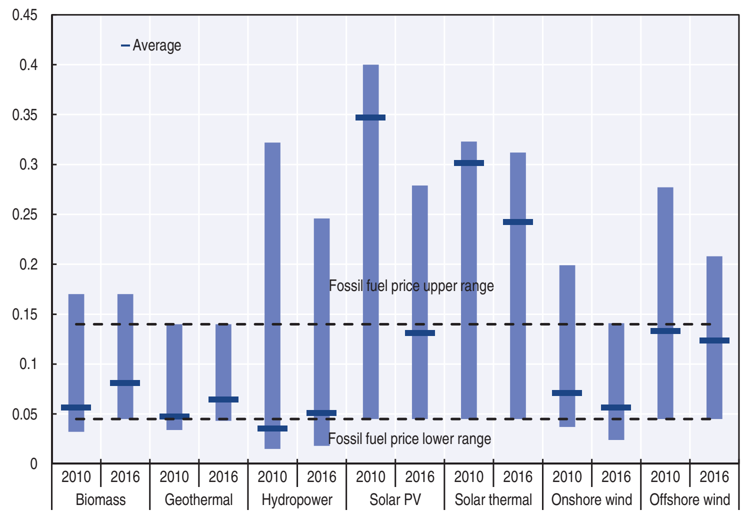


Source: Authors' analysis based on IEA (2016), "Statistics", and Global Trends in Renewable Energy Investment 2016. https://www.iea.org/statistics/

Chile is currently Latin America's main solar energy producer. Since 2008, non-conventional renewable energies (NCREs) have been gaining ground in Chile.[1] Biomass was the first to appear on a large scale, accounting for 175 megawatts (MW) in 2009, rising to 343 MW in 2013. Wind and solar then started to gain ground. By 2017, solar represented 43% of the NCRE capacity installed in Chile, at more than 1800 MW (Figure 3.3). Today, Chile leads solar energy production in Latin America, accounting for almost half of the total installed capacity in the region (Figure 3.4). This expansion has been coupled with record world prices. Indeed, in 2017, Chile and the United Arab Emirates earned the world record for the lowest prices, signing contracts for solar PV projects at below 0.03 USD/KWh for 2018 (IEA, 2017b).

Figure 3.2. **Solar PV has seen costs fall the most, 2010-16**

Average, minimum and maximum price, constant USD (2016)/kWh, by renewable energy source

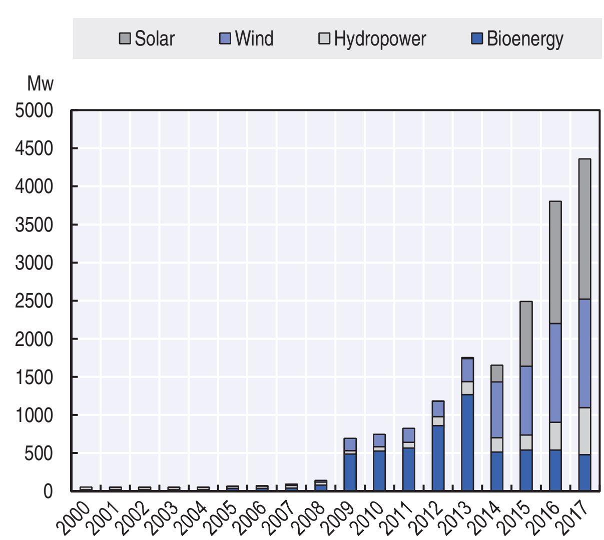


Note: Dashed line shows fossil fuel upper and lower price ranges.

Source: Authors' analysis based on IRENA (2017), IRENA Dashboard, http://resourceirena.irena.org/gateway/dashboard/

Figure 3.3. **Solar leads in installed electricity capacity in Chile, 2000-17**

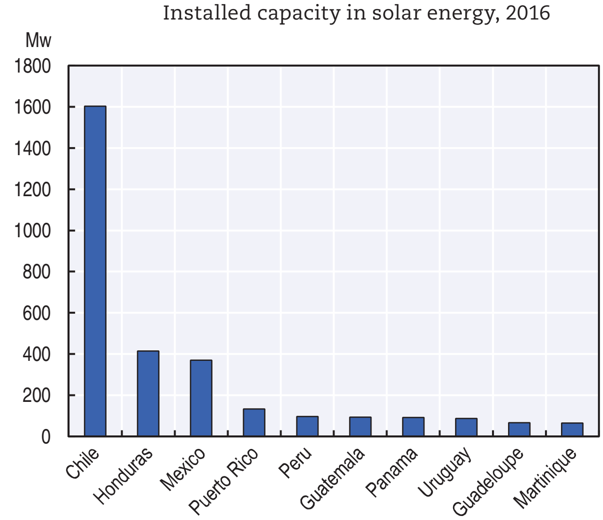
Non-Conventional Renewable Energies (NCRE) installed capacity by energy type



Source: Authors' analysis based on IRENA (2017), IRENA Dashboard, http://resourceirena.irena.org/gateway/dashboard; and official information from the Ministry of Energy of Chile, 2017.

Figure 3.4. **Chile is Latin America's biggest solar energy producer**

Installed capacity in solar energy, 2016



Source: Authors' analysis based on IRENA (2017), IRENA Dashboard, http://resourceirena.irena.org/gateway/dashboard/

The rise of solar in Chile can be explained by its energy policy, which has offered incentives for renewables since 2008, combined with the global evolution of the industry. Chile was a relative latecomer in introducing targets for renewable energy in its domestic energy policy (Table 3.1). Law 20.257 of 2008 implemented a target for electricity generators and/or suppliers to source at least 5% of their electricity needs from NCREs through a Renewable Portfolio Standard (RPS). Having reached the 5% target in 2013, Chile revised it upwards, requesting companies to source at least 20% by 2025 (Law 20.698). The target has been reached again in 2017, eight years in advance. The year 2015 marked a landmark in the energy policy approach as the country approved an energy policy with a road map towards 2050. This agenda was developed, for the first time in the country, through a multi-stakeholder consultation process that defined a shared national long-term vision for energy. In this policy, renewables matter not only as major sources of energy, but also as development drivers (Box 3.1).

Box 3.1. **A shared long-term vision: the Chilean Energy Agenda 2050**

The vision of the national policy for 2050, approved in 2015, is a landmark in Chile's energy policy-making process. Building on previous efforts, it is the first to set shared, agreed long-term goals. The agenda was based on the proposal of a committee chaired by the Minister of Energy, and composed of 27 ministries and representatives of key public institutions, trade associations, civil society and academia. The agenda rests on four pillars:

1. Supply quality and security
2. Energy as a driver of development
3. Environmentally-friendly energy
4. Energy education for efficient use of resources.

The agenda sets ambitious goals, including generating at least 60% of energy from renewables by 2035 and 70% by 2050, and reducing greenhouse gas emissions (GHG) by 30% by 2030.

Source: Ministry of Energy (2017a), "Chile, Energy 2050: Chile Energy Policy", http://pelp.minenergia.cl/

Table 3.1. **Chile came relatively late to the renewable energy agenda**

Energy policies for renewables, selected countries, 1978-2016

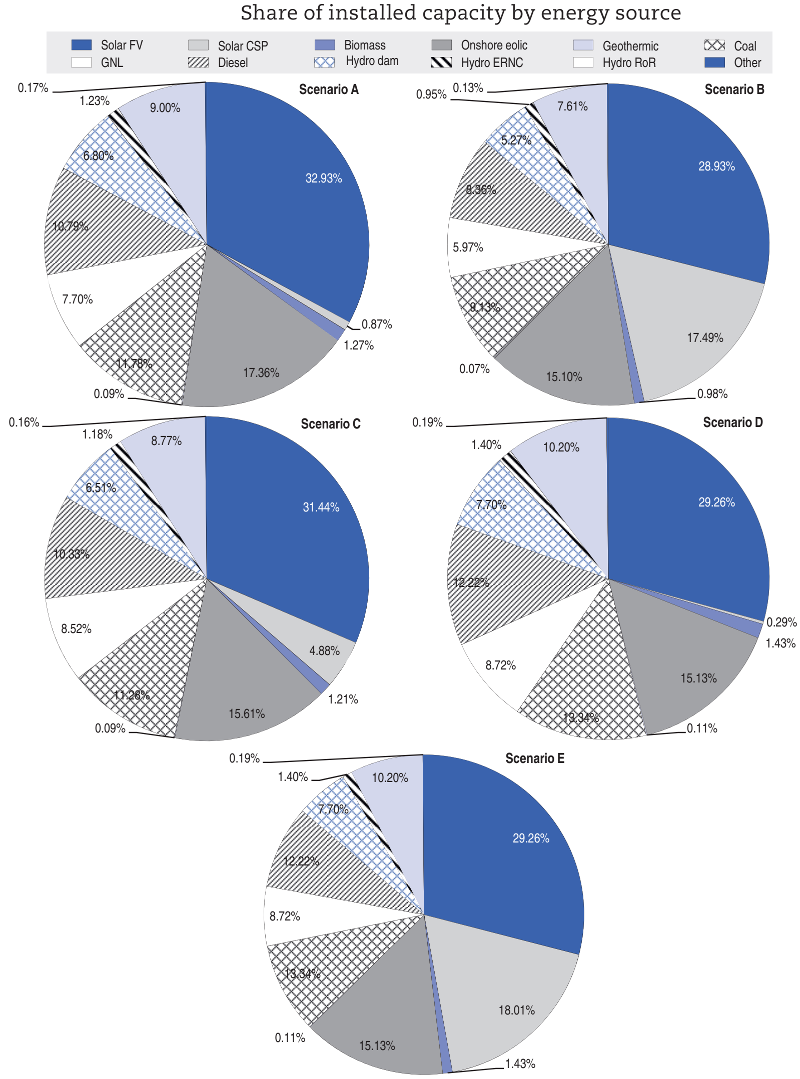
Year	RPS (quota policies)	Feed-in tariff
1978		United States
1983	United States	
1988		Portugal
1990		Germany
1991		Switzerland
1992		Italy
1993		Denmark; India
1994		Luxembourg; Spain; Greece
1997		Sri Lanka
1998		Sweden
1999	Italy	
1999		Norway; Slovenia
2001	Australia; Flanders (Belgium)	
2001		Armenia; France; Latvia
2002	United Kingdom; Wallonia (Belgium)	
2002		Algeria; Austria; Brazil; Czech Republic; Indonesia; Lithuania
2003	Japan; Portugal; Sweden	
2003		Cyprus; Estonia; Hungary; Slovak Republic; Republic of Korea
2004	Poland	
2004		Canada; Israel; Nicaragua
2005		China; Ecuador; Ireland; Turkey
2006		Argentina; Pakistan; Thailand
2007	China	
2007		Albania; Australia; Bulgaria; Croatia; Dominican Republic; Finland
2008	Chile; India; Philippines; Romania	
2008		Iran; Kenya; Liechtenstein; Philippines; San Marino
2009		Japan; Serbia; South Africa; Ukraine
2010	Republic of Korea	
2010		Belarus; Bosnia and Herzegovina; Malaysia; United Kingdom
2011	Albania;	
2011		Ghana; Montenegro; Netherlands; Syria; Viet Nam
2012	Norway	
2012		Jordan; Nigeria; State of Palestine; Rwanda; Uganda
2013		Kazakhstan; Pakistan
2014		Egypt; Vanuatu
2016		Czech Republic

Source: based on Sawin, J., K. Seyboth and F. Sverrisson (2016), REN21 Renewables Global Status Report 2016, www.ren21.net/wp-conten

All scenarios estimate that solar will be the leading energy source in Chile by 2045. The Ministry of Energy is scanning for possible futures. It has developed five future scenarios based on global trends and domestic conditions, and the parametrisation of multiple factors, including future demand, rate of technological change, environmental externalities and cost of investment (Ministry of Energy, 2017). In all five scenarios, solar dominates the domestic energy matrix of the future, ranging from 30% to 47% of the installed capacity by 2045 (Figure 3.5). PV is identified in all scenarios as the main solar energy type. Only two scenarios identify concentrated solar power (CSP) as another important form of solar energy generation. This is due to the high projected increase in energy demand (3.2% annual average) derived from the expansion of electro-mobility, the electrification of heating in apartments, and a high penetration of air cooling in the residential sector, coupled with the expected increase in the price of fossil fuels (for example, assuming a price for diesel oil of around USD 1 200/m3 in 2045).

Figure 3.5. **Five scenarios for energy in Chile by 2045**

Share of installed capacity by energy source



Note: CSP (concentrated solar power); LNG (liquefied natural gas), NCRE (non-conventional renewable energy). The scenarios are based on the parametrisation of six factors: social licences, energy demand, technological change in batteries storage, environmental externalities, cost of investment in renewables, and cost of fossil fuels. The combination of each factor along three different parameters led to the definition of five scenarios for 2045. For further information visit http://pelp.minenergia.cl/

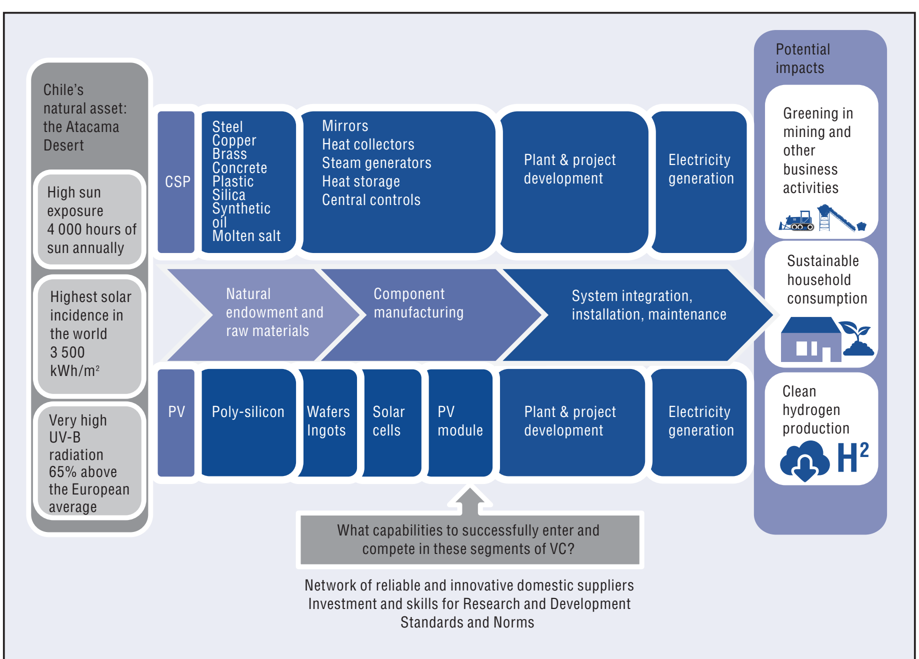
Source: Authors' analysis based on Ministry of Energy (2017b), Long-Term Strategic Planning Database.

Solar could be the next driver of development

Chile's natural endowments, together with falling renewable energy prices and ongoing technological changes, open up a window of opportunities. Solar energy can help not only to green the energy matrix, but also to transform the economy and its growth model. The Atacama Desert in the north of Chile has a surface of 105 000 km2, receives 4 000 hours of sun a year, has the highest solar incidence in the world at 3 500 kWh/m2 DNI (direct normal irradiance), and UV-B radiation 65% above the European average. These unique geographical and geological conditions give Chile the opportunity to benefit from very cheap solar electricity, as well as thermal energy (Figure 3.6). In addition to the positive impact on mining and manufacturing, cheap electricity could also alleviate Chile's dependence on fossil fuel imports, which represent 70% of the country's total primary energy supply (in 2016). These are dominated by petroleum products (41%), followed by coal (19%) and natural gas (10%).

PV and concentrated solar power (CSP) are the two main technologies in the solar industry, and entail different value chains. The core component of PV is its cells, which are made out of a semiconducting material that transforms sunlight directly into electricity, whereas CSP generates electricity by using sunlight to heat a fluid that is then used to produce electricity. CSP needs greater economies of scale than PVs; the latter can be installed in smaller projects. Chile imports most PV modules from China, which accounted for 96% of the total imported PVs in 2016. Unlike PV technology, CSP has the advantage of being able to store energy. A CSP plant is currently under construction in the Atacama Desert; upon completion the plant is expected to have 110 MW of installed capacity and 17.5 hours of thermal storage. World-leading companies are planning to set up more CSP plants in the north of Chile. In addition, there are prospects for hydroelectric seawater pumped storage; combined with these new solar photovoltaic plants, Chile could be guaranteed a reliable, sustainable and permanent source of electricity.

Figure 3.6. **The solar value chain: natural endowments and potential impacts of PV and CSP in Chile**



Source: Authors' analysis based on the outcomes of the Round Table on the Future of Solar Energy in Chile organised in the framework of the PTPR of Chile, hosted by CORFO in Santiago, Chile in June 2017.

Solar energy could also open up new opportunities for learning and innovation. Solar energy is the result of high value-added activities (Figure 3.6). Unlike fossil-fuel based energies, solar is not extracted through drilling or mining. It involves a manufacturing value chain and can be produced and used locally (Mathews, 2017). In PV, the space for local manufacturing suppliers is quite limited, as the industry has already developed based on PVs imported as ready-made packaged solutions into the country. Nevertheless the development of specific applications for high temperature and highly irradiated zones could be an opportunity for Chile to expand its knowledge base and take its first steps along the value chain. CSP offers more scope for business opportunities as the design, deployment and maintenance of CSP technologies require scientific and technical capabilities that are specific to the context in which the plants operate. In addition, in the case of Chile, existing technologies and business models need to be adapted to the specific local solar irradiation patterns in order to increase their profitability and effectiveness.

