



COUNTRY PRIVATE SECTOR DIAGNOSTIC

CREATING MARKETS IN CHILE

A Stronger Private Sector for a More
Productive and Inclusive Society

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ABBREVIATIONS AND ACRONYMS

AChEE	Chilean Energy Efficiency Agency
ADSL	asymmetric digital subscriber line
AEF	Association of Family Businesses
AFP	Chile Pension System
AGCID	Chilean Agency for International Cooperation for Development
ANID	National Agency for Research and Development
AR	Argentina
ARCLIM	Climate Change Risk Atlas
ARG	Argentina
ARPU	Average Revenue per User
ASCC	Sustainability and Climate Change Agency (Corfo)
ASECH	Chilean Association of Entrepreneurs
ASOEX	National Fresh Fruit Industry Association
AUS	Australia
BCCh	Central Bank of Chile
BCN	Library of the National Congress of Chile
BPS	Business Pulse Survey
BPG	Good Practices on Livestock Certification
BR	Brazil
BTI	Bertelsmann Transformation Index
CAE	Chile State-Guaranteed Loans
CAEX	combustion system for mining
CAGR	compound annual growth
CASEN	Socioeconomic Characterization Survey
CCS	Carbon Capture and Storage
CfD	contract for difference
CFT	technical training center
CH₄	Methane
CHL	Chile
CL	Chile
CLP	Chilean Pesos (currency)
CMF	Financial Market Commission

CNA	Chile's National Accreditation Commission
CNED	Chile National Board of Education
CNID	National Council of Innovation for Development (Spanish form Consejo Nacional de Innovación para el Desarrollo)
CNP	Chilean National Productivity Commission
CNR	National Irrigation Commission (Comision Nacional de Riego)
CO	Colombia
CODELCO	National Copper Corporation of Chile
Corfo	Chile Economic Development Agency
CO2	carbon dioxide
CO2eq	carbon dioxide equivalent
CPI	Infrastructure Policy Council
CPSD	Country Private Sector Diagnostic
CPTPP	Comprehensive and Progressive Agreement for Trans-Pacific Partnership
CSA	climate-smart agriculture
CSP	concentrated solar power
CR	Costa Rica
CRI	Costa Rica
DER	distributed energy resources
DIPRES	Budget Office of the Finance Ministry
DT	Labor Directorate
ECLP	Chilean Long-term Climate Strategy
EHS	environmental, health, and safety
ELPI	Longitudinal Survey of Early Childhood (Spanish form Encuesta Longitudinal de Primera Infancia)
ENADEL	National Survey of Labor Demand
ENCLA	Labor Survey
ENIA	Annual Industrial Survey produced by Chilean National Statistical Agency
ENAP	National Petroleum Company
ESCO	energy service company
EU	European Union
FAO	Food and Agriculture Organization, United Nations
FCIC	Conditional Credit Facility to the Increase in Bank Loans
FDI	foreign direct investment

FEDEFRUTA	Chilean Federation of Fruit Producers
FIA	Foundation for Agricultural Innovation
fintech	financial technology
FNE	Chile National Economic Prosecutor
FOA	Fibra Optica Austral
FOB	free on board
FON	Fibra Optica Nacional
FOGAPE	credit guarantee scheme
FTTB	fiber to the building
FTTC	fiber to the curb
FTTH	fiber to the home
FTTx	fiber to the x
G	generation (cell technology)
GAP	good agricultural practice
GDP	gross domestic product
GEM	global entrepreneurship monitoring
GH	green hydrogen
GHG	greenhouse gases
GII	Global Innovation Index
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German society for international cooperation)
GORE	Regional Government
GRASP	Global GAP Risk Assessment on Social Practice
GTT	technological transfer group
GVC	global manufacturing value chains
GW	gigawatt
GWh	Gigawatt Hour
H₂	hydrogen
ha	hectares
HFC	hybrid fiber coaxial
HHI	Herfindahl-Hirschman Index
HNWI	high-net-worth individual
ICT	information and communication technology
INDAP	Institute for Agricultural and Livestock Development
INE	National Statistics Institute
INIA	Chilean Agricultural Research Institute