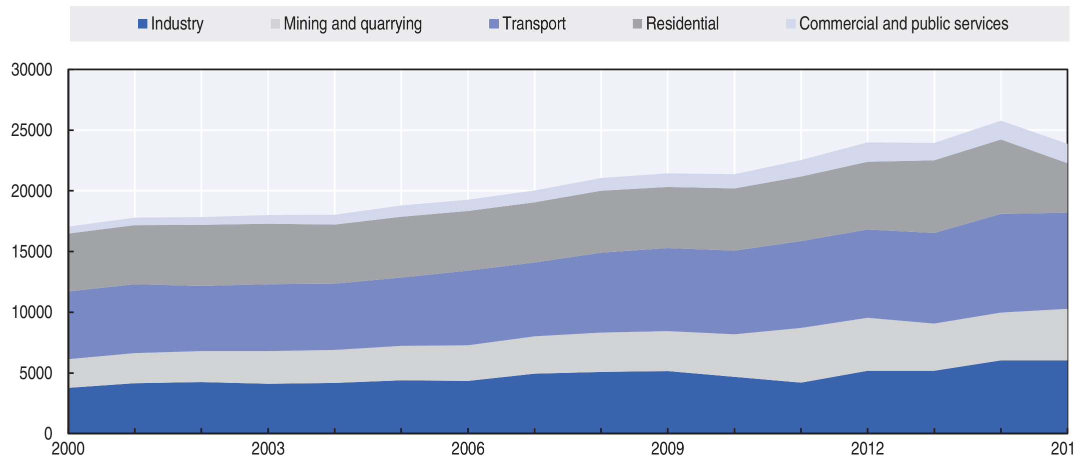
Innovating and identifying solutions for solar energy will require shared efforts from all actors in the ecosystem, including energy providers, academia and government. Chile already hosts world-leading energy providers, including Engie, Enel, SanEdison, SENER, Acciona and Abengoa. These players are important investors in Chile. Investments in electricity and energy projects accounted for 46% of total greenfield investments and 15% of all jobs created in Chile between 2013 and 2016. Over the same period, greenfield investments in solar accounted for USD 8.1 billion (Chapter 1). Establishing partnerships with these players could open up important innovation opportunities. For example solar thermal technology has been used worldwide for sanitary heating, but industrial applications that require higher temperatures (i.e. smelting) are emerging thanks to developments in CSP technologies. This is an important field of innovation as it applies to areas such as use, transfer and storage of heat for industrial processes and buildings.

Chile is exploring opportunities to strengthen its learning and knowledge base through global partnerships. Since 2011, Chile has been hosting the Solar Energy Research Centre (SERC) – a network of researchers and institutions focusing on solar energy. SERC is actively engaged in international research co-operation, in particular with the International Energy Research Centre (ISC) in Germany; Plataforma Solar de Almeria (PSA) in Spain; and NREL, Argonne and SANDIA labs in the United States. Germany, which has a long-standing tradition of cooperation with Chile in multiple economic development fields, has set up a partnership with CORFO to establish a research centre in the country as part of the Chilean government support for strengthening applied research. The Fraunhofer research centre (FCR-CSET), hosted by the Catholic University of Chile, plans to carry out applied R&D on electricity storage and heat as well as water treatment.

Solar energy could help to green mining in Chile. There is growing global demand for sustainable production. Greening the economy implies involving all actors in the value chain, from raw materials to final assembly. The pressure to green mining will increase. In fact, leading world companies are already investing in this direction. This implies searching for solutions to reduce environmental impact, including the use of renewable energies to cope with mining's growing energy demand. In Chile, in 2000, the mining industry was responsible for 13% of domestic energy consumption; that share reached 20% in 2015 (Figure 3.7).

Figure 3.7. **Final energy consumption by economic activity, Chile 2000-15**

Ton of oil equivalent (toe)



Source: Authors' analysis based on IEA (2017a), "Statistics", https://www.iea.org/statistics.

To realise the potential benefits of participating to the solar value chain, Chile faces several barriers (Table 3.2):

1. **Building capabilities in a rapidly changing technological environment takes time** and requires benefiting from global research and production networks. It has taken China more than two decades to become the main producer in solar PV modules (Quitzow, 2015). Production and trade linkages between Chinese manufacturers and German equipment makers and buyers, and R&D partnerships with global research centres, have played important roles in deepening China's technological capabilities in the industry (Quitzow, 2015). Chile could build on its reputation as a reliable partner and scale up its efforts to co-operate within the region and globally in this field.
2. **Chile is a latecomer with respect to leading countries and global competition to lead in the value chain is high**. Asian countries account for 90% of global PV module production, and China alone represents 65% of word PV module production (Sawin et al. 2016). China, Germany, the United States and Japan are the world leaders in this value chain. They all have major leading firms, and have accumulated a high critical mass of technological and innovation capabilities, as well as skills and infrastructure. In PV, 14 out of the top 20 patents owners are from Japan and new entrants come mainly from China and Korea. In CSP, 6 of the top 20 patents owners are from Germany and 9 are from China (Helm et al. 2014). Strategic partnerships with investors could open opportunities for developing capabilities in specific segments of the value chain, as in Morocco and India.
3. **The current status of the power grid connection and low spot prices could limit future investments and hamper future development**. Chile's solar industry has expanded quickly but power grid infrastructure has not developed at the same pace. The lack of adequate transmission capacity in the northern section of the SIC (Central Interconnected System) to the additional three southern sections limits the capacity to transmit electricity, resulting in overcapacity in the northern section. To alleviate the solar overcapacity on the SIC, transmission lines and electrical sub stations for its interconnection with the Great Northern Interconnected System (SING) are underway and are supposed to be operative as of 2018. In addition, spot prices in some points of the north reached zero during a few hours of the day due to lack of demand (mostly caused by the reduction in copper prices and the overall

slowdown in GDP growth) and transmission constraints, increasing the operational risks for power plants owners and energy developers.

4. **The lack of specialised skills and knowledge, as well as of technological and innovation infrastructure, could limit the potential to move up the value chain**. Patent applications related to solar energy in Chile have increased considerably since 2012. By 2016, Chile had filed 238 patents in CSP, 70 in PV, and 40 in PV-thermal hybrid technologies. This is a big increase since 2012, when it had filed 59 patents in CSP, 16 in PV and 7 in PV-thermal hybrid. Despite this progress, Chile lags behind other countries in terms of domestic scientific and technical capabilities in this industry. The country's patent filings in solar energy in 2016 made up only 0.01% of total world patent applications in the field (IRENA, 2017).
5. **The social acceptability of solar energy should not be taken for granted**. Currently in Chile, renewable energies, and solar in particular, benefit from high social acceptance. This is due in part to a generalised perception that these energy sources are "good" for the environment and for the people (users and workers in the value chain), and in part to the major social dissatisfaction with big energy projects, such as polluting thermal plants, and the environmental impacts of large hydro-plants. However, the social licence which these energies currently benefit from will not be sustained in the long run if new agreements, negotiations and benefit sharing with local communities are not developed. New forms of dialogue and partnership with local communities will be needed.

Table 3.2. **Multi-stakeholder assessment of the future of solar energy in Chile**

Strengths	Weaknesses
• Strong solar irradiation Abundance of salts for storage for CSP • World biggest lithium reserve • Established presence of world leading energy companies • Long-term & shared vision for the energy policy • Open and stable economy • Existing public-private dialogue through the Solar Energy Strategic Committee	• Late mover in PV manufacturing value chain • Limited grid connection • Scant domestic S&T capabilities • Small domestic market • Low investment R&D • Reduced skills base
Opportunities	**Threats**
• Global rise in electro-mobility • Greening mining • Exporting specialised solutions for desert applications • Self-sustained energy production • Self-production for/in sparsely populated areas • Potential to develop locally adapted solutions for system installation (downstream)	• Desert context may not be ideal for PV (dust) • Technological uncertainty (form of manufacturing & storage technologies) • Social acceptance • Energy spot prices • Slow progress in regional integration • Lack of sustained commitment from leading companies

Source: Authors' analysis based on the outcomes of the Round Table on the Future of Solar Energy in Chile organised in the framework of the PTPR of Chile, hosted by CORFO in Santiago, Chile in June 2017.

The green shift needs a shared long-term vision and strategic actions

Recognising the potential opportunities for Chile offered by solar energy, in 2015 CORFO, in co-operation with the Ministry of Energy, set up public-private consultations to define a road-map for future actions. These consultations led to the identification of three gaps that require public investment if Chile is to maximise the benefits from solar energy:

- weak research and technological capacity, including the lack of a technology centre
- a limited supply chain base
- lack of adequate infrastructure, standards and norms.

In response, in 2016 CORFO set up a strategic solar programme with a time horizon to 2025. In line with international practices, this plans to foster value chain development through several channels (Table 3.3). The programme is managed by a committee chaired by the Minister of Energy and envisages the participation of both public and private sector. The Committee oversees 50 initiatives to address the three gaps, to support private sector development and to favour private investment. In particular, the programme aims to: 1) enable the creation of 100 new firms in the solar value chain; 2) reduce CO2 emissions by 4.5 tons every year; and 3) achieve a LCOE of USD 25 Mw for PV in desert zones. The estimated budget for the programme is USD 800 million up until 2025, of which approximately 15% is expected to be financed by the public sector and the rest by private stakeholders. For the period 2015-2018, USD 22 million have been financed by the government (CORFO, through the FIE and FIC), and USD 1.8 million by the private sector.

In particular, the solar programme encompasses actions in the following areas:

- **Technology and skills development**. Chile is helping to set up R&D consortia, and attracting foreign direct investment by creating conditions for investors to enter and co-finance innovation. The main action in this field includes the creation of the International Institute of Solar and Mining (IISM) to foster applied research in solar energy, mining and production of clean hydrogen and other energy-storage components. The estimated cost of the project is USD 94 million up to 2025 for building the infrastructure and the initial operational costs. Approximately, the private investment for the next ten years will amount to USD 80 million. The remaining USD 14 million will be conveyed through CORFO's fund for Technology Centres for Innovation. The International Institute of Solar and Mining (IISM) plans initially to employ 35 researchers who seek to develop applied research industrial applications. The country is also planning to finance a ten-year R&D programme to adapt PV technologies to high radiation conditions through a consortium involving local and international universities, research centres and firms.
- **Supply chain development**. Chile is planning to facilitate supply chain development in two main ways: 1) though an open platform, launched in 2017 and managed by Fundación Chile, to match demand and supply for developing solutions for operating in desert conditions; and 2) by setting up standards and regulations, including by standardising measurement, testing, and certification processes associated with the design, development, construction, operation and maintenance of solar power generation systems, as well as by setting standards linked to component design and manufacturing processes for specialised desert solar technologies. This appears crucial given the climate conditions that might affect the durability and performance of photovoltaic systems in the Atacama Desert.
- **Infrastructure development**. This involves 1) building a Solar Technology District, a large-scale generation plant that is expected to facilitate the development of specialised solutions for solar power generation and storage, as well as the participation of domestic suppliers by allowing all the actors in the supply chain to be located near one another; and 2) investing in developing the corridor Cuenca del Salado Solar, a pilot project that would allow widespread adoption of solar energy in the cities of Chañaral and Diego de Almagro.

Table 3.3. **Chile's strategic solar programme, 2017-25**

Areas	Actions	Estimated budget
Technology and skills development	International Institute of Solar and Mining (IISM)	USD 94m between 2017-27
Supply chain development	Open innovation platform	USD 6.6m between 2016-19
	Contribution to develop international standards and regulation	USD 2m between 2016-19
Infrastructure and territorial planning	Solar Technology District (DTS)	USD 0.8m between 2016-17 (pre-phase investment)
	Corridor Cuenca del Salado Solar	USD 0.5m between 2016- 17

Source: Authors' analysis based on official information from the Solar Strategic Committee of Chile.

The actions in Chile's solar energy programme are at an early stage (Table 3.4). In some aspects they are aligned with international practices, including:

- **Creating a long-term vision**. A road-map to 2035 drawn up with the active participation of all stakeholders is a positive step. Other countries are also creating long-term visions for increasing their capabilities in renewable energies. Since 2007, the European Strategic Energy Technology Plan (SET-Plan) has been promoting research and innovation to accelerate the EU's transformation to a low-carbon economy. The SET-Plan is the technology pillar of the European Energy and Climate Policy. It identifies specific actions for research and innovation, based on an assessment of the energy system's needs, on their importance for the energy system transformation, and on their potential to create growth and jobs in the EU. In 2015 the SET-Plan identified ten priority actions with a time horizon to 2030. The plan addresses the whole innovation chain, from research to market uptake, and tackles both financing gaps and regulatory framework needs.
- **Building consensus among diverse stakeholders**. Chile has been successful in bringing all stakeholders on board, including academia, civil society and the private sector, and it has implemented actions in line with international good practices. The formulation and implementation of the EU SET-Plan also relies on consensus building. Its priorities were set by a participatory process involving governments, firms and research, under 154 umbrella organisations representing 16 700 entities. The Technology and Innovation Platforms also provided relevant inputs. The European Technology and Innovation Platform Photovoltaics (ETIP PV) is a platform to gather together all relevant stakeholders in the PV sector, including firms, research centres, and industry associations. They engage in consultations with member and associated countries of the EU and EU Commission institutions, with a view to providing consensus-based advice on increasing the competitiveness of the European PV sector.
- **Information sharing**. The creation of the open platform in Chile to match clients and suppliers is another positive step in line with international practices. The SET-Plan Information System (SETIS) is a platform for sharing information on low-carbon technologies; assessing the impact of various technology policies, conducting cost and benefit analyses of various technological options, and estimating implementation costs. The Energy Research Knowledge Centre under SETIS collects and organises information on energy research programmes and projects, as well as their results and analyses. In Germany, the government's co-financed Fraunhofer Institutes co-operate with universities on industrial research and testing. The institutes favour information sharing between universities and businesses by allowing talent mobility between the institute and the firms and allowing students to gain practical experience in commercially-oriented research.
- **Territorial management for sustainable deployment**. The creation of the technology district will generate technology for commercial products and processes, enable

companies and research centres (both national and international) to test equipment and industrial processes on pilot manufacturing lines, and foster a continual flow of trained engineers and technicians to the private sector. It is important that the district embraces activities that go beyond industrial development, to incorporate infrastructure and territorial development. For instance, solar district heating in Europe supports supplier and local communities.[2] The large-scale solar thermal technology supplies renewable, zero-emission heat from large solar collector fields via district heating networks to residential and industrial areas, and at the same type they represent a laboratory for industrial application and research. Long-term experience is available from demonstration projects in Sweden, Denmark, Germany and Austria.

In going forward, there are additional aspects that would be important to address:

- **Scale up resources and foster private sector participation**. The budget allocation for 2017 represents only 2.8% of the total resources required to achieve the goals of the solar programme; private sector participation accounts for 8% of the total budget in 2017. The SET-Plan receives support from the European Union framework programme for research and innovation (Horizon 2020) for low carbon technologies and national governments, but the private sector also has an active role. In 2014, funding from Horizon 2020 reached EUR 1.1 billion and public investment from national research and development (R&D) programmes account¬ed for nearly EUR 4.2 billion. In 2014, total investments in the research priorities of the plan by European countries reached 27 EUR billion and the private sector contribution represented almost 85% of the total investment.
- **Strengthen opportunities for learning and innovation**. World leading research centers in solar, such as the German Aerospace Center (DLR) in Germany, benefit from a wide science base and networks with multiple fields of research that enhance not only the impact of research in solar, but also enable cross-fertilisation and self-discovery in multiple technological and industrial fields. In going forward it would be desirable to identify mechanisms to enlarge the mission of the solar institute in Chile, and to also explore interoperability with other renewable energies. Pursuing synergies with other renewable energies, such as wind, hydro and biomass, offers untapped potential. In Europe, for example, the SET-Plan has moved away from vertical and technology-specific approaches to a more horizontally integrated approach aiming to find complementarities across renewables and linking them with other enabling technologies, such as ICT, advanced manufacturing, advanced materials, industrial biotechnology, nanotechnology, photonics and nano-electronics.
- **Strengthen international and regional co-operation in research and supply-chain development**. Pooling resources for research at the regional level, exploiting synergies in Latin America, and creating opportunities for SME development by building on complementarities with neighboring countries would be important priorities in going forward. Strengthening regional ties in these dimensions could help to scale up investments and reach the critical mass needed to compete effectively at the global level. For example, European countries emphasise co-operation and resource pooling at a regional level. The European Research Area Network (ERA-NET) was launched in 2011 to support public-public partnerships and joint research between EU countries in solar energy. By the end of 2016, nine ERA-NET co-fund networks had been established in the priority areas identified by SET, with financing of EUR 217 million for 2012-15. International co-operation is also relevant. An interesting step in this direction is the South-South co-operation programme that Chile signed in 2017 with Morocco to foster learning and co-operation to strengthen capabilities in the solar value chain (Box 3.2).

Table 3.4. **Progress overview of Chile's solar programme, 2017**

Governance dimensions		
Anticipation capacity	√	Having a road-map with a long-term horizon (to 2025) takes Chile a step forward in line with international good practices. Aligning financing with the time-line of the road map will be an additional step forward.
Adaptation capacity	≈	In the fast changing technological environment the time for design and validating road-maps could be shortened from the current 13 months, while adaptability could be increased by introducing periodical revision of road-maps.
Learning and upgrading potential	√	The creation of the Solar Research Institute and the open platform to connect local providers fills two main gaps in enabling learning and upgrading in the value chain and are positive steps in line with international practices.
	×	The specific focus on current challenges (e.g. solar energy for mining and solar energy solutions for high radiation areas) could limit knowledge spillovers and self-discovery processes. There is room to identify synergies with other renewable energies (in the framework of Energy 2050) and with other industrial applications beyond mining.
	√	**Within government**. The programme benefits from multi-agency co-ordination and buy-in (e.g. Ministry of Energy, Ministry of Economy, InvestChile, etc.).
	×	**Private sector**. Businesses participated in the road-map process, but co-operation with lead-investors would be needed in going forward.
Interconnectedness propensity	√	**Academia**. The programme benefits from commitment and co-operation mechanisms with academia and research centres.
	≈	**Civil society**. There is room to increase the participation of civil society in the process, especially to realise the potential of solar energy beyond industrial applications (e.g. self-production and energy to sparsely populated areas).
	×	**Regional**. Strengthening regional ties could help to scale up investments and reach the critical mass needed to compete effectively at the global level.
Embeddedness potential	≈	Mechanisms to avoid rent seeking and capture are needed to ensure that publicly-financed actions benefit all stakeholders and deliver public and club goods not available otherwise. In this respect open government and effective monitoring and evaluation are needed to track progress and performance and identify areas for improvement.

Note: √: positive progress; ≈: margin for improvement; x: reform needed.
The definition of the five governance dimensions can be found in OECD (2017c) and in Box 2.1 in Chapter 2 of this report.

Box 3.2. **How Morocco is building on its natural assets to participate in the renewable energies value chain**

Morocco has significant renewable energy potential: 25,000 MW of wind power, 20,000 MW of solar (3 000 hours of sunshine/year), and 200 sites usable for hydraulic micro-power plants, equivalent to about 3 800 MW.

Morocco's proactive commitment to the energy transition process has resulted in significant improvements over the last several years, as a result of the successful first phase of the National Energy Strategy (2009-2015). Evidence points to an increase in the share of solar and wind energy from 2% in 2009 to 13% in 2016, and a reduction in the energy dependence rate, from 98% in 2008 to 93.3% in 2016. The second phase of the strategy (2016-2030), already well underway, aims at achieving a sizeable goal: to increase the share of renewables in the energy mix to 52%, and to reduce energy dependence to 82% by 2030. The strategy also aims at achieving energy savings of 15% by 2030 and a massive introduction of natural gas (Figure 3.8).

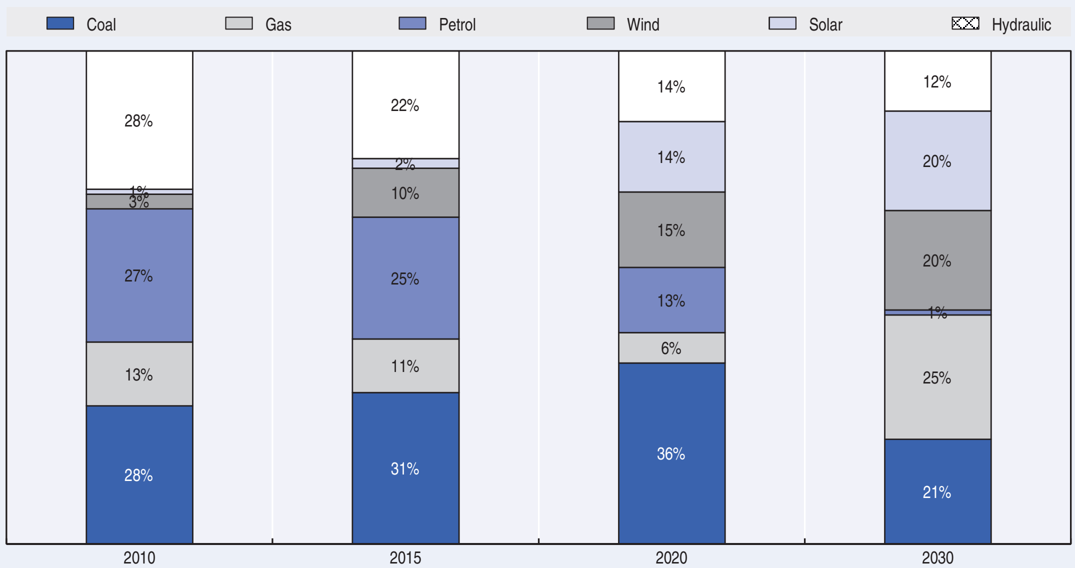
To reach a share of 52% of total installed capacity coming from renewables, Morocco is to develop additional capacity in electricity generation from renewable sources of about 10 100 MW, of which 4 560 MW from solar, 4 200 MW from wind, and 1 330 MW from hydro-power plants, between 2016 and 2030.

The development of renewable energies is expected to reduce CO^2 emissions by 20 825 kilotonne (kT) by 2030.

Box 3.2. **How Morocco is building on its natural assets to participate in the renewable energies value chain** *(Cont.)*

Figure 3.8. **Projected evolution in the structure of Morocco's installed capacity, 2010-30**

Share of installed capacity by energy source



Morocco's strategic programme for renewable energies

Solar programme of 2 000 MW: with an overall cost estimated at USD 9 billion, this programme will be launched in 2020 with a view to producing 4 500 gigawatt hours (GWh) of electricity per year through different sites in the Kingdom. To this end, the successful operationalisation in February 2016 of the first solar plant (Noor 1) with a capacity of 160 MW, enabled the production of 400 GWh in 2016. At end of May 2017, its production grew 14% from the previous year. This site's solar electric capacity will be complemented by the launches of Noor 2 (200 MW) and Noor 3 (150 MW) by the end of 2017. On other sites, processes of pre-qualification for the project Noor Midelt (800 MW) and for corresponding financing have already started. The call for bids on the Noor PV I has also been awarded. With an overall capacity of 170 MW, this programme will foster the development of three photovoltaic plants on three separate sites (80 MW in Laayoune, 70MW in Ourazazate, and 20MW in Boujdour).

Wind programme of 2 000 MW: This programme includes the installation of 2 000 MW in wind power by 2020 and an annual production of 6 600 GWh of electricity, at an estimated cost of USD 3.31 billion. Following the completion of the Tarfaya plant (300 MW), the current total installed capacity is close to 780 MW. Scheduled in 2018 are the operationalisation of the wind park of Taza (150 MW), as well as the launch of the integrated wind power project with a capacity of 850 MW: Tanger II (100 MW), Jbel Lahdid (200 MW), Midelt (150 MW), Tiskrad (300 MW) and Boujdour (100 MW).

Hydroelectric programme of 2 000 MW: the capacity installed to date is of 1 770 MW, of which 460 MW is in the form of pumped hydroelectric energy station (PHES). The hydropower programme will be complemented, by 2020, by the construction of the hydroelectric complex of El Menzel (125 MW) and of the pumped hydroelectric energy station (PHES) of Abdelmoumen (350 MW). Furthermore, several micro-hydropower plants, totalling about 100 MW, are being developed by the private sector as part of the renewable energy law 13-09, and about 300 MW are currently being assessed.

Box 3.2. **How Morocco is building on its natural assets to participate in the renewable energies value chain** *(Cont.)*

Lessons learned

In 2010, the Moroccan Agency for Solar Energy (MASEN) was initially in charge of the development and the implementation of solar programmes. Following the adoption of two laws (57-09 and 38-16), on the role of MASEN and that of the national Office of Water and Electricity (ONEE) respectively, the production of electricity from renewable sources will be provided by the company MASEN and the electricity production of ONEE will be limited to fossil sources.

Every system of energy production from renewable sources is subject to a regime of authorisation or declaration. The adoption of law 13-09 gives an operator the right to produce electricity from renewable energy sources on behalf of a consumer or a consumer group connected to the national grid of average voltage (AV), high voltage (HV) and very high voltage (VHV). This applies to Morocco or abroad, under an agreement to extract and consume electricity produced exclusively for their own use.

The removal of subsidies on petroleum products, with the exception of butane gas, has been implemented since 2013. Initially, products affected by the partial indexing system were diesel, premium fuel, and industrial fuel no2. In 2014 the complete indexing of premium fuel, industrial fuel and special fuel intended for the production of electricity was approved. In 2015, fuel prices were fully indexed to world prices.

The adoption of law 58/15 made important amendments to law 13-09 on renewable energy, in particular:

- The opening of the market for electricity from renewable energy sources of low voltage was embedded in the regulatory framework: for producers of electricity from renewable energy sources, law 58-15 opens up the possibility of connecting to urban and rural low-voltage power grids, in order to promote the development of small and medium-sized industrial facilities, including photovoltaics.
- The increase of the threshold of installed capacity for hydroelectric power generation projects. The exclusion of projects whose electric power was more than 12 MW in the scope of law 13-09 was "a barrier to the exploitation of the maximum threshold given by the physical and hydrological characteristics of production sites". Law 58-15 has thus increased the threshold of installed capacity for projects of electric energy production from hydraulic source from 12MW to 30 MW.
- The point of view of the Hydraulic Basin Agency will now be taken into account in the process of provisional authorisation for the construction of systems for the production of electricity from renewable energy sources
- The possibility to sell surplus production that is not used by the operator to ONEE or the manager of the distribution network. For the latter, the operator cannot sell more than 20% of its annual energy production surplus.

The creation of the National Agency for Regulation of Electricity (NARE) following the adoption of law 48-15: for greater transparency, this law brings answers to better manage the transitional phase marked by the conflict of interest currently underway due to the current status of ONEE as a producer, carrier, and distributor of electricity.

Adoption of the law on self-power generation, allowing power generation greater than 300 MW: this law intends to give producers of over 300MW of electricity the possibility to access the national grid to bring the energy produced from the production site to the various places of consumption.

Adoption of order 2-15-772 on access to grids of average voltage: this reform aims at defining a regulatory framework that is attractive to potential investors in renewable energy systems connected to average voltage grids.

Source: Ministry of Economy and Finance of Morocco, as member of the Peer Learning Group (PLG) of the PTPR of Chile.

In Chile, mining needs to shift up a gear

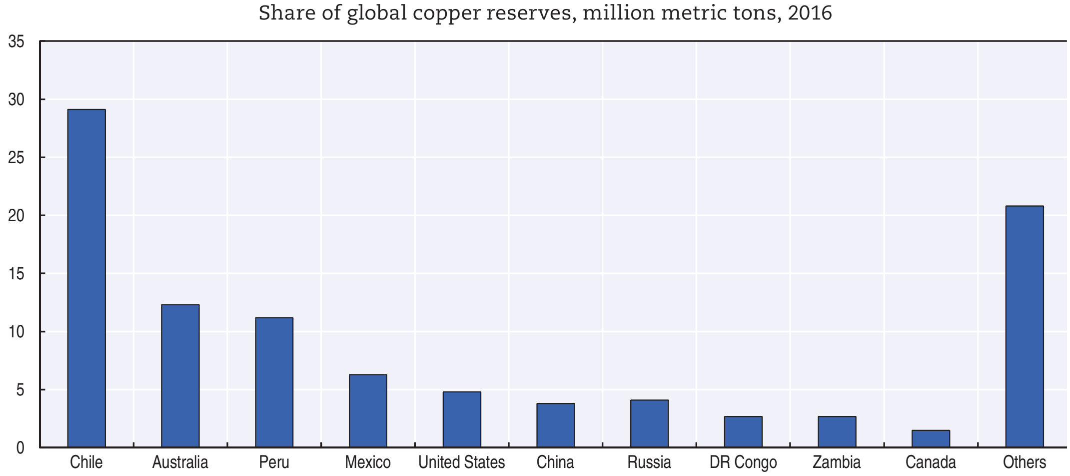
This section focuses on mining. It discusses the current opportunities and challenges of this industry in a comparative perspective and it identifies key issues at stake for the future. It summarises what actions are needed from businesses and government to make mining a driver of sustainable and inclusive development.

Mining needs to increase productivity

Mining is the backbone of the Chilean economy. Chile is the biggest producer of copper in the world: with 5.5 million metric tons produced in 2016, Chile accounts for 30% of the world's copper production and reserves (Figure 3.9). Chile is also the world's leading producer of iodine (63.2% of world production), of rhenium (50%), and of lithium (39%); the third global producer of molybdenum (13.5% of world production), and the sixth producer of silver (4.6%). The Escondida mine, in the north of the Atacama Desert, produces 1 million tons of copper a year and is the world's largest open-pit copper mine as well as the largest contributor to Chile's copper output. Mining employs around 220 000 workers and has an important weight in Chile's GDP and exports. Over the last decade it accounted for 13% on average of national GDP and for 55% of domestic exports, 50% of which came from copper alone.

Figure 3.9. **Chile has the largest copper reserves in the world**

Share of global copper reserves, million metric tons, 2016

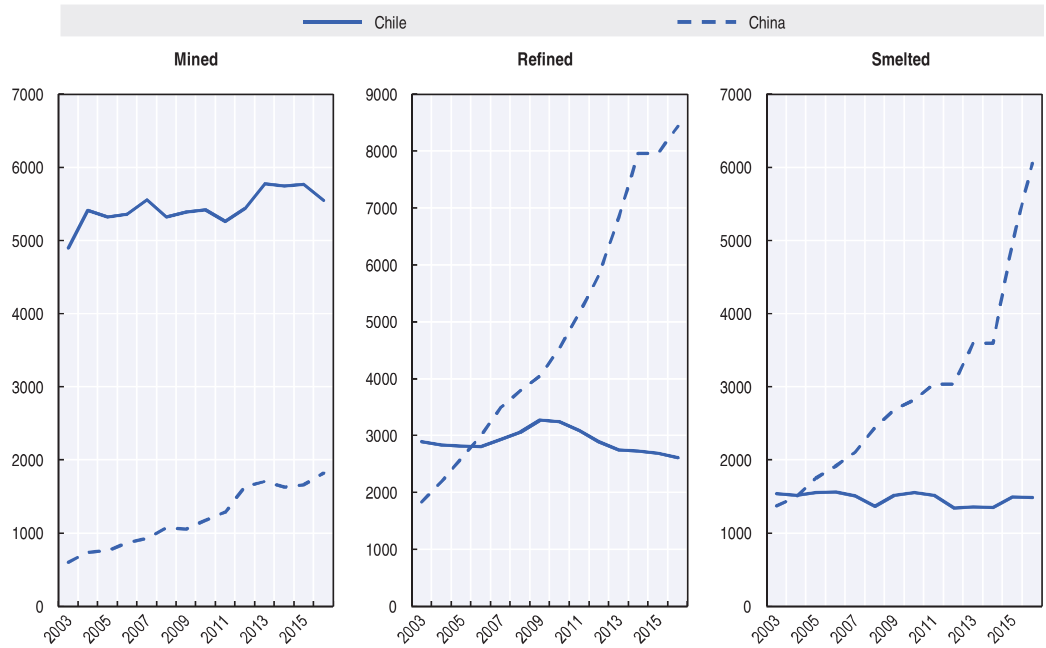


Source: Authors' analysis based on US Geological Survey and COCHILCO (2017), database, https://www.cochilco.cl/

In the last decade, Chile has increased its specialisation in extraction at the expense of smelting and refining. As of 2016, Chile accounted for 8.5% and 11% of world's smelting and refined production. The downward trend in smelting and refining has been due to the emergence of China, which increased its smelting and refining capacity fivefold between 2000 and 2016 (Figure 3.10). The Chinese appetite for copper ores has boosted Chilean mining exports; however it has also contributed to increasing specialisation in the less sophisticated segments of the value chain (see Chapter 2).

Figure 3.10. **Copper production stages, Chile and China, 2003-16**

Kilo metric ton (kMT) of copper content, by production stage

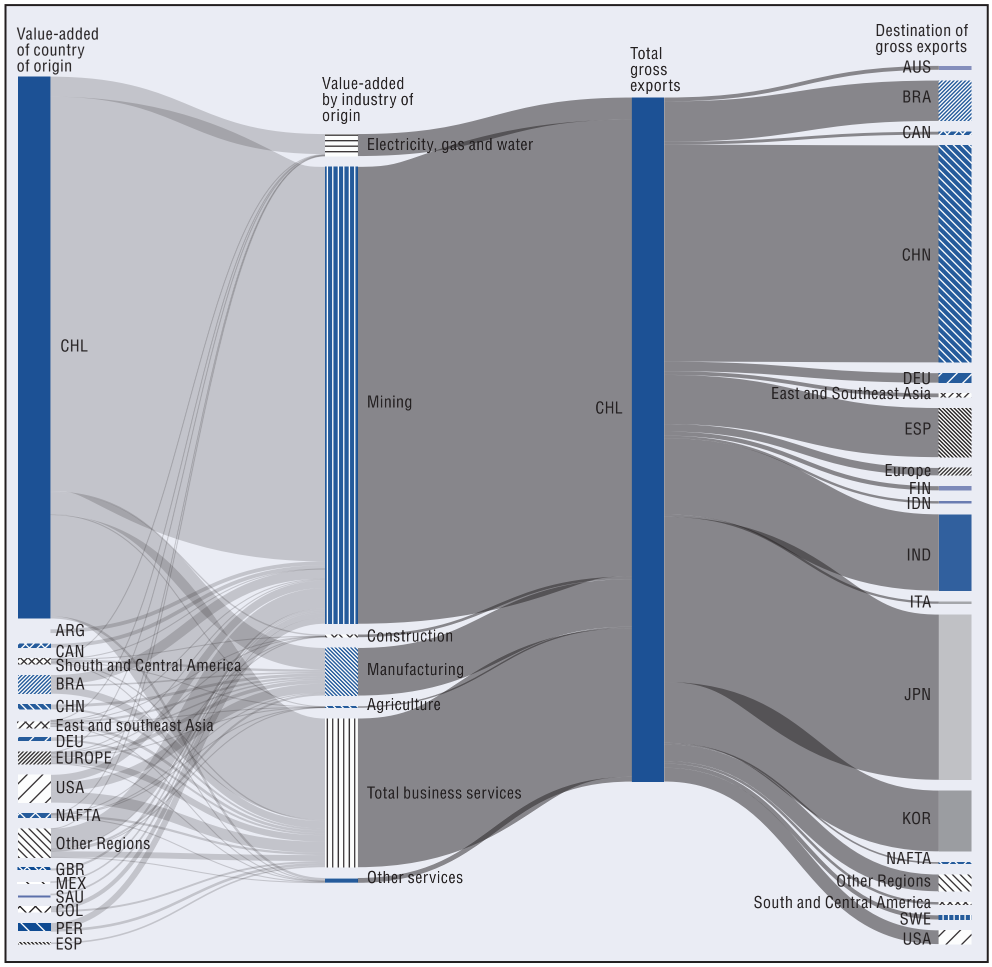


Source: Authors' analysis based on World Metal Statistics, www.world-bureau.com; and Cochilco database https://www.cochilco.cl/, 2017.