IoT	internet of things
IP	professional institute
IT	information technology
kg	kilogram
km	kilometer
kWh	kilowatt-hour
LAC	Latin America and the Caribbean
LC	levelized costs
LCOE	levelized cost of energy
LCOH	Levelized Cost of Hydrogen
LNG	liquefied natural gas
LTE	long-term evolution
MeOH	methanol
MFN	most favored nation
MINAGRI	Ministry of Agriculture
MINAMB	Ministry of Environment
MINECON	Ministry of Economy
MINEDUC	Ministry of Education
MinEnergía	Ministry of Energy
MINSAL	Ministry of Health
MMt	million metric tons
MNO	mobile network operator
MOF	Ministry of Finance
MOP	Ministry of Public Works
MoU	memorandum of understanding
MSTI	Main Science and Technology Indicators (OECD)
MSTKI	Ministry of Science, Technology, Innovation and Knowledge
MX	Mexico
NDC	Nationally Determined Contribution (in the UNFCCC context)
NH3	ammonia
NZL	New Zealand
ODEPA	Office of Agricultural Studies and Policies (MINAGRI)
OECD	Organisation for Economic Co-operation and Development
OLM	Metropolitan Region Labor Observatory
OPEX	Operating Expenses
OTIC	Intermediation Technical Training Organization

PE	Peru
PIAAC	Program for the International Assessment of Adult Competencies
PMGD	distributed energy resource
PMR	Product Market Regulation
PPA	purchasing power agreement
PPP	public-private partnership
PTA	preferential trade agreements
PV	photovoltaic
R&D	research and development
RILES	liquid industrial waste; residuos industriales líquidos
RISES	solid industrial waste; residuos industriales solidos
RPS	renewable portfolio standards
SDG	Sustainable Development Goal
SEGPRES	Ministry General Secretariat of the Presidency
SENCE	National Training and Employment Service Institute
SEP	State-Owned Enterprises System
SERCOTEC	Chilean government's SME promotion agency
SIES	Higher Education Information Service (Servicio de Información de Educación Superior)
SME	small and medium enterprises
SNA	National Society of Agriculture
SOE	state-owned enterprise
SP	Superintendency of Pensions
SSAF	Flexible Allocation Seed Grant (Spanish form Subsidio Semilla de Asignación Flexible)
STEM	science, technology, engineering, and mathematics
STI	science, technology, and innovation
STKI	science, technology, knowledge, and innovation
SUBREI	Undersecretary of International Economic Relationships, Ministry of Foreign Affairs
SUBTEL	Undersecretary of Telecommunications (Spanish form Subsecretaría de Telecomunicaciones)
SUBSIDES	Undersecretary of Assistance Networks, Ministry of Health
TCO	total cost of ownership
TDLC	Chile Competition Tribunal
telecom	telecommunication

TFP	total factor productivity
TiVA	trade in value-added
TPA	third party access
TTG	technological transfer group
TVET	technical and vocational education and training
UK	United Kingdom
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
US\$	United States dollars
VC	Venture Capital
WBG	World Bank Group
WDI	World Development Indicator
WEF	World Economic Forum
WMS	World Management Survey
ZAF	South Africa

EXECUTIVE SUMMARY

Chile has long had a strong private sector that has enjoyed an accommodating and supportive policy environment. Vibrant private activity, domestic and foreign, has supported a development success story, with sustained growth and falling poverty. Chile was the first country in Latin America to reach high-income status, joining the Organisation for Economic Co-operation and Development (OECD) in 2010. Economic growth was robust over several decades, averaging 6.0 percent during the 1990s and 4.5 percent between 2000 and 2013. Poverty plummeted, and the country now has one of the lowest poverty rates in Latin America. Substantial growth in wages also brought with it an expansion of the middle class to more than 60 percent of the population.

The imperative of building a green, knowledge-based, inclusive economy will inevitably continue to rely on the private sector playing a potent role as a partner in development. Remarkable opportunities are emerging to transform the economy, including through greater digitalization, the development of green hydrogen, and the expansion of climate-smart agriculture, as argued in this report. Yet today, the private sector and its role as an agent of inclusion, innovation, and growth are central issues in the ongoing debate over the future of Chile.

In an environment constrained by lower growth and productivity, Chileans are demanding access to better opportunities and improved services. The market liberalization reforms initiated in the late 1970s and early 1980s—which supported a private sector-driven and price-deregulated market economy, amplified by sustained commodity demand from China in later years—brought steady progress and economic growth until the mid-2000s. But lately growth rates have been on the decline. The end of the commodity cycle, combined with the lagging quality of some services, including tertiary education—which is provided largely by the private sector—have fed perceptions of unmet expectations. Segmentation continues in education and health care, and labor markets remain segregated, pointing to high inequality of opportunities. Moreover, many in the middle class are vulnerable to falling back into poverty. The impacts of the COVID-19 pandemic on jobs and incomes have strengthened these perceptions.