Asia is the main destination for Chile's mining exports. In 2016, Chile's copper ore exports mainly went to China (38%), Japan (22%), India (13%) and South Korea (8%), for a total value of USD 11 billion. In the same year, Asian countries combined also absorbed USD 9.8 billion of refined copper from Chile, with China alone accounting for 47% of the total. The decomposition of the gross exports of Chilean mining allows for a more detailed analysis of the source of inputs in terms of sectors and countries of origin. Chile has lower foreign value added content in gross exports (20%) than Sweden (25%). Chilean mining exports embed fewer inputs from other sectors than Sweden. The contribution of business services to mining is 21% in Chile, whereas in Sweden it is 30%. A similar pattern is also evident in the role of manufacturing, which in Chile contributes to 7% of total value added in mining exports, compared to 10% in Sweden (Figures 3.11 and 3.12).

Figure 3.11. **Decomposition of Chilean gross exports by origin and destination, mining, 2014**

Value added of gross exports by origin and destination (%)

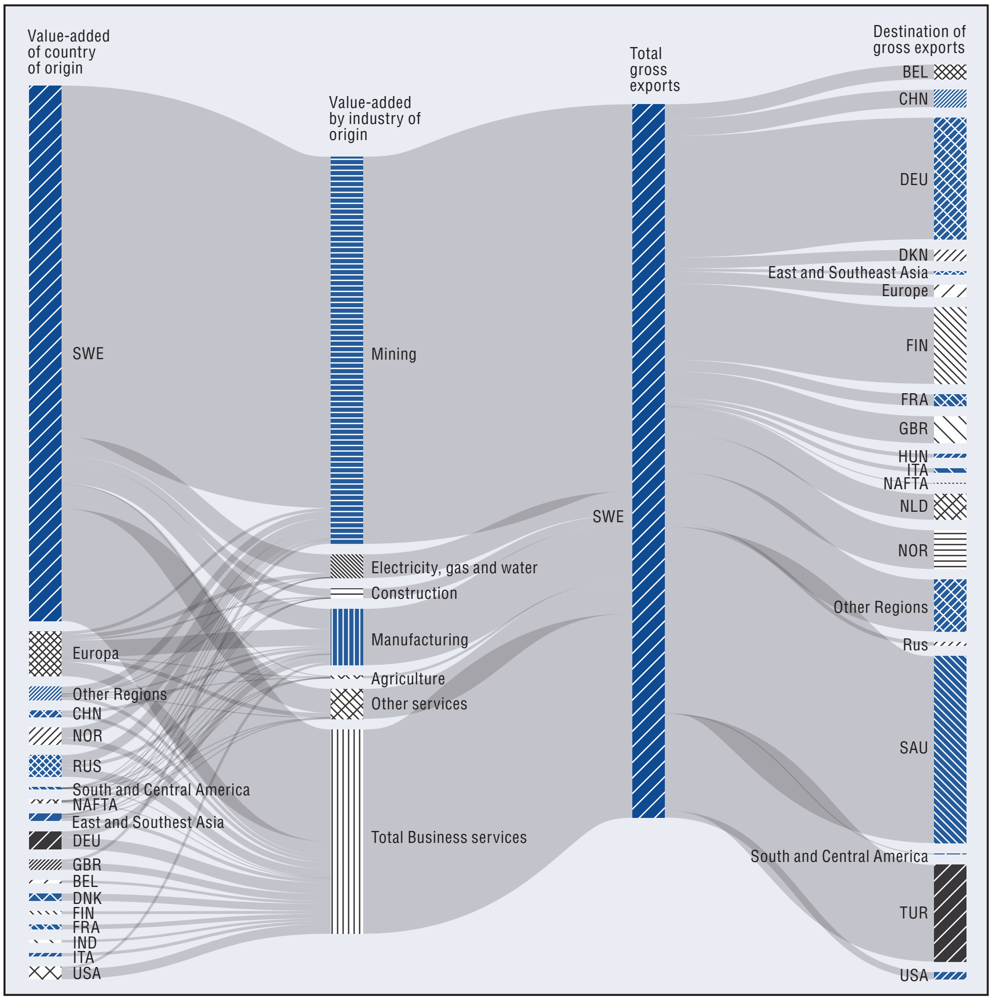


Note: Regional aggregates exclude member countries reported in the graph.

Source: OECD (2017b), TiVA Nowcast Database, http://stats.oecd.org/Index.aspx?DataSetCode=TIVA_NOWCAST; see also www.oecd.org/std/its/tiva-nowcast-methodology.pdf

Figure 3.12. **Decomposition of Swedish gross exports by origin and destination, mining, 2014**

Value added of gross exports by origin and destination (%)



Note: Regional aggregates exclude member countries reported in the graph.

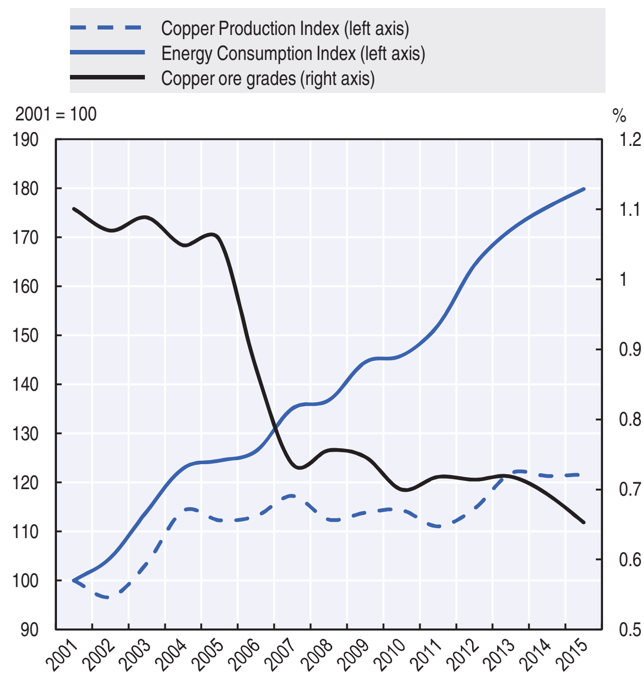
Source: OECD (2017b), TiVA Nowcast Database, http://stats.oecd.org/Index.aspx?DataSetCode=TIVA_NOWCAST; see also http://www.oecd.org/std/its/tiva-nowcast-methodology.pdf

Chile's high dependency on natural resources makes the country vulnerable to external shocks. The contraction of the Chinese economy in 2015, along with sluggish world economic growth and the expected appreciation of the dollar, have affected copper prices, which dropped to USD 2.10 per pound (lb) in 2016, almost USD 2.00/lb lower than the peak of 2012. The decline in copper prices has had a direct effect on employment. Employment rates in mining dropped by 5.5% on average between 2012 and 2016, and the impact has been particularly severe in mining regions. The unemployment rate during the first quarter of 2017 reached 6.8% nationally, but was 8.3% in Antofagasta, and 8.9% in Atacama. Although the second half of 2017 saw copper prices stabilise around USD 3/lb, the recent contraction reveals how structural problems are affecting the industry. Rising costs, declining productivity, and increasing concerns about social and environmental sustainability are all hampering the country's historical position as a global leader. Some of these structural problems are discussed next.

Since the 2000s, the productivity of mining in Chile has been declining. This is not a uniquely Chilean problem: between 2000 and 2015, many commodity-rich countries faced productivity declines in industries associated with natural resources. For example, the value added per hour worked in Norway's mining and services sectors fell by a yearly average of 4% between 2000 and 2015. In Australia, it fell on average by 5% per year between 2000 and 2011, while in Canada, the average decline was 1% per year between 2007 and 2013. Available estimates by the National Productivity Commission of Chile reveal that between 2000 and 2014, Chile's copper production increased by 19%, while the use of inputs for production increased by much more: energy requirements grew 79%, labour 157%, and capital investment 178% (CNP, 2017). This combination of a modest increase in output with high growth in the use of inputs led to an overall decline in total factor productivity. Additionally, there was a sharp reduction in labour productivity. Depending on the methodology used, and accounting for several factors including ore grade deterioration, labour productivity fell by 15% to 50%. When comparing the Chilean mines with an international benchmark, the results are even more worrying. In 2015, moving 1 000 tons of material in the world's best-practice mining sites in Australia, Canada, Sweden and the United States required on average 30 hours, less than half the time required for the average Chilean site of 67 hours. Moreover, mines in Chile employ 1.8 technical support people per plant while the international benchmark average is 1.3 (CNP, 2017).

The decline in mining productivity can be explained by several factors. On the one hand, Chile's main mining sites are experiencing ore grade deterioration, leading to lower productivity. In 1991, the average ore grade in Chile was 1.4%. Current estimates show that ore grades now range between 0.7% and 1%, and are expected to be 0.6% by 2020 (CNP, 2017). When a copper resource is developed, mining begins by extracting ore close to the surface. Once this is removed, ore is extracted from increasing depths. Deeper pits lengthen the process before milling can start, and decreasing ore grades mean that greater amounts of material must be moved and processed to achieve the same quantity of final product, which results in greater energy consumption and water use (Figures 3.13 and 3.14). The increasing water demand is an additional challenge for mining in Chile, as most sites are located in the northern regions, next to the Atacama Desert, one of the driest places in the world. The region of Antofagasta alone requires 5 000 litres of water per second, and demand for water in Chile's mining industry is expected to increase to 500 million cubic litres by 2020. To meet this increase in water demand, water will need to be desalinated and pumped to the mountains, a process that is costly and highly intensive in energy consumption.

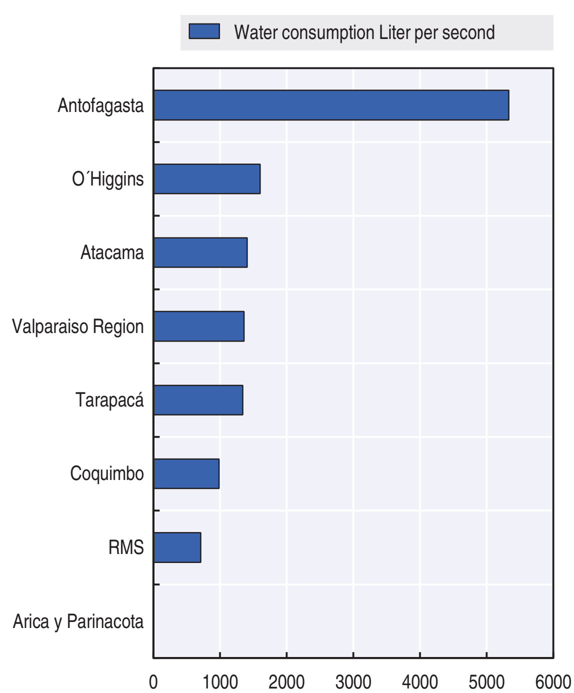
Figure 3.13. **Chilean ore grades are falling while energy consumption is rising, 2001-15**



Note: The Copper Production Index measures thousands of tons exctracted and the Energy Consumption Index measures terajoules necessary for extraction.

Source: Authors' analysis based on US Geological Survey and COCHILCO (2017), database, https://www.cochilco.cl.

Figure 3.14. **Total water consumption by region, Chile 2015**

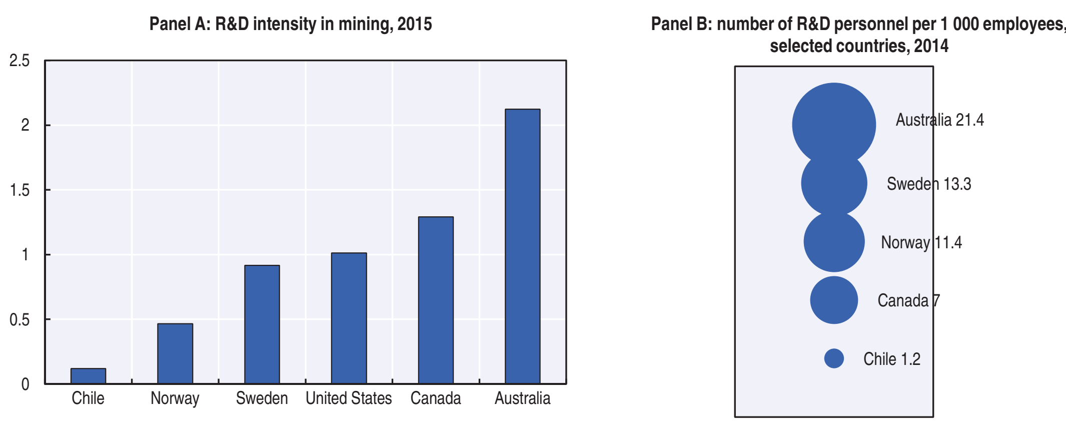


Source: Authors' analysis based on COCHILCO (2017), database, https://www.cochilco.cl.

Chile's mining business is mostly focused on extraction and invests little in innovation. Increasing specialisation in extractive activities, along with the industry's focus on maximising volume during the super cycle of commodity prices of the 2000s, overshadowed the importance of research and innovation. When the cycle ended, inefficiencies were revealed in operations and organisational structures. A sustained effort in innovation is essential to compete at the international level. Total business expenditure in R&D over total gross value added in the mining industry is 0.15% in Chile, versus 2% in Australia, 1.5% in the United States and 1% in Sweden (Figure 3.15, Panel a).

Qualified human capital is necessary to fully exploit new technological advantages. Chile's specialisation in low value-added segments of the mining value chain means its labour force is largely composed of low-skilled workers, often with short-term contracts. In Australia, 21.4 out of every 1 000 mining employees are dedicated to R&D activities; in Sweden and Norway the numbers are 13.3 and 11.4 respectively. In Chile that number is only 1.2 (Figure 3.15, Panel b). Chile is aware of the need to increase its skills base for the future of mining, and some initiatives have been put in place to do so. In the region of Antofagasta, a public-private partnership involving the University of Antofagasta, the Centre for Industrial Training (CEIM) and the Catholic University of the North has set up the Andes Pacific Technology Access (APTA) programme. Its aim is to increase knowledge transfer between universities and firms through on-campus and off-campus training. Companies are also co-operating with universities and technical schools to build skills. For example, the Chilean state-owned copper company CODELCO is co-operating with the technical school Don Bosco-Calama to train workers in extraction and industrial mechanics.

Figure 3.15. **Chile lags behind world leading mining countries in innovation**



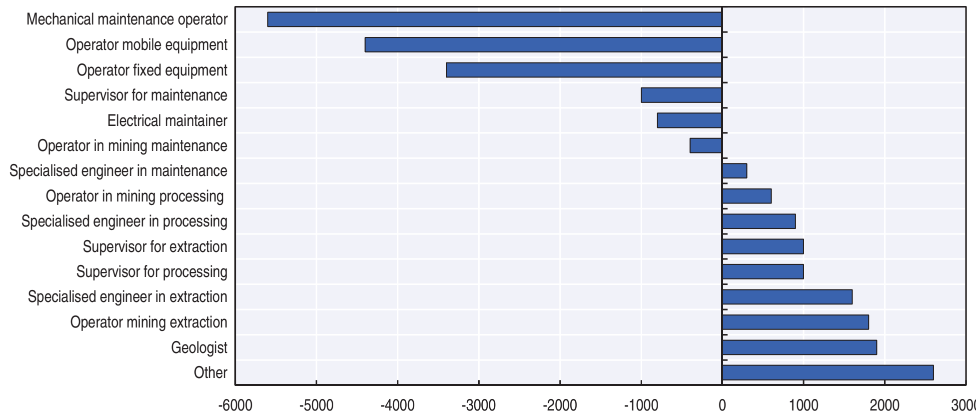
Note: Panel a: R&D intensity in mining is the ratio of total business enterprises' expenditure on R&D over total gross value added in the mining sector (ISIC rev 3.1); Panel b figures refer to private sector employment, 2015: Chile, 2014: Norway, 2013, Australia and Canada, 2010: Sweden.

Source: Authors' analysis based on OECD STAND stats.oecd.org; ILO Statistics, www.ilo.org/ilostat; and Australian Department of Employment, https://www.employment.gov.au (databases), 2017.