The current constitutional process is an opportunity to set the stage for the private sector to be a stronger partner in building a more inclusive society and an innovative, productive, and greener economy. For this to happen, this Country Private Sector Diagnostic (CPSD) argues that three avenues will be essential:

- Enhancing productivity,
- Building a knowledge-based economy through more support to innovation, and
- Upgrading skills for greater inclusion and innovation.

After a consideration of these transversal themes, the CPSD delves into three areas that illustrate the potential for the private sector to support a transition to a green, knowledge-based economy: green hydrogen development, climate-smart agriculture, and the digital economy.

Jumpstarting Productivity Growth

Economic growth in Chile over the past three decades has largely stemmed from substantial capital deepening, while growth in total factor productivity (TFP) has been weak or negative. Poor TFP growth is behind the growth slowdown, undercutting convergence with the average OECD income level. Factors linked to weak productivity performance in Chile include the concentration of the export base in natural resource sectors and limited adoption of, and investment in, new technologies as well as limits to competition, growing challenges in the regulatory framework, and inadequate labor force skills.

Upgrading managerial and worker skills, investing in innovation, ensuring better access to finance for new ventures, and strengthening competition can improve firm efficiency and support productivity growth. Gaps in these areas—skills, innovation, risk finance, and competition—may explain declining firm efficiency and abnormalities in the contribution of entries and exits to aggregate productivity. At the firm level, declining efficiency appears to be behind falling productivity, and to some extent to the exit of more productive firms, which are then replaced by less productive ones—the opposite of “creative destruction”.¹ The persistently negative contribution of firms’ internal efficiency to productivity, at least in manufacturing, is worrisome. On a positive note, more productive incumbents appear to be gaining in the reallocation process, growing in size as less productive firms shrink in comparison.

Enhancing competition to boost productivity

Chile enjoys a robust regulatory framework to promote competition as well as competent institutions that have gained more power to enforce the law over time. Chile compares well to regional peers in this respect, and its indicators are only slightly more restrictive than the OECD average.² Some of the gaps that remain explain the divergence in Chile’s indicators from top performers and include the need for additional simplification and consistent evaluation of regulations and the removal of barriers in services and obstacles to trade and investment.

Enhancing competition through reforms can spur productivity and efficiency and improve market outcomes in key enabling sectors and network industries. State-owned enterprises (SOEs) are present in some enabling sectors, and enhanced application of competitive neutrality principles could translate into a more level playing field for private operators. In some network industries such as telecommunications (telecom) and gas, despite growing competition in the former in recent years, regulation appears to protect incumbents.

Competition can be increased by reforms in three areas. First, the government could strengthen the competitive neutrality framework in sectors with SOE presence by evaluating the need for the state to directly participate in markets that are being served by the private sector and by separating the commercial and noncommercial activities of SOEs. Second, regulatory gaps in network industries such as telecom and gas should be addressed. These reforms include strengthening the independence of the telecom regulator; addressing within the gas sector public operator the lack of separation between transmission and distribution, production, and retail supply; and regulating (rather than negotiating) third-party access to the transmission grid and to the distribution networks. Third, the government could reinforce merger control by implementing the recently adopted regulation (Decree No. 41) and by reassessing proposals that could derail existing efforts to strengthen anticartel policy by allowing the public prosecutor to conduct parallel investigations of cartel cases.

Untapping the potential of global value chains and the services trade

Chile is rightly seen as a model of export diversification. Over the past 50 years, the country has evolved from one of the most highly concentrated commodity exporters in the world to a much more diversified exporter. This progress includes greater domestic value addition in the traditional mining sector as well as the development of successful agro-industries, including fresh-fruits and nuts, fish, wood, and wine, where Chile is a global leader. Although these products are linked to Chile's traditional comparative advantage in natural resources, most involve sophisticated logistics, processing, and manufacturing-based value addition.

However, exports have not played their role as a driver of economic growth and productivity in Chile in nearly two decades. The share of exports in Chile's gross domestic product (GDP) has declined steadily from its peak of 43 percent in 2004 to about 31 percent today. This drop in exports is correlated and contemporaneous with the fall in the contribution of TFP growth to overall GDP growth. Boosting export dynamism to promote productivity-driven growth is a priority in the post-COVID-19 recovery period and beyond.

Engaging with global value chains (GVCs) in manufacturing to a greater extent and boosting services trade are two options for Chile to spur greater integration and to further tap foreign direct investment to drive productivity growth. GVC participation in manufacturing and trading in services provide channels for firms to grow, specialize, access new technology, and increase the sophistication of their production chain. Cross-country comparisons also reveal that a higher portion of imported inputs used in export production translates into more dynamic growth in value addition in exports. Chile is currently located toward the lower end among countries in terms of growth in both backward GVC participation and domestic value addition in exports.

The potential for greater growth of trade in services is large, both for nontraditional export services, such as business services, and for service imports in the production of manufacturing exports. Business services (including consulting, research and development [R&D], and engineering services) have shown a positive trend, growing their share in total service exports from 17 percent in 2003 to 27 percent in 2019. Chile could also benefit from increasing the import value added of services in its manufacturing exports to drive greater export productivity. With more competitive services, firms adopt a more complex production structure and improve managerial practices.

While Chile's limited GVC participation and service trade can be explained by the country's high share of natural resources exports and its remoteness from GVC hubs, policy actions can help foster deeper integration. Although Chile performs in the midrange of peer countries in terms of average most favored nation tariffs, and it benefits from an extensive network of preferential trade agreements (PTAs), some nontariff barriers to trade remain. For instance, unlike in the case of merchandise imports, Chile employs fairly high trade restrictions in services, in particular in financial services but also in business services and telecom. Moreover, services trade is undermined by policies that, while not discriminating against foreign providers, inhibit transparency and competition. Chile stands out among OECD countries for the relatively large share of its restrictions in areas that deal with competition and domestic transparency procedures. This is particularly true for telecommunications and transport

services, activities that drive productivity and affect Chile's connectivity with the global economy. Restrictions impose significant markups in telecom, air and maritime transport, and warehousing. The coverage of Chile's PTAs is exceptional, reaching almost 98 percent of exports. However, increasing the depth of its agreements—in particular the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP)—for instance in the areas of intellectual property rights protection and competition, could also foster GVC upgrading, including in services sectors. Additional policies could include reducing transactions costs by aligning regulatory measures to those of key trading partners and improving connectivity and trade facilitation to overcome geographical disadvantages.

Raising productivity through digitalization

Chile is well-positioned to profit from a vibrant digital economy. Technological change could open a window of opportunity to transform Chile's economy and overcome structural weaknesses, including low firm productivity. Increasing digital uptake and exploring opportunities and synergies in, for instance, mining, solar, electro-mobility, and smart agriculture could be a game changer. Although digitalization accelerated among firms during the COVID-19 pandemic, the adoption of more sophisticated uses of technology in Chile would have an even more transformational impact. The use of digital platforms and digital finance has increased significantly, and the country is at the forefront of technology innovation in some respects. To push the frontier forward, Chile needs to close the remaining infrastructure, skills, and risk-financing gaps and address other barriers so that digital entrepreneurship and the digital economy can be developed further. The CPSD considers the potential of the digital economy in Chile in one of its three sector assessments.

Unleashing Innovation to Foster a Knowledge-Based Economy

Some of the stronger innovators in Chile are its young and exporting firms, but overall Chile's investment in innovation seems to have stagnated. According to the XI National Innovation Survey,³ 14 percent of firms innovated during the 2017–18 period, substantially below levels prevalent in OECD countries.⁴ Spending on R&D, at about 0.35 percent of GDP, is lower than would be expected for Chile's level of development, even after adjusting for its economic structure, and just one third of the total is financed by the private sector. As expected, exporting firms show higher innovation, in part because they are more exposed to international competitive pressures (Havranek and Irsova 2011) and the newest technologies (Meyer and Sinani 2009). Innovative clusters have emerged in the Chilean wine and fruit industries, for example, both major global exporters. Younger companies, those that are less than five years old, innovate more than companies that are older than 20 years. This observation highlights the importance of easing constraints to firm entry and fostering innovative entrepreneurship to spur productivity.⁵ Still, innovation by Chilean firms that operate in international markets lags the levels found in most OECD countries and in Chile's structural peers.