Mining is also facing a skills gap at the technical level. Estimates from the public-private Council for Competitiveness in Mining in Chile forecast a gap in 16 000 technical profiles by 2024. The gap will be critical in technical areas such as mechanical and electrical maintenance, as well as operators of both fixed and mobile equipment. On the other hand, there is an oversupply of university professionals in the extraction, exploration and development (production geology) areas (Figure 3.16). Available estimates reveal that the profiles with less demand, for example mining professionals and geologists, continue to show an increase in university enrolments (CCM, 2016). Addressing this skills mismatch will be an important driver of productivity growth in the future.

Figure 3.16. **Skills gap in mining, 2015-24**

Thousands of employees



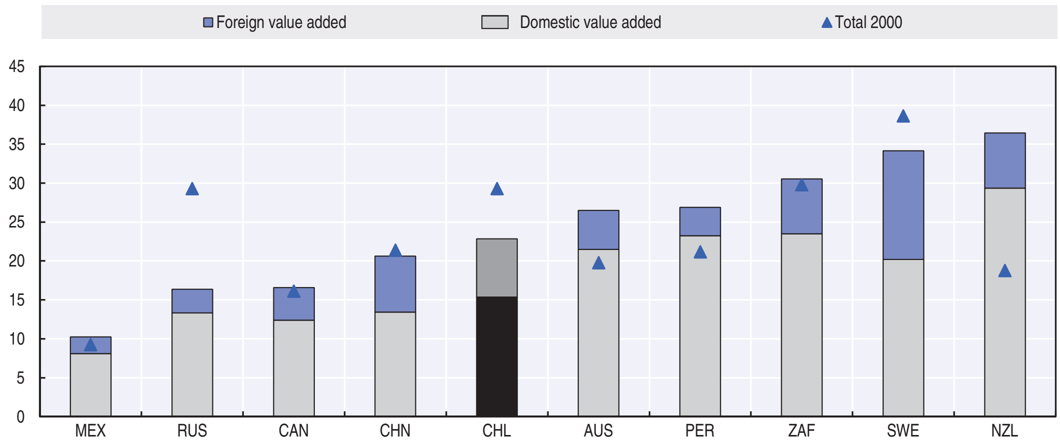
Source: Estimates from *Consejo de Competencia Minería* (CCM), 2017.

Chile could take more advantage of the opportunities offered by services linked to mining. The mining of the future will be more focused on the efficiency and sustainability of extraction and smelting activities. Integrating service-related activities in upstream and downstream segments can boost the total value added of the sector. Services represent 35% of the value added of mining exports in Sweden and New Zeeland, while in Chile the same figure is around 20%. In addition, while emerging economies like Peru and South Africa have increased the value added of services in mining exports, in Chile value added declined from 30% in 2000 to 23% in 2014 (Figure 3.17). This reduction can partly be ascribed to the contraction of copper prices, which led to a fall in the purchases of operational services (-8%) between 2012 and 2014. In Chile in 2015, 4 500 suppliers (1 500 in the Antofagasta region) provided services and intermediate inputs to mining operators (CNP, 2017).

Generating more domestic value added in services linked to mining requires a shift towards a solution-based approach to technology and innovation. New technologies and business solutions often emerge through collaborations along the whole value chain, when mining companies work hand in hand with suppliers and research centres. This is the case for the Canadian Mining Innovation Council (CMIC), and the Australian Commonwealth Scientific and Industrial Research Organization (CSIRO). The former operates with a cross-sectoral focus that favours knowledge transfer and accumulation, and which aims to strengthen ties among the operators along entire value chains. These channels have served very well as a platform for collaborative innovation amongst the competitors to solve shared challenges, especially around socio-economic and sustainability issues.

Figure 3.17. **Services value added content of mining and quarrying gross exports, Chile and selected countries, 2014**

Domestic and foreign services value added as share of gross exports



Source: Authors' analysis based on OECD Trade in Value Added (TIVA), 2017. stats.oecd.org/

New technologies and demands are reshaping the global mining industry

Automation and artificial intelligence are driving productivity growth in mining, and are enhancing safety in the work place. Autonomous mine haulage trucks are estimated to have the potential to increase output by 15-20%, to lower fuel consumption by 10% to 15%, and to reduce maintenance costs by 8% (OECD, 2017a). Automation is also becoming increasingly relevant as mining is shifting from open-pits to underground mining. Automation increases the productivity and changes the skills profile of employees. In 2014, Sweden's leading companies, including Boliden and ABB, inaugurated the world's most automated mine in Garpenberg. The project required private investment of USD 480 million and achieved up to 25% energy savings by using smart ventilation. Mining extraction doubled as automation enabled a 24-hour extraction process.

Digital technologies are improving strategic planning and decision making through the use of real-time data, analytics and predictive tools. In 2016, the largest gold mine in the world, Canada-based Barrick Gold, teamed up with Cisco to set up an analytics hub. The new tools will not only allow Barrick Gold to improve planning and financial management, but also to enhance transparency and business-community relationships by sharing real-time data with civil society. The hub will also enable the design and implementation of innovations to improve safety, productivity and environmental performance. The company estimates that by automating its equipment, using predictive algorithms to gain greater metallurgic precision, and using digital technologies to streamline its permitting activities, it can reduce production costs from USD 800 to less than USD 700 per ounce of gold (Deloitte, 2017). Sweden's mining business is also active in identifying opportunities to transform mining through new mobile communication technologies. The Pilot for Industrial Mobile Communication in Mining (PIMM), started in 2016, brings together a group of Swedish companies in mining and ICT in a consortium to identify shared solutions for new business models for increasing productivity, maintenance and safety.

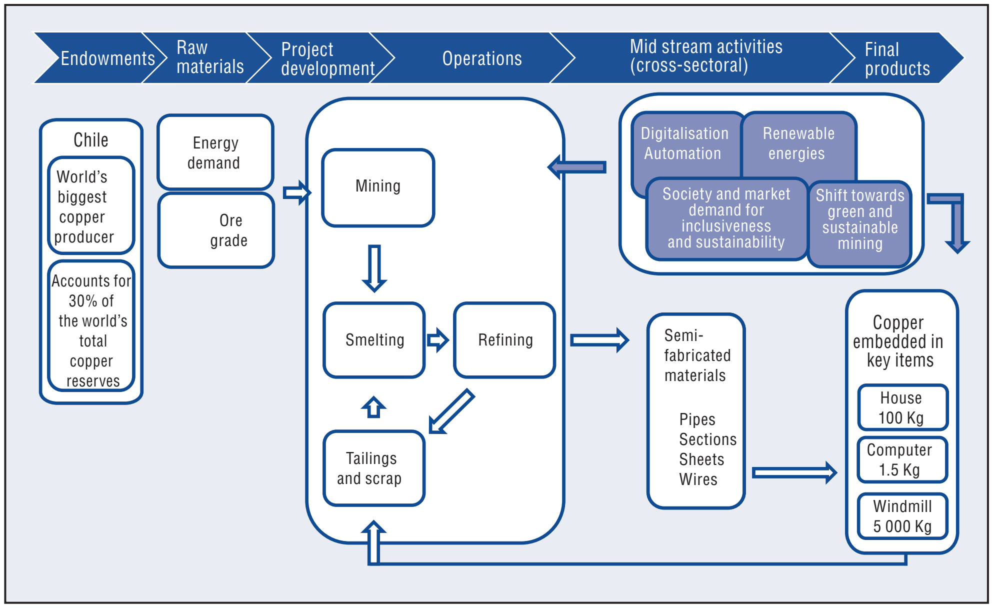
The mining industry is also responding to the growing global demand for sustainability and is searching for green solutions. Greater co-operation between governments and businesses is needed in this area, as most projects involve business-specific solutions and the provision of public goods. In Sweden, the steelmaker SSAB has partnered with mining company LKAB and utility provider Vattenfall to develop breakthrough technology to decarbonise its operations over the next 20-25 years. Through this partnership, the companies aim to use hydrogen fuel instead of fossil fuels in the steelmaking process, achieving waste product of pure water and no carbon dioxide emissions. This project is at an early phase and is currently looking for public support to bridge the financing gap and shift from prototype to scale (see also Chapter 2).

Growing energy consumption in mining can open opportunities for integrating renewable energies. A growing number of mining companies are investing in renewable energy, often in partnership with public authorities. In Australia, the DeGrussa copper mine is implementing a solar project that aims to reduce the mine's dependence on diesel by investing in a 10.6 MW PV plant with 6 MW of lithium ion battery storage. The objective is to provide more consistent, clean, and cost-effective electricity. The total cost of USD 30 million is 50% co-financed by the Australian Renewable Energy Agency (ARENA). Commissioned in June 2016, solar power provides the majority of the mine's daytime electricity requirements, offsetting up to 20% of total diesel consumption annually. In Chile, the state-owned mining company Codelco is planning to produce sustainable copper cathode. A pilot project began in 2013 in the Gaby mine in Antofagasta. In this case the Pampa Elvira solar thermal plant, which produces 54 megawatt hours per year of electricity (MWh/y), covers 85% of the heat needed to refine copper and has reduced the mine's CO2 emissions by 15 000 tons a year since 2014.

Renewed partnerships could boost mining and transform it into an innovative and sustainable industry

Public and private stakeholders in Chile's mining ecosystem are aware that global trends offer opportunities to shift gear and transform it into an innovative and sustainable industry (Figure 3.18 and Table 3.5). Chile's natural endowments in copper and lithium make mining an obvious driver of future growth, development and diversification. Ongoing transformations in the global mining industry (e.g. the shifts towards green and automated mining), coupled with the challenges that Chile is facing (e.g. the need to sustain productivity in an industry that is shifting from open-pit to underground with growing energy requirements), call for a renewed approach to public-private partnership in this field.

Figure 3.18. **Trends in Chile's copper value chain, 2017**



Source: Authors' elaboration based on the outcomes of the Round Table on the Future of Mining in Chile, organised in the framework of the PTPR process, hosted by CORFO in Santiago, Chile in April 2017..

Chile already has an established public-private dialogue with lead firms in the mining industry. The programme "World Class Suppliers", co-financed in 2009 by Fundación Chile and BHP Billiton, and since joined by CODELCO, has helped to strengthen trust between the government and the private sector. It has matched the needs of lead firms to save costs and increase efficiency in their operations, with opportunities to strengthen the domestic supply chain by fostering partnerships with local suppliers. In the first three years of the programme, over 100 innovation projects were submitted for consideration, 20 of which led to contracts with BHP Billiton.

Table 3.5. **Multi-stakeholder assessment of smart and green mining in Chile, 2017**

Strengths	**Weaknesses**
• World biggest reserves of copper and lithium • Largest copper producing company in the world (CODELCO) • Stable macroeconomic situation	• Decrease in productivity • Decline in copper ore concentration • Shift from open pit to underground mining • Increasing demand for energy • Water scarcity in mining regions • Market concentration • Low-skilled labour force • Poor science and technological innovation
Opportunities	**Threats**
• Rise in electro-mobility • Green mining value chain • Synergies with other sectors (i.e solar industry)	• Exogenous price variation of copper • Reduction in global and Chinese demand • Environmental and social impacts

Source: Authors' elaboration based on the outcomes of the Round Table on the Future of Mining in Chile, organised in the framework of the PTPR process, hosted by CORFO in Santiago, Chile in April 2017.

The trust built over time between government and businesses in mining has enabled Chile to take a step forward in defining a shared vision for the future: *Mining: A Platform for Chile's Future*, was released in 2014 by the National Council for Innovation and Development (CNID, 2014). This identifies three pillars for going forward: productivity, sustainability and inclusiveness. The sustainability and inclusiveness areas have been turned into two major initiatives. At national level the initiative *Valor Minero* promotes actions that foster social dialogue and ensure the positive social and environmental impact of mining operations. In particular, the project for Territorial Dialogue (IDT) has set up roundtables to identify how mining companies could contribute to the achievement of the Sustainable Development Goals (SDGs) in the communities in which they operate. At the local level, *Creo Antofagsta* aims to provide opportunities for socio-economic integration and development by enhancing social capital (Box 3.3). This is a result of the commitment of the private sector and local authorities in the northern mining city.

Box 3.3. ***Creo Antofagasta*: a long vision for sustainable growth**

CREO Antofagasta is a public-private strategic initiative created to address the growth challenge of the city of Antofagasta. It aims to build a model city by 2035.

Antofagasta is a coastal city, located in the north of Chile, within the Atacama Desert, where mining is the mayor economic activity (65% regional GDP). In terms of incomes and job satisfaction, Antofagasta has one of the highest performances within Chilean cities; however, to achieve a more sustainable development and better quality of life, the city needs to deliver higher quality and access to public services, urban amenities, affordable housing and community participation. To address these challenges, Creo Antofagasta has developed a masterplan for Antofagasta, with a strong focus on public spaces, socio-spatial integration, environmental sustainability, community participation, enhancing social capital and public-private collaboration. This is the first plan of its kind in Chile, as it has managed to bring together public sector, private companies and the community into one city vision and a portfolio of over 300 initiatives that should bring USD 1.3 billion of concerted investment by 2035.

This plan also includes a short-term portfolio to develop 38 initiatives and more than USD 160 million of investment by 2021, some of which is already underway. These initiatives include:

- the development of a 22 km waterfront as the city's main urban park
- an integrated urban mobility strategy, focusing in transit and no-motorized modes like walking and cycling for re-connecting the disadvantaged neighbourhoods to urban services and public spaces in a more sustainable way
- the reuse of wastewater to irrigate and make feasible the aim to increase green areas and plant trees through the city
- a waste management programme to boost recycling and compost generation to improve soil quality in parks

Box 3.3. *Creo Antofagasta*: a long vision for sustainable growth *(Cont.)*

Creo Antofagasta is organised through an executive board led by the Regional Government and the Municipal Government of Antofagasta including, among its members, NGOs, regional universities and private companies' representatives.

Lessons for the future:

- build a shared vision with a rooted and realistic plan
- complement and support, not replace, local government
- focus on long-term strategic projects and delivering early wins with public sector leadership
- build trust by strengthening local capacity, developing an inclusive governance and boosting an active - not passive - collaborative culture
- secure public and private funding through formal investment agreements and accelerating feasibility and design processes.

Source: Information provided by Creo Antofagasta, www.creoantofagasta.cl.

Chile is implementing two major initiatives at the national and regional level to address the productivity challenges. *Alta Ley* is a public-private partnership, co-ordinated by CORFO in partnership with the Ministry of Mining, to identify long-term priorities to transform Chile's mining industry. It builds on the successful experience of the World Class Supplier Programme mentioned above. Through public-private dialogue, *Alta Ley* has developed a shared vision and road-map for 2035 that aims to mobilise investments and partnerships to increase productivity, competitiveness and innovation in the national mining industry and among its suppliers (Table 3.6).

Table 3.6. **Shared public-private goals for mining, 2015-35**

Objectives	Baseline 2015	by 2035
Increasing production	5.5 metric tons of copper	7.5 metric tons of copper
Increasing global leadership	40% of production in the 1st quartile of cost	80% of production in the 1st quartile of cost
Developing world class suppliers	65 firms	250 firms
Increasing annual exports of goods and services	USD 537 million	USD 4 000 million

Source: Authors' analysis based on information from CORFO, 2017.

The public-private partnership has identified four shared needs that require public and private action (Table 3.7):

1. developing technology-based solutions to ensure tailing's safety and sustainability
2. increasing the efficiency of smelting and refining processes
3. facilitating the shift towards smart mining and the adoption of autonomous solutions
4. enabling bottom- up innovations, facilitating the participation of domestic suppliers to the value chain and fostering the export orientation of these providers.

Consultations between the public and the private sector revealed gaps in four areas – skills, financing for innovation, standards, and supply chain development. Specific actions have been planned to address these gaps. The estimated budget for implementing these actions is around USD 100 million by 2035. As of 2017, the government had committed USD 35 million and the private sector had invested USD 10 million.

Table 3.7. **Priorities, gaps and actions for the future of mining in Chile, 2015-35**

NEEDS	Developing technological solutions to ensure the safety and sustainability of tailings			Increasing the efficiency of copper smelting and refining processes	Shifting to smart mining & autonomous solutions	Increasing the participation of domestic firms as suppliers of specialised goods and services	
GAPS	Human capital	R&D and innovation			Standards & regulation	Supply chain	
ACTIONS	Create a Technical Training Centre	Support smart tailing through online monitoring	Enable treatment and recovery of valued metals	Create a technological programme for copper smelting and refining processes	Develop standards for mining interoperability	Support internationalisation	Set up a Mining Innovation Platform
Expected public budget up to 2026	USD 7.43 million	USD 8.17 million	USD 3.19 million	USD 0.86 million	USD 8.17 million	USD 4.51 million	USD 8.04 million

Source: Authors' analysis based on official information from CORFO, 2017 on the mining strategic programmes.

The actions at the national level through *Alta Ley* are complemented by initiatives at the local level. The Mining Cluster of Antofagasta replicates the structure of national actions, but focuses on the regional ecosystem. This cluster program aims to increase mining competiveness in the region by fostering the development of a high-value added supply chain to exploit opportunities in the provision of technological services and by supplying specialised human capital. The program, which came about through public-private consultation, identifies several projects around a road map to 2025 for a total joint public and private expected budget of USD 5 million.

Alta Ley and the Mining Cluster of Antofagasta build on past experiences and previously-established trust between the public and private sector. Setting up effective spaces for consultation with the private sector strengthens the competitiveness programmes by ensuring the commitment of the business community. While it is too early to assess their impact, as they are in the early stages of implementation, some good practices in line with international experience (e.g. from Sweden, see Box 3.4) can be identified, along with some possible areas for improvement (Table 3.8):

- **Establishing trust between government and the private sector to achieve a shared vision for the future**. Chile, in line with international practices, has invested in trust building. Mining is, in fact, one of the areas in which Chile actually has a common practice of private-public consultation. *Alta Ley* has marked a step forward by making government and businesses looking into the future to identify opportunities and challenges to identify a road–map for action.