The high quality of Chile’s institutions, its open economy, and the strength of its overall business environment have generally been conducive to innovation, but other factors undermine these advantages. As highlighted by the Global Innovation Index (GII), a focus on human capital and research, as well as on business sophistication and especially on linkages with the innovation system, is needed. Strong managerial skills lead firms to pursue innovation and improve their technological capabilities, but the latest management survey conducted in Chile indicates that management skills remain below those of its structural peers and most OECD countries. And although a growing number of Chileans pursue graduate degrees, few do so in STEM areas: 7.3 percent of graduates, compared to an average of 22.6 percent in the rest of the OECD.

Stronger linkages across the innovation system, especially between universities and firms, can foster the transfer of technology and broaden learning spillovers, as can widespread access to risk finance and vigorous competition. A significant part of the execution of R&D resources is concentrated in universities (46 percent versus the OECD average of 18 percent), but they have limited linkages to industry, especially SMEs. Risk-financing instruments, also important to support investments in intangibles and innovative entrepreneurship, are not adequately developed in Chile. The size of the venture capital industry barely reached US\$147 million in 2020, and most early-stage funds are publicly sponsored. Insufficient competition in some sectors might have also discouraged innovation efforts, but enabling greater competition without building firms’ capabilities will not induce innovation. These results point to the need to improve plant capabilities and managerial practices, which drive “the leaders,” as an important innovation policy complementing efforts to increase competition (Cusolito, Garcia-Marin, and Maloney 2021).

The new institutional framework for innovation is still under consolidation, and a top priority will be to build consensus around a long-term innovation strategy that provides more continuity to policy making. Other international experiences show that it takes time to develop capabilities and transform a country’s innovation ecosystem. A more dynamic innovation system will not only be important to productivity but will also foster a transition to a greener economy. The innovation strategy will also need to consider the process of decentralization under way in Chile and the role that the regions will progressively play in the design and implementation of innovation initiatives that complement efforts at the national level.

Developing Skills for an Inclusive and Innovative Economy

Steady growth in coverage and improved governance have placed Chile in a leading regional position in educational quality; despite this, there is a perception of crisis in the higher education system. This perception stems from continuing inequality of access to high-quality tertiary education—only 32 percent of 18–24-year-olds from the bottom-income quintile were enrolled in higher education, compared with 58 percent for the same age group in the top quintile in 2019. Student funding mechanisms, now moving to a tuition-free model, have helped expand access, with gross enrollment growing from 37 percent in 2000 to over 86 percent in 2016, creating a basis for a more inclusive society and supporting the acquisition of 21st-century skills. They have, however, also created new frictions in the system. Whereas for a majority of graduates higher education is a good investment, for a significant minority—10 percent—the returns are negative. High levels of student debt and unemployment, combined with a gap between acquired skills and job market needs, have added to dissatisfaction. A series of reforms have attempted to address the challenges in the system, including a major reform of higher education in 2018, but implementation on several important fronts (such as accreditation) has been incomplete.

Rapid growth of access to higher education has itself transformed the student profile, challenging the education system to find the flexibility and market relevance to respond to the needs of students and the job market. Today, roughly 60 percent of students in higher education are part of a first generation to access universities or technical and vocational education and training (TVET) institutions. Most are older and already working, many are women, some have families and pay for themselves, many live in remote locations, and most face greater responsibilities and time constraints. These students require a tertiary education system that is sufficiently flexible, diversified, and relevant to cater to their needs.

The need for flexibility is not yet reflected in policy priorities. Student funding schemes tend to be rigid, with limited funding available for part-time students or distance learners. The structure of degrees and titles is narrow and designed without full consideration of growing needs for life-long learning. Continuing education still lacks a legal definition or a clear place and role in educational trajectories. Quality assurance mechanisms, in some cases, deter innovation in modes of education and the granting of new credentials. The higher education system is struggling to meet the demands of an emerging knowledge-based, innovation-driven, inclusive society.

Through ongoing reforms, Chile can promote greater inclusion, flexibility, and curricular innovation in higher education and increase its relevance by decisively engaging the private sector in shaping its offerings. Bolder public-private partnership initiatives—such as in digitalizing higher education—and more fluid ways to obtain and update qualifications will be crucial to prepare Chilean higher education for the challenges of the future and prevent a widening of the skills gap. Stakeholders, including the private sector, should seize the opportunity provided by the discussion of new criteria and standards of accreditation to move toward a consensus in Chile for a flexible approach to quality education.

Greater flexibility in financing higher education institutions also could be considered. A financing system based on institutional performance may be more appropriate, based on indicators related to the quality of graduates and research, degree of employability, and other factors. More flexible rules for financing students are also needed, including financing for continuing education, modular programs, part-time study, and other forms of training. Engaging with the business sector could make higher education programs more market-relevant, including through flexible training programs with multiple entry and exit points between different types of institutions and the labor market, and a greater recognition of knowledge and competencies students have acquired previously. There is also a need to harness the power of high-performing TVET programs, especially short-cycle ones, to upskill and reskill workers and bridge a potentially widening the skills gap.

A more inclusive, integrated labor market could also incentivize skills acquisition. Segmentation in Chile’s labor market—the persistence of differences in working conditions that cannot be attributed to difference in productivity alone—is a source of inequality and can be a constraint on productivity. Women, temporary workers, informal workers, and people engaged in telework tend to be disadvantaged in their labor arrangements, not always for reasons associated with skill or ability. Although Chile’s dynamic labor market provides flexibility to adapt to cycles, the high proportion of temporary jobs reduces job quality, human capital accumulation, and productivity. Differences in contract types have contributed to labor market segmentation: 25 percent of private sector salaried workers in Chile are on temporary contracts,⁶ the third-highest proportion of temporary contracts in the OECD after Colombia and the Republic of Korea. Legislation provides little security to such workers. Workers on fixed-term contracts lose out on many work benefits, receive less training, and have less job security. This situation tends to reduce incentives for specialization and accumulation of human capital.

Greening the Economy While Ensuring a Just Transition

Chile has been a regional and global leader in sustainable development and has committed to achieving net zero emissions by 2050. Updated Nationally Determined Contributions reflect a renewed commitment to the country’s increasingly competitive green and clean energies, as well as the promise to integrate adaptation measures in its productive sectors. Priority actions include extending transmission infrastructure and implementing regulatory reforms to allow the massification of renewable energy and greater electrification of the economy; promoting electromobility and the use of clean fuels in the transport sector; and consolidating carbon pricing instruments.⁷

For Chile to achieve its commitments and to increase its resilience to climate change, it will need to deepen the decarbonization of major greenhouse gas (GHG) sources, improve the absorptive capacity of natural sinks, harness digital technologies to reverse the high growth–high carbon trend, and support innovation and sustainable resource management. This report considers opportunities for Chile and for its private sector in three areas that can contribute to a greener, more resilient, and more inclusive economy, namely:

- Green hydrogen, which has the potential to reduce emissions and to become a significant new export sector;
- Climate-smart agriculture, whose more widespread use among producers of all sizes would strengthen the sustainable management of some of Chile’s land and water resources while improving GHG absorption capacity; and
- The digital economy, which has the potential to decouple emissions and resource use from economic growth while transforming and democratizing education and jobs.

Adopting Green Hydrogen as a Source of Future Growth

Chile hopes to become a global leader in the nascent green hydrogen (GH) industry by leveraging the abundance and low cost of its renewable energy resources, key to the production of GH. Chile has the potential to be one of the most competitive countries for GH production in the world, with the capability to produce GH at costs of US\$1.60 per kilogram of GH (kgGH), or lower, in the long term. In addition to Chile's cost and capacity advantages in renewable energy, the country's ambitions are supported by (a) a strong overall policy environment, (b) concrete advances in regulations to incorporate GH into its energy matrix, (c) hosting of the largest number of GH projects under development in the Latin America and the Caribbean region, (d) international cooperation agreements with several international ports, and (e) the existence of important potential domestic off-takers in the mining industry, in ports, and for electricity supply. Technological advances will expand the list of uses for GH in the future.

GH investments have the potential to substantially support the greening of Chile's economy, as well as to create high-quality jobs across the country, boosting inclusion. Chile's National GH Strategy estimates that GH can create 100,000 associated jobs by 2030 and that the industry could lead to investment opportunities worth US\$200 billion and to exports of US\$30 billion in 2030, representing 10 percent of GDP and rivaling Chile's copper exports. GH also features in Chile's ambitious GHG emissions reduction goals as the second largest contributor to emissions reductions after industry by 2050.