- **Getting the right stakeholders at the table**. Setting up effective public-private consultations is an important step in defining better policies. The effectiveness of these consultations depends, however, on the representativeness and inclusiveness of the participants. Over the last decade, Chile has strengthened the public-private dialogue with lead mining firms. In going forward it would be important to strengthen the participation of civil society, entrepreneurs along the entire value chain and local governments and communities.
- **Aligning the long term vision with long term financing**. Mobilising resources for innovative, high risk projects requires multi-annual budgeting. Enabling the multi-annual commitment of resources also favours partnerships with the private sector. The recently created Strategic Innovation Fund (FIE) is a step towards enabling financing strategic projects. Moreover it is important to reinforce the complementarity among the different programs, avoid duplicate interventions, resources and administrative procedures as well as overlapping in governances.
- **Fine tuning the policy mix with the objectives**. The dialogue with the private sector contributes to reveal competitiveness gaps in multiple areas. It is important to identify which instruments are more effective in addressing these gaps. In line with international practices, Chile is now shifting from a logic of simply providing financing to offering services to businesses. The creation of an innovation platform where lead firms in mining can interact with potential suppliers is a good step in this direction. Chile also has a gap in terms of technological capabilities and the creation of a modern technology institute that could address the challenges of mining together with the energy challenges seems a promising step in closing the gap in terms of technological and scientific capabilities.
- **Enabling learning and innovation in mining and beyond**. Facilitating innovation in mining could also open opportunities for innovation and learning in the overall economy. On the one hand, Chile could leverage on the transition of mining towards industry 4.0 to reveal the gaps that Chile will need to address to enable that its stakeholders participate and effectively compete in industry 4.0 types of business environments. These gaps include ensuring a high speed, resilient and redundant internet connection and enabling training for having the right skills for the digital world. On the other hand, the shift towards digital mining will expose the national innovation system (universities, researchers, firms) to these new technologies and will favour learning and potential spillovers to the whole system.

Box 3.4. **Smart and green mining: lessons learned from Sweden**

In Sweden, an innovation and solution-oriented private sector is leading the shift towards smart and green mining.

The high trust and social capital of the system, and the effective connection between businesses, universities and government, make the Swedish industrial system highly responsive to embracing change. This is coupled with the long-term financing that innovative and risky projects require. In Sweden, the fund “VINNOVA – Regional Growth through Dynamic Innovation Systems” finances large-scale initiatives and guarantees a public contribution of up to 50% of the total project cost for 10 years, for up to EUR 1 million annually. An evaluation of 12 of the first projects financed - up to 12 year financing - found clear impacts in strengthening the quadruple helix model and in the innovations focus of the regions.

Box 3.4. **Smart and green mining: lessons learned from Sweden** *(Cont.)*

The government and the private sector have built trust and capacity to work together to achieve a common vision over time. For example the Strategic Innovation Programme for the Swedish Mining and Metal Producing Industry (STRIM) follows a quadruple helix approach and is embedded within the strategic innovation programmes backed by high political commitment. The programme includes participation by national government, firms, universities, NGOs and municipalities. The programme has identified an agenda to 2030 that includes both industrial and social challenges. The programme finances full-scale innovation and pilot projects along the entire value chain: exploration, resource characterisation, mining, metallurgy, recycling, reclamation and environmental performance. In 2017, 51 projects were under implementation.

The government is highly responsive to business needs, and the private sector operates with high social and environmental standards, thus focusing not only on business growth, but also on how this growth is achieved (in terms of social and environmental impact) and how the benefits are shared across the community and society.

Sweden values highly a participatory approach in policy making and national policies benefit from structured mechanisms to consult with civil society, and with regions, local authorities, and communities.

Source: Contribution by International Council of Swedish Industry (NIR) to the Round Table on the Future of Mining in Chile, organised in the framework of the PTPR of Chile and hosted by CORFO in Santiago, Chile in April 2017.

Table 3.8. **Progress overview of the mining strategic programme, Chile, 2017**

Governance dimensions		
Anticipation capacity	√	The two long-term road-maps (to 2025 for the cluster programme and 2035 for national programme Alta Ley) bring Chile a step closer to international best practices. Aligning the two road maps with financing limited to 2018 will be an additional step forward that will secure impact.
Adaptation capacity	≈	The road-maps could be revised in light of changing international and domestic market dynamics. In a fast-changing technological environment the time for design and validating road-maps could be shortened from the current 13 months, while adaptability could be increased by introducing periodical revision of road-maps and of mid-terms targets.
Learning and upgrading potential	√	The focus of the programme and road-map on four specific gaps (human capital, R&D and innovation, standards & regulation, and the supply chain) is a step towards a logic that embraces all dimensions of the production system and that allows for the expansion of the knowledge base.
	√	Facilitating innovation in mining could also open opportunities for innovation and learning in the overall economy. Chile could build on the transition of mining towards industry 4.0 to reveal the gaps it will need to address if its industries and services are to work in an industry 4.0 environment.
	√	**Within government**. The programme benefits from multi-agency coordination and buy-n (e.g. Ministry of Mining, Ministry of Economy, Fundación Chile etc.).
	×	**Multi-level governance**. The presence of various programmes and actions at national and regional level over several dimensions may lead to a certain degree of overlap that could result in duplication of efforts and investment. It is important to reinforce the complementarity of the various programmes, avoid duplicate interventions, resources and administrative procedures, as well as overlap in governance structures.
Interconnectedness propensity	√	**Private sector**. Businesses participated in the road-map process and are represented within the governance structure of the programme.
	≈	**Civil society**. There is room to increase the participation of civil society in the process. Local community tends to have a negative opinion of mining operations in Chile.
	√	**Academia**. The programme benefits from commitment and co-operation mechanisms with academia and research centres.
Embeddedness potential	≈	Mechanisms to avoid rent seeking and capture need to be in place to ensure that publicly-financed actions benefit all stakeholders and deliver public and club goods not available otherwise. In this respect open government and effective monitoring and evaluation are needed to track progress and performance and identify areas for improvement.

Note: √: positive progress; ≈: margin for improvement; x: reform needed.
The definition of the five governance dimensions can be found in OECD (2017c) and in Box 2.1 in Chapter 2 of this report.

The future of agro-food: towards high-quality and functional food

This section focuses on agro-food in Chile. It presents a snapshot of the characteristics of the industry in Chile highlighting its strengths and weaknesses. It provides an overview of global trends with a view to discussing the future opportunities and challenges for Chile. It concludes by reviewing the current policy approach in a comparative perspective, and identifies avenues for going forward.

Chile has been successful in positioning its exports globally

Agro-food is an important economic activity for Chile, comprising agriculture, fishery and food processing industries. Together these account for 8% of Chile's GDP, contributeto more than 20% of domestic exports, and employ 17% of the national work force. The food and beverages industry accounts for almost 40% of total national manufacturing value added. Agro-food related activities are mostly concentrated in the Central Valley, even though the production frontier has been progressively shifting south due to climate change, making new areas cultivable. Almost 30% of Chilean firms (approximately 320 000) operate in activities linked to the agro-food value chain. They are specialised in agriculture (which alone accounts for 10% of total domestic firms), food processing (2.5% of total domestic firms) and retail. The market is dominated by a few, large companies, while 70% of the firms are micro-enterprises. Large firms (i.e. firms with an annual turnover above USD 4 million) represent 1.3% of firms in agriculture and 2.7% in food processing. Medium sized companies (i.e. firms with an annual turnover between 1 and 4 USD million) represent 2.9% of firms in agriculture and 3.6% in food processing, while small companies account for 23% of the total firms in agriculture and 25% in food processing (SII, 2016). On the export side, large firms outpaced others. Although SMEs represent 50% of exporting firms large firms account for 90% of total export for a value of 7.3 USD billions (Table 3.9).

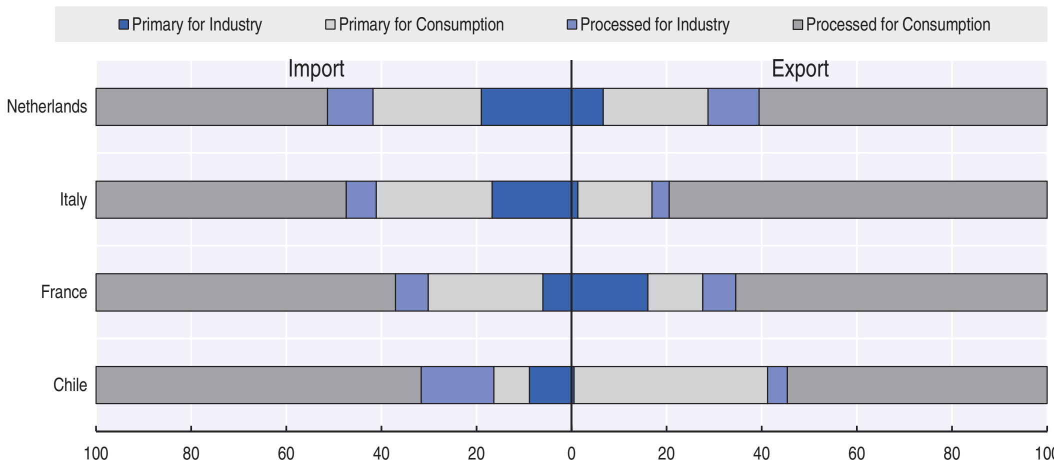
Table 3.9. **Large companies account for the bulk of Chile's agro-food exports, 2016**

Size class	No. of firms	Share of firms	Export value USD millions	Share of exports
Large	617	35.4%	7 299	89.2%
SMEs	830	47.6%	625	7.6%
Micro	148	8.5%	22	0.3%
Unclassified	148	8.5%	233	2.8%
Total	1 743	100%	8 179	100%

Note: Tabe includes firms in agriculture and food processing.
Source: Official information from DIRECON-Pro-Chile and SII, 2017.

Chile mostly exports primary products for consumption, and its exports are less diversified than other countries. For example, primary products account for 41% of Chile's domestic agro-food exports, compared to 15% and 11% in Italy and France respectively (Figure 3.19). In 2016, 49 products accounted for 90% of Chilean exports of agro-food. In comparison, 112 products explain 90% of Italy`s exports, 121 in France and 165 in the Netherlands. Chile is specialised in the export of fresh fruits and has emerged as a leading exporter in the wine industry. Grapes, pome and stone fruits account for 50% of total domestic agricultural production and 50% of agricultural exports. In 2016 Chile was the 8th world largest wine producer and the 5th world exporter, accounting for 8% of total international trade, by volume. Chile exports 70% of its production of wine to 150 countries, reaching on average 1.5 billion consumers per year (AAWE, 2017).

Figure 3.19. **Trade in agro-food by type, cumulative share 2013-16, selected countries**



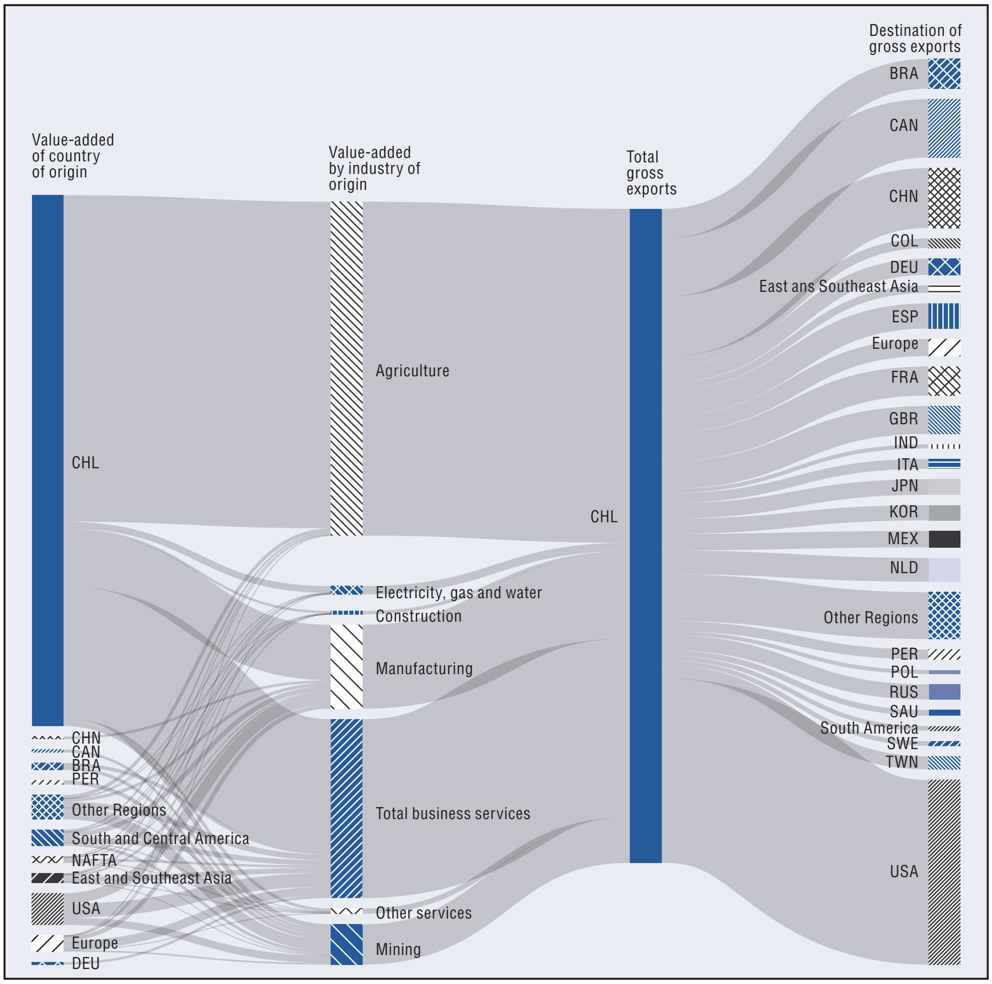
Note: Trade in agro-food by type is obtained by combining the Harmonized System (HS) classification with the Classification by Broad Economic Categories (BEC).
Source: Authors' analysis based on UN Comtrade (2017), Comtrade database, https://comtrade.un.org.

The export market has been highly dynamic in the last decade. Agro-food and beverages exports, which together account for half of Chile`s non-mining exports, have been more dynamic than overall domestic exports. They have been growing on average 10% annually between 2005 and 2015, while total domestic gross exports grew on average 2.5% annually over the same period.

An effective and open trade policy managed by DIRECON, combined with targeted efforts to strengthen Chile's reputation and image abroad, have contributed to the expansion of this industry. In 2015, 94% of agriculture, food and beverage processing exports were destined to the 64 markets covered by the 25 preferential trade agreements that Chile has in place. The primary market for the Chilean agro-food industry is the United States, accounting for 32% of Chilean agricultural exports and 24% of its food and beverage exports in 2015 (Figure 3.20). Japan is the second destination market, accounting for 15% of all Chilean food and beverage processing exports. Other important destination markets are the Netherlands (8% of total domestic exports), the United Kingdom (5%) and Brazil (4%). In the food and beverage processed industry, besides the United States and Japan, other important destination markets include China (6.5% of domestic exports), the Russian Federation (5%), Mexico (4.5%) and Korea (3.5%) (Figure 3.21). Chile's top 10 destination markets absorb 75% of total domestic agro exports and 70% of domestic exports of food and beverages.

Figure 3.20. **Decomposition of Chilean gross exports by origin and destination, agriculture, 2014**

Value added of exports by origin and destination (%)



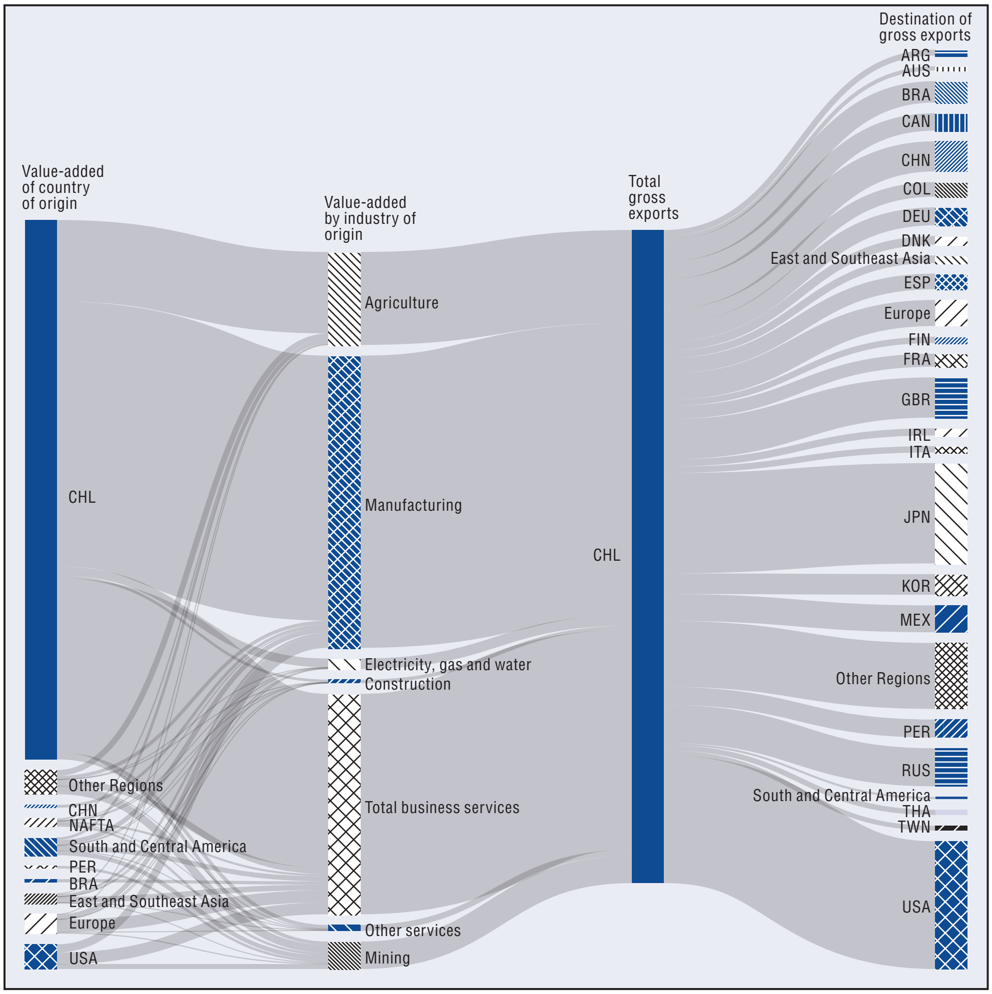
Note: Regional aggregates exclude member countries reported in the graph.