Although GH production may become competitive relatively soon, the various GH applications vary in terms of their attractiveness and their timeframes for viable adoption. An analysis conducted for this report concludes that some GH uses are competitive today—assuming a secure GH supply and the announced willingness by countries to pay a premium for GH—whereas others may become attractive in the medium and longer term. Promising applications include ammonia exports, which represent a large potential market and are feasible at today's costs. GH forklifts in the mining sector also outperform the electric benchmark at today's costs, assuming a secure GH supply. GH in Chile may also have high potential in the near to medium term to integrate renewable electricity into isolated microgrids, most of which are currently supplied with 100 percent fossil fuels. GH blending into gas grids could reach parity in 2030, whereas ammonia for use as an explosive in mining and for hybrid combustion system for mining (CAEX) trucks used in the mining sector should reach competitive costs in the longer term (2030–50).

There remain significant challenges, however, to reaching economies of scale in GH production, despite encouraging signals that reflect high global expectations. These challenges include financing hurdles, difficulties in gauging market size for GH, significant technological issues, and competition from other GH producers. Green hydrogen projects are risky for investors: they are capital intensive, have high up-front costs, and are not profitable when competing against gray hydrogen unless sufficient carbon taxes or subsidies are in place. Uncertainties surround the scale of global demand and supply of GH. In Chile, the size of the domestic market is limited, thus there is a need to develop and rely on export markets for the development of GH—another risk. Competing technologies that may develop to outperform GH on costs include blue hydrogen, higher-capacity batteries, the production of hydrogen

from landfills, and others. And perhaps most critical today is the need to rely not only on supportive developments in climate policy and carbon taxation, but also on concessional and blended financial resources to incentivize early investment in costly, front-loaded projects. Nevertheless, the outlook for GH production has been bolstered by a number of significant signals reflecting high global expectations; these include the European Union (EU) Green Hydrogen Strategy and the decision by Japan to substantially increase reliance on GH use to reach decarbonization. These initiatives underscore the potential of GH to contribute substantially to the greening of economies, given the diversity of its applications and its game-changing potential for energy storage and transport.

To support the development of GH production, the CPSD recommends measures that the government can introduce to incentivize investors, establish financial mechanisms to reduce risks for early adopters, and bridge the gap between supply and demand. Most measures focus on the demand side, because it is critical to achieve economies of scale to enable project investment. Price-based mechanisms could provide a stable and predictable source of revenue for GH investments to achieve a level of installed capacity. Supporting the aggregation of demand for GH from early movers, including hard-to-abate sectors and ports, is also needed. A strategy that could be feasible in the near to medium term is the promotion of GH as a long-duration energy storage medium and as a balancing asset that can enable the integration of renewables in isolated microgrids. On the supply side it would be important to design and deploy blended finance mechanisms to attract private investment for infrastructure while mitigating exogenous risks and reducing market uncertainty from shared infrastructure assets.

Enhancing Resilience and Competitiveness through Climate-Smart Agriculture

Climate change poses important risks to Chile's agricultural sector, which together with the food industry is the second-most important contributor to GDP and exports after mining. Chile accounts for nearly 60 percent of all fruit exports from the southern hemisphere and is the largest global exporter of grapes, plums, apples, blueberries, nectarines, and peaches. Climate variability and extreme weather events, such as the megadrought that lasted from 2010 to 2015, are already increasing. Chile is among the 30 countries in the world with the highest water stress and is the only one in Latin America that will undergo extremely high water stress by 2040. Wind, solar radiation, and forest fires will also increase, and new pests will be unleashed on crops as observed during the past decade.

This study, in partnership with the Chilean Climate Risk Atlas (ARLCIM) team, offers new estimates of the costs of climate change for 13 priority agricultural and livestock value chains. To date, few studies have provided estimates of the impact of climate change, and they have mostly focused on specific regions or basins. According to this study's results, most of Chile's regions are expected to suffer losses across a wide range of agricultural products. The areas most affected correspond to the agricultural land located from the Bío Bío region and toward the north, which contains the largest high-value fruit and vegetable production in the country. Without new climate adaptation measures, total annual losses in the 10 priority agricultural value chains are estimated at close to CH\$0.330 billion (US\$410 million) on average for the period 2030–50. Apples, walnuts, cherries, and corn will experience the largest losses.

The adoption of climate-smart agriculture (CSA) practices can lead to substantial reductions in GHG emissions and production costs, more resilient crops, and new export opportunities. CSA technologies comprise a broad range of complementary strategies that embody different degrees of technological sophistication and upfront investments, including the use of renewable energy and technically sophisticated irrigation; organic nutrients and biodigesters; more resilient plants through genetic improvements; and precision agriculture to optimize the application of inputs. As discerning importers place greater value on sustainably produced goods, access to prime international markets will be increasingly determined by the use of green production practices, while traditional exports are expected to stagnate, relegated to low-value market segments if CSA practices are not embraced more widely. Changes are being spurred by the demand side in both high- and middle-income countries (especially China) and also by regulatory changes such as the General Food Law in the EU, which limits the amount and type of waste produced throughout the production chain, and new carbon taxes that demand deforestation-free products.

Chile's large producers are increasingly adopting CSA practices, especially to address growing water scarcity, and the government is already promoting CSA technologies. Large producers have been investing in better water management technologies, and investments in genetic innovation to increase yields and resilience are growing, spearheaded by innovative public-private research in the wine and fruit consortiums. Precision agriculture has also expanded in the fruit sector, resulting in higher yields and savings on water and agro-chemicals. A few large agribusinesses have pioneered in the issuance of green bonds. In the public sector, the Ministry of Agriculture (MINAGRI) and its agencies are making important investments in CSA initiatives, including the recently released “Agri-Food Sustainability Strategy 2020–2030,” the first of its kind, which provides strategic guidelines for advancing CSA technologies in the country.

The adoption of CSA technologies, however, remains quite limited among small producers. Several obstacles are hindering the adoption process. Access to finance and information are among the most important barriers to adoption of CSA technologies—especially, but not only, among small producers. The financing of agriculture is typically challenging, but the characteristics of CSA projects, including high upfront investments and long maturities, make financing them even more complex. Producers and financial institutions often have insufficient knowledge of how CSA will improve production, thus raising their perceptions of the risks. High upfront costs also deter investments in renewable energy that would significantly reduce emissions. Higher penetration of digital technologies in rural areas together with capacity building, as noted in the discussion of the digital economy, would also support the broader adoption of precision agriculture and other CSA practices. Agri-environmental information can also be strengthened to support policy making and investments by the private sector. More intense efforts are also needed on innovation and R&D as well as better coordination among the various agencies supporting CSA innovation and technology transfer.

Embracing climate-smart agriculture is essential to maintaining one of the country's most dynamic and competitive export sectors and to enhancing the resilience and productivity of family agriculture. The expansion of the digital infrastructure in rural areas at affordable rates will be critical to advancing CSA and precision agriculture. Opportunities abound for government institutions and the private sector to expand innovative financing instruments for CSA, including along supply chains, and a strategy to foster such initiatives would fill a critical gap. Efforts to expand insurance coverage need to be complemented with CSA measures that foster sustainability and prevent market distortions, especially when insurance programs are subsidized. The expansion of more efficient irrigation systems is necessary but will not suffice, and sizable investments in physical infrastructure to increase reservoir capacity will have to be undertaken in the long term. In terms of strategy, the “Agri-Food Sustainability Strategy 2020–2030” fills an important vacuum, but it would benefit from a detailed roadmap that identifies concrete targets to be monitored over time and resources needed to achieve those targets. Governance mechanisms could be strengthened by including the Ministry of Science, Technology, Innovation and Knowledge within the new Inter-ministerial Committee on Agri-Food Sustainability since R&D and technology transfer are central to the CSA agenda. Agri-environmental information could also be strengthened to guide policy making as well as private investments.

Enhancing Productivity and Entrepreneurship through the Digital Economy

Technological change could transform and green Chile's economy and overcome structural weaknesses such as low firm productivity, disparities in service delivery, and high territorial concentration of economic opportunities. Chile has built a solid telecommunications infrastructure with high penetration rates and good-quality services that position it well to benefit from the digital economy. The telecom market has seen rapid growth, and recent regulatory changes and the entry of a new provider have increased competition, although operators still have considerable market power. Penetration rates are high, especially for mobile broadband, and the government recently awarded fifth-generation (5G) spectrum to different operators, the first country in Latin America and the Caribbean to do so. However, infrastructure gaps in fixed broadband remain in peri-urban and rural areas, while affordability issues limit access by lower-income households even within cities. Some regulatory issues continue to challenge fostering effective competition