Source: OECD (2017b), TiVA Nowcast Database, http://stats.oecd.org/Index.aspx?DataSetCode=TIVA_NOWCAST; see also www.oecd.org/std/its/tiva-nowcast-methodology.pdf

Chile has the potential to increase land productivity and the value of its agro-food exports (Figure 3.22). Despite having 15 million hectares of cultivable land, Chile only exports agricultural products worth USD 6 000 million annually, while the Netherlands, with a cultivable surface of only 1.84 million hectares, exports agricultural products worth USD 28 000 million.

Figure 3.21. **Decomposition of Chilean gross exports by origin and destination, food manufacturing, 2014**

Value added of exports by origin and destination (%)

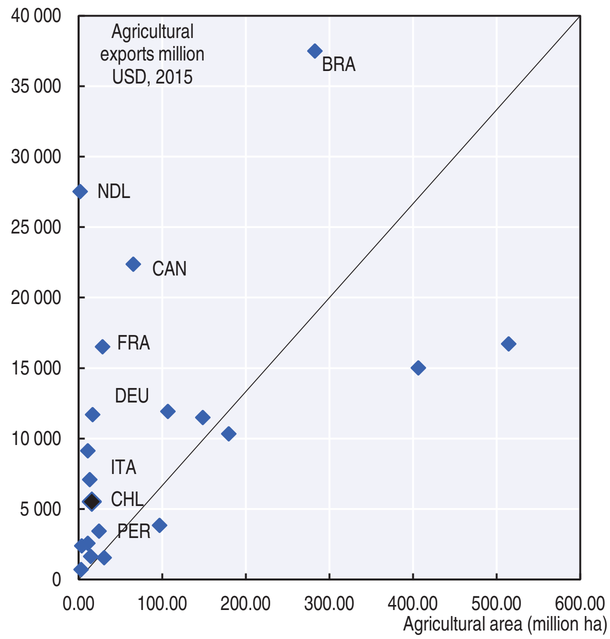


Note: Regional aggregates exclude member countries reported in the graph.

Source: OECD (2017b), TiVA Nowcast Database, http://stats.oecd.org/Index.aspx?DataSetCode=TIVA_NOWCAST; see also www.oecd.org/std/its/tiva-nowcast-methodology.pdf

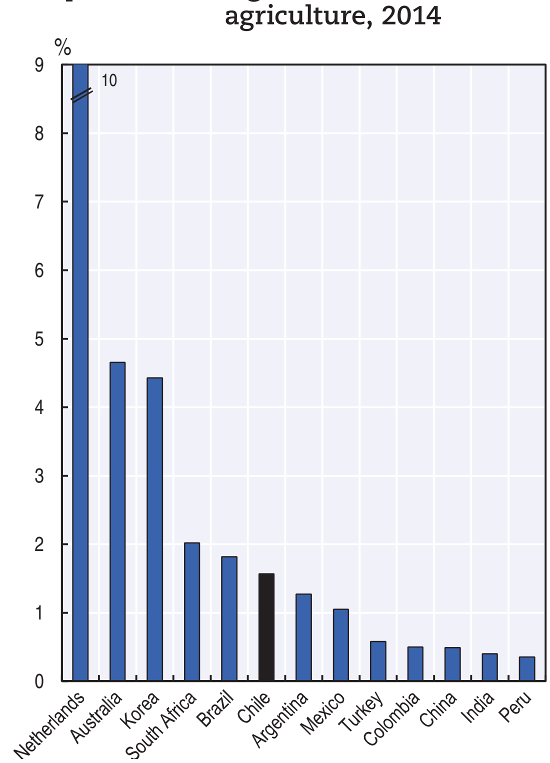
Increasing the impact of applied research and development in the agro-food value chain could help to increase the value added of domestic production. In Chile, the R&D intensity in agriculture, measured as a share of R&D expenditures on agriculture-related matters in agricultural value added, is higher than the national average (1.6% versus 0.4%). In Latin America, Chile is second only to Brazil for its R&D intensity in agriculture-related areas, where it is 2%. However, the gap with other emerging and advanced countries remains high. In South Africa, investment in agro-related R&D amounts to 2% of agricultural value added; in Australia the indicator reaches 5% and in Netherlands 10% (Figure 3.23).

Figure 3.22. **Agricultural exports and land area, 2015**



Source: Authors' analysis based on OECD National Accounts https://data.oecd.org/ and FAO Statistics database www.fao.org/faostat/, 2017.

Figure 3.23. **R&D expenditure in agricultural science as a share of value added in agriculture, 2014**

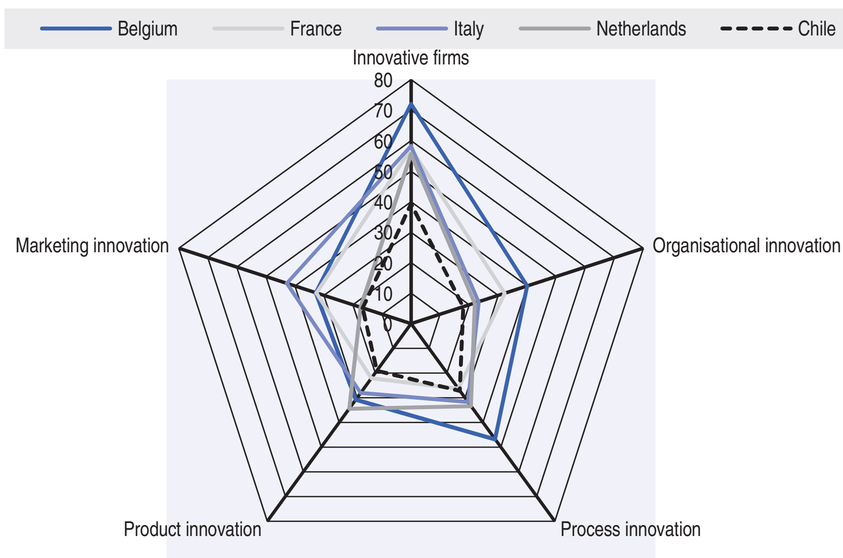


Note: R&D figures refer to 2014 or last available year: 2011 for South Africa; 2013 for the Netherlands, Australia, Korea, Brazil, and Peru

Source: Authors' analysis based on OECD National Accounts https://data.oecd.org and ASTI-IFPR https://www.asti.cgiar.org, 2017.

The private sector commitment to innovation in Chile's food processing industry is below that of international leaders. In Chile fewer firms introduce innovations, and among the innovators, Chilean firms tend to be less radical than firms in other countries and they tend to focus on process, rather than on product innovations. In Chile, 40% of food processing companies report being active in innovation, compared to 70% in Belgium and around 60% in France, Italy and the Netherlands. Additionally, 27% of Chile's innovators report having introduced a process innovation, 19% have introduced product innovations, and 17% have introduced organisational innovations (Figure 3.24).

Figure 3.24. **Share of food processing firms engaged in innovation activities by type of innovation, 2014**



Note: For comparing different innovation surveys we adopted the scheme proposed by Crespi et al (2016).
Source: Authors' analysis based on Eurostat (2014), "Community Innovation Survey", http://ec.europa.eu/eurostat/web/microdata/community-innovation-survey; and Chilean Innovation Survey 2013-14, 2017.

New trends in global markets are reshaping the global agro-food value chain

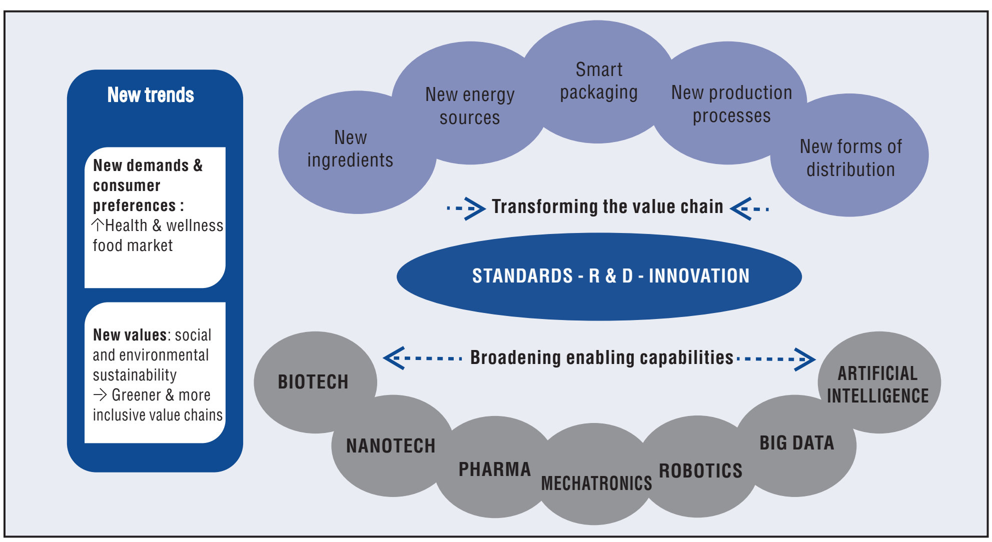
New consumer preferences are changing the global agriculture, food and beverage markets (Figure 3.25). The global functional food[3] market reached USD 140 billion in 2015 and is expected to exceed USD 250 billion by 2024. While a decade ago the demand for sustainable, safe and healthy food was limited to a niche market, the trend has recently become more diffused and is expected to keep growing in the future (Grand View Research, 2016). Consumers worldwide are more aware of the consequences of long and complex food value chains for the environment and their health. In the US, total food sales were up 1.9% in 2015 while organic food sales were up 16.9%. The market for functional and healthy food is growing, linked to the increased attention of middle classes to wellbeing.

Demand is shifting to "local" products (0-Km products), and "authentic" and unique products, often coming from distant markets but with a recognised impact on health. This is the case for the booming market in quinoa, a product almost unknown a decade ago in Western markets. Consumers are more aware of the impact of food on their quality of life, on the environment and on the people involved throughout the value chain, and demand for local and foreign products is growing. However, these trends come with higher requirements in terms of transparency and information on the characteristics of each product, the environment it comes from, the processing methods, and the overall sustainability of its production and distribution. Many lead firms in the food and beverage industry are taking steps in this direction. Some of these firms are strengthening the accountability procedures of their sourcing practices and their relationship with industrial suppliers and farmers, and are shifting from a logic of traditional responsible business conduct (RBC) to a logic of partnerships for competitiveness and development.

These changes are influencing the whole agro, food and beverage value chain standards, traceability and innovation, which are increasingly important. The standards linked to ISO 22000 define international norms for food safety. In addition to that, there are currently multiple bottom-up initiatives for setting sustainability norms for production, processing, and use of ingredients. The proliferation of these various standards makes it increasingly difficult for small and medium-sized companies to access the market. Clarification of international standards will be needed to ensure consumers' interest and fair market access for producers (OECD, 2013).

Innovations linked to new ingredients, smart packaging, new forms of production and distribution, and new energy sources are helping to redefine the value chain and the competitiveness opportunities for lead firms and suppliers. Major innovations are taking place in packaging, as focus is increasingly drawn to sustainable solutions, such as biodegradable packaging. As Chile mostly exports fresh fruit, smart packing is needed to preserve the products' freshness during transport, and to ensure a high-quality experience for the final consumer. Renewable energies also open up new opportunities to green the agro-food value chain, which accounts for 30% of global energy consumption (Sims et al., 2015).

Figure 3.25. **The future of global agro-food: new markets, innovation and standards**



Source: Authors' elaboration based on the outcomes of the Round Table on the Future of Agro-food in Chile, organised in the framework of the PTPR of Chile, hosted by CORFO in Santiago, Chile in April 2017.

The agro-food value chain is increasingly sophisticated and a growing number of scientific and technological areas will drive competitiveness in the future. Bio and nano technologies will be increasingly relevant for the value chain, but also competences linked to pharmaceuticals and new forms of packaging and manufacturing. For example, natural bioactives, including phytosterols, are used as ingredients in creating functional foods. However, because of their lack of solubility, stability and bioavailability, many of these ingredients cannot be directly consumed by people. Nanotechnology research is helping to improve the solubility and stability of these bioactive ingredients to transform them as inputs for functional food products. Research in chemical and pharmaceuticals is also increasingly relevant for the agro-food value chain, as food and chemicals are combined to develop nutritional products to prevent and treat diseases. The region of Emilia Romagna

(Italy), is investing USD 20 million in 74 applied research projects with a time horizon of 2014-2020 to connect the regional agro-food value chain to new technologies. The projects involve six regional universities, four regional research centres and the business community, including the Consortium of Parmigiano Reggiano.

Robotics, big data and cloud computing are also major enablers of future competitiveness. The global market for agricultural robotics is expected to grow from its current USD 1 billion to USD 28 billion by 2025 (Business Wire, 2016). Applied to smart farming, the Internet of Things and Big Data will shape precision agriculture through smart sensing and monitoring, smart analysis and planning, leading to increased yields and productivity and reduced environmental impact. Data science also benefits the sector through enhanced traceability and greater food safety. Big data coupled with neurosciences, behavioural sciences, and linguistics will also be increasingly relevant as they will contribute to develop new marketing techniques and will increasingly be used to define "nudging schemes" for inducing healthier consumer choices.

In Chile, world-leading neuro-scientists have contributed to the work of the Future Commission in the Senate, leading to the approval of a law that sets nutritional standards for food products that are allowed to be distributed in Chilean schools. Digital technologies can also help to green the whole value chain by helping farmers reduce their energy consumption. Precision irrigation systems based on GPS information can provide reliable and flexible water application and facilitate wastewater reuse. Crops often take up less than 50% of the applied irrigation water, so there is potential to improve efficiency by reducing water run-off and evaporative and infiltration losses. This can result in fewer electricity and fuel inputs for pumping. Both water and energy can be reduced by altering crop sowing dates to avoid anticipated periods of water deficit, by mulching, and by adopting sensor-based, water demand-led irrigation systems (Sims et al., 2015).

A pro-innovation mind-set, greater science-industry co-operation, and international standards will be crucial

Chile's agro-food value chain is built on well-established public and private institutions. The Ministry of Agriculture is responsible for promoting, steering and co-ordinating Chile's agricultural, livestock and forestry activities. It fosters technological research and transfer through INIA (the National Agriculture Research Institute). INIA, created in 1964, employs 320 researchers (measured in full-time equivalents), accounting for 45% of all researchers specialised in agricultural-related activities in Chile (IFPRI, 2016). Its mission is to generate, adapt and transfer technologies to ensure that the agricultural sector contributes positively to the security and quality of the food supply in Chile, as well as to transfer technology to increase the productivity of the agro-food industry. CORFO, ProChile (the Chilean Export Promotion Agency) and Invest Chile contribute, respectively, to strengthen domestic capacity, favour exports and attract foreign investment. The three operate with a combination of horizontal programmes and targeted actions for the agro-food value chain. CORFO focuses on enabling innovation and production development, especially in small firms. It also supported the creation of a universities consortium in 2016, which resulted in the creation of the Technological Centre for Food Innovation (CeTa). The centre aims, in co-operation with the private sector, to close the country's infrastructure and technological gap in order to facilitate the upgrading of the Chilean agro-food firms into functional and sophisticated food value chains. The Ministry of Foreign Affairs, through DIRECON-Prochile, promotes exports and access to foreign markets and facilitates trade through awareness raising, image promotion and partnerships, whereas Invest Chile is aiming to attract investments conducive to achieving the world frontier in the global functional and healthy food industry.

The setting up of the Chilean Agency for Quality and Food Safety (ACHIPIA) in 2005 to regulate phytosanitary and food safety in the country is another positive step. The agency defines and ensures compliance with standards and measures related to food safety and quality. The Agricultural and Livestock Service (SAG) is responsible for enforcing Chile's import regulations concerning alcoholic beverages, organic foods, animal and plant quarantine; the grading and labelling of beef and some processed food products, both for human and animal consumption, including pet-food, feed and feed supplements. In this respect, alignment with international standards is necessary to facilitate trade.

Lead firms count on strong business associations and have an export-oriented attitude. The Association of Fruit Exporters (ASOEX) and the Chilean Fresh Fruit Trade Association (FEDEFRUTA) are active in export promotion, targeting especially the United States, Europe, and Latin America. The Federation of Food Processing Industries of Chile (CHILEALIMENTOS ex-FEPACH) advises exporters on foreign trade issues, conducts statistical and tariff reviews of new markets, advises members on the proper use of export incentives, and advises exporters on certificate of origin issues. Chile is also home to some pioneer firms in functional food. For example, Granote was founded in 1981 with a mission to increase the value added of the wheat and grain value chain by focusing on technological solutions for nutrition, biotechnology and health.

For a country like Chile, in which the agro-food value chain accounts for 16% of employment and 12% of all firms, and contributes to 25% of domestic exports, it is essential to scan for and monitor global trends, and to identify niches where the country, with its limited production base, can compete effectively (Chile accounts only for 1.6% of global agricultural production). The business community and government share the vision that Chile has potential to benefit from emerging trends in the industry. Stakeholders also recognise that overcoming several barriers to scaling up in the global agro-food value chain will require co-operation among various actors. These barriers are related to: 1) enabling conditions for business development, such as reducing red tape, creating incentives for public-private R&D, and improving physical and Internet connectivity; and 2) specific issues linked to the agro-food value chain, such as co-ordination among the various actors and reaching a critical mass of investment in research and development to keep up with global trends (Table 3.10).

Table 3.10. **Multi-stakeholder assessment of the functional agro-food value chain, Chile, 2017**

Strengths	Weaknesses
• Availability of high-quality inputs (e.g. fruit) for functional food • Counter-seasonal supply to the north hemisphere • Effective image and reputation • High openness of the economy and effective trade policy • Ongoing international business to business co-operation with foreign companies	• Low productivity of micro enterprises • Low propensity to innovation in food processing • Limited co-ordination within and between government • Geographical distance from main destination markets that increases logistics costs & shelf-life challenges • Limited technology transfer capacity between universities, research centres and firms • Limited investment and installed capacities in ingredient development and smart packaging
Opportunities	**Threats**
• New, more sophisticated consumer tastes • Growing demand for functional food • New technologies to address logistic challenges • Leveraging on existing institutions for applied R&D in agriculture • Big domestic companies with a Latin American (and global) aspiration • Strengthened regional integration	• Small-scale production • Lack of appropriate standards and traceability systems • Climate change • Increasing water scarcity

Source: Authors' elaboration based on the outcomes of the Round Table on the Future of Agro-food in Chile, organised in the framework of the PTPR of Chile, hosted by CORFO in Santiago, Chile in April 2017.

In response to global trends, Chile has set up a process to identify a shared vision for the future and to clarify priorities for public investment. CORFO, with its mandate to foster business development in the country, has capitalised on past experiences and since 2014 has led a process of dialogue between businesses, academia and government agencies. In line with what is happening in other countries and regions, CORFO set up a consultative public-private process to define a vision and a road-map for 2025 in co-operation with the Ministry of Agriculture and the Ministry of Health, INIA, other government agencies, and in consultation with the private sector. The process involved 71 firms, 17 business associations and 17 public and private universities and research centres. The public-private dialogue led to the shared objective of positioning Chile among the top 10 world leading countries in the production and commercialisation of sustainable and functional food products. CORFO is co-ordinating the process, and it has helped to set up a road-map for 2025 with specific goals linked to increasing export diversification and sophistication and augmenting the value of exports (Table 3.11). This current national programme, *Transforma Alimentos*, builds on its precursor programme, PIAS (*Programa de Innovacion en Alimentos Saludables*). Set-up in 2012 the programme encouraged and promoted the development of a sustainable food value chain in Chile.

Table 3.11. **Vision and objectives for agro-food in Chile, 2013-25**

GOAL: To be among the leading global processors and exporters of healthy foods			
Targets	Indicator	Baseline 2013	by 2025
Diversifying exports	Number of agro-food products that cover 90% of exports	64	74
A more sophisticated export basket	Average Product Complexity index	0.61	0.50
Increasing export value	Free on board (FOB) export value	USD 18 billions	USD 32.2 billion

Note: The Product Complexity Index measures the knowledge intensity of a product by considering the knowledge intensity of its exporters. For more information see Hidalgo & Haussmann 2009: http://www.pnas.org/content/106/26/10570.short

Source: Authors' analysis based on official information from CORFO, 2017.

The road-mapping exercise identified six main gaps: 1) infrastructure; 2) human capital; 3) innovation; 4) co-ordination; 5) market access; and 6) standards for enabling the development of new food categories and high-value ingredients for specific consumer groups, as well as for ensuring high-quality inputs (e.g. fresh fruit), and the development of new packaging techniques to ensure effective shelf-life, quality and safety of Chilean products (Table 3.12). The government is mobilising public resources of around USD 30 million, and the private sector is contributing USD 10 million for the period 2015-18. The planned overall investment by 2025 is USD 100 million, of which 63% is expected to come from the public sector. The national actions are complemented by four regional plans: fruit in Valparaiso, horticulture in O'Higgins, semi-processed agroindustry in Maule, and high value-added processed food in Los Rios. The regional programmes foster co-ordination among the different actors, including farmers, producers, universities and local and national research centres. These regional programmes are managed by CORFO and co-financed by FIC (Innovation and Competitiveness Found) and FIE (Strategic investment Fund).

Table 3.12. **The Chilean agro-food strategic programme: gaps and actions by 2025**

GAPS & ACTIONS	Developing and promoting new food categories for specific consumer groups	Developing high-value ingredients from natural sources	Increasing productivity and quality of fruit exports taking into account climate change	Developing packaging to ensure effective shelf-life, quality and safety of Chilean products	Ensuring high quality inputs (e.g. new tubers for natural colorants, etc.) for specific demand from dynamic markets
INFRASTRUCTURE	Lack of adequate infrastructure for applied research and technology transfers => Creation of an Innovation & Technology Centre				
	USD 27.84 million				
HUMAN CAPITAL	Lack of adequate technical skills => Provision of extension services (USD 3.83million)				Lack of adequate technical skills => Provision of extension services (USD2.30million)
R&D & INNOVATION	Little investment in research for industry-related problem solving and innovation => R&D grants with request of matching funds from firms and services				
	USD 5.25 million	USD 18.10 million	USD 14.46 million	USD 6.78 million	USD 2.55 million
NETWORK and CO-ORDINATION	Scant co-ordination across and within regions => Grants for joint financing and for technology transfers				
	USD 0.51 million	USD 7.94 million	USD 1.10 million		USD 1.56 million
MARKET ACCEwwS	Financing for business scaling up		Financing and services for access to market		Financing for suppliers development
	USD 7.81 million		USD 0.35 million		USD 0.18 million
INFORMATION, STANDARDS, REGULATIONS	Lack of adequate standards & norms => Modernisation of the National System for Assessment, Quality and Food Safety => Modernisation of the traceability system				
	USD 0.69 million	USD 0.08 million	USD 0.29 million		USD 4.50 million

Source: Authors' analysis based on CORFO information, 2017.

The programme is in the early stages of implementation so it is too difficult for any type of impact assessment, but comparing the Chilean approach with international benchmarks can help identify key issues in going forward (Table 3.13):

- **Foster self-discovery and long-term thinking**. Chile's visioning approach is in line with global trends. All countries and regions with an exports-oriented agro-food industry are currently scanning for ongoing and potential future opportunities in the global market in response to changing demand and technology. Most countries are involved in exercises to identify long-term goals through public-private consultations. One example is the region of Emilia Romagna in Italy (Box 3.5).
- **Identify gaps that need public action**. The gaps and areas for public intervention identified by Chile also reflect international trends. These include: 1) public support, in the form of financing and/or services for infrastructure development, and in particular strengthening the research base; 2) skills development, with a particular focus on competences linked to technological convergence and digitalisation, and scientific areas relevant for the future of the industry; 3) market access facilitation; 4) co-ordination among different actors in the ecosystem; and 5) investment in standards and regulations.
- **Mobilise public and private resources for amounts that reflect global challenges**. The competitiveness challenges posed by the ongoing technological and demand revolutions require high mobilisation of resources. The Emilia Romagna region, with less than 5 million inhabitants, is mobilising USD 800 million between 2015 and 2020 for investments to improve the competitiveness of its agro-food system. Chile, according to current plans, is aiming to mobilise one-eighth of this amount (USD 100 million from 2014 to 2025). Considering Chile's future priorities to reduce

public debt, actions involving regional and global partnerships could help the country overcome its funding limitations.

- **Monitor implementation and assess impact**. New technologies offer new opportunities to guarantee easier and real-time access to information linked to the implementation of public action. Setting up a clear, easy-to-access mechanism for tracking implementation increases accountability and enables actions to be adjusted when expected results are not achieved. The region of Emilia Romagna has an open platform that monitors the implementation of actions linked to the agro-food system. It shows indicators of output (number of projects financed, firms participating, research centres, etc.) and impact (investment in R&D by firms, patents, among others).[4]

Table 3.13. **Progress overview of Chile's agro-food programme, 2017**

	Governance dimensions	
Anticipation capacity	√	The road-map to 2025 represents a step forward in line with international best practices. Alignment of the road map with financing limited to 2018 will be an additional step forward to secure impact.
Adaptation capacity	√	The programme is in line with global increasing demand for functional and healthy food products. The programme is also the result of long- standing tradition and relies on past experiences.
Learning and upgrading potential	**x**	Beside the national programme, other regional and national programmes are currently under implementation. These concern other complementary activities in the agro-food value chain, such as livestock, fishing and fruticulture. It is important to avoid excessive splitting of programmes, which could result in overlapping actions and information asymmetries.
	≈	The programme encompasses several lines of work. Nevertheless it should incorporate specific actions to better promote learning through technology complementarities with such as big data, smart farming and the Internet of Things, as well as the potential offered by renewable energies.
Interconnectedness propensity	√	**Within government**. The programme benefits from multi-agency co-ordination and buy in (e.g, Ministry of Economy, Ministry of Agriculture).
	≈	**Private sector**. Though businesses participated in the road-map process there is lack of buy in from a broad section of value chains, particularly those in upstream activities.
	√	**Academia and research centres**. The programme benefits from commitment and co-operation mechanisms with academia and international research centres, such as Fraunhofer Chile Research.
	x	**Regional co-operation**. Chile is a small economy that could build on its openness to foster greater integration at regional level to achieve critical scale in order to be competitive in the international market.
Embeddedness potential	≈	Mechanisms to avoid rent seeking and capture need to be in place to ensure that publicly-financed actions benefit all stakeholders and deliver public and club goods not available otherwise. In this respect open government and effective monitoring and evaluation are needed to track progress and performance and identify areas for improvement.

Note: √: positive progress; ≈: margin for improvement; x: reform needed.
The definition of the five governance dimensions can be found in OECD (2017) and in Box 2.1 in Chapter 2 of this report.

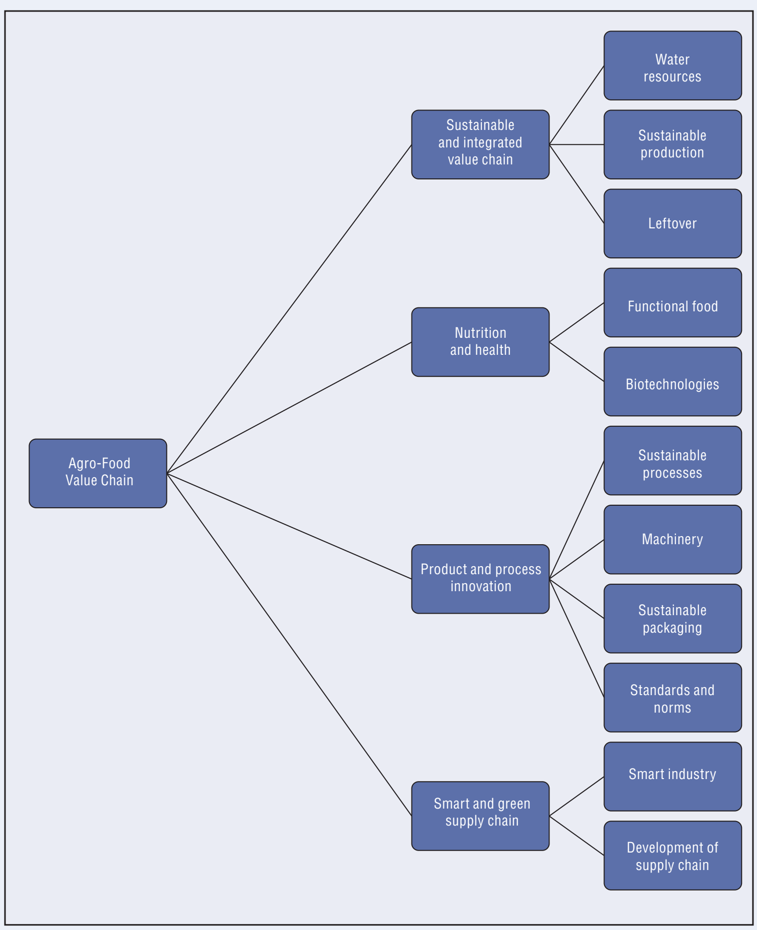
Box 3.5. **Scanning possible futures in agro-food: the experience of Emilia Romagna, Italy**

Emilia-Romagna is a world-leading region for agro-food. The industry benefits from complementarities between excellence in production, unique products and regional strengths in the whole value chain, including high quality capabilities in specialised machinery, education, training and research.

The agro-food system employs more than 16% of the regional workforce, employing around 313 000 people spread across agriculture (25%), food industries (20%), retail (20%), mechanical engineering (11%), chemical and complementary industries (2%), and other related services (22%). More than 770 co-operative firms are active in the region and generate 60% of the turnover of agro-food.

In 2013 the government of the Emilia Romagna region carried out a technology foresight process to define a strategy to sustain the competitiveness of the agro-food industry in line with the Horizon 2020 European Structural Funds. The process was co-ordinated by the regional government and the regional Agency for Research (ASTER). The process also involved the private sector and universities. As a result the region has identified 4 main challenges that have been associated with 11 areas of intervention (Figure 3.26).

Figure 3.26. **Scanning future challenges to set priorities for agro-food in Emilia Romagna**



Source: Regional Government of Emilia Romagna, 2017.

Conclusions

The changing global technological and economic landscape is opening up new opportunities for Chile. The definition of long-term agendas based on trust and dialogue between the government and the private sector is the cornerstone of future progress. This chapter has reviewed Chile's current public-private dialogue and roadmaps for the future in solar energy, mining and agro-food.

Solar energy could open up new opportunities for learning and innovation. Chile has a unique natural advantage in this industry. Unlike fossil-fuel based energies, solar is not extracted through drilling and mining, but is the result of high value-added activities. It involves a manufacturing value chain and can be produced and used locally. Innovating and identifying solutions for solar energy requires shared efforts from all actors in the ecosystem, including energy providers, academia and government. Chile is investing in closing the knowledge and regulatory gaps to unleash the potential of solar energy. Identifying potential synergies with other renewable energies and economic activities and strengthening regional ties to scale up investments and reach the critical mass needed to effectively compete at the global level will be important. In going forward, the social acceptability of solar energy should not be taken for granted. The social licence from which these energies currently from will only be sustained in the long run if new agreements, negotiations and benefit sharing with the local communities are developed. New forms of dialogue and partnership with local communities will therefore be needed.

Mining has been, and will remain, a key economic activity in Chile. Global trends are transforming mining into a more inclusive and sustainable sector. Green mining is already a business priority, in part because of high and growing energy costs, and also because of growing demand for "greener" products, pushing the need to green entire value chains. Chile could build on its effective partnerships with lead firms in the value chain to participate in this transformation at an early stage. This will require a pro-development attitude from the business community, and targeted policies to foster learning and innovation. Chilean mining will benefit from a shift in logic away from using technology as a "ready-made technical solution", to a discovery process that requires partnerships and trust between technology providers and mining operators. Working together to identify innovative solutions is the next step for trust-building between government and businesses in mining. *Alta Ley* is a promising step in this direction. The results will depend on effective monitoring of the implementation process, and on the capacity of government to adjust accordingly. It will also depend on the capacity to generate synergies with other industrial development opportunities, most notably solar energy. In going forward, a more integrated approach between social and environmental sustainability will be needed, as well as greater integration among different activities, such as *Alta Ley* and *Valor Minero*.

Chile's long-standing tradition in the agro-food value chain is reflected in its definition of actions and targets towards a more sustainable and productive system. In going forward, Chile needs stronger commitment from the private sector to innovate; greater co-operation between research and the business community; and effective policies to facilitate business development and enable strategic innovation through partnerships between academia, businesses and the government. Moreover a more holistic approach that avoids duplicated efforts would be important. Chile also needs to be actively involved in international discussions on standards and norms, as these will be increasingly relevant in the agro-food value chain and especially in the functional food segment. The institutional capabilities in this area that are already present in the country will be key for creating the transparent and stable regulatory framework needed to enable production development and trade.

Notes

1. Excluding hydroelectric larger than 20 megawatts (Mw).
2. For more information see http://solar-district-heating.eu/SDH/forheatsuppliers.aspx.
3. Functional foods are those types of food that provide additional health elements generated around a particular functional ingredient, for example foods containing probiotics or prebiotics.
4. The information is available here: http://www.regione.emilia-romagna.it/s3-monitoraggio/risultato.html.

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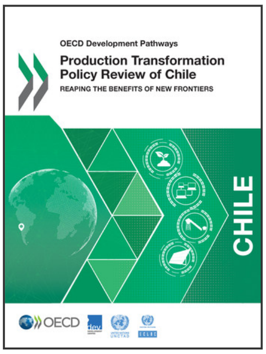

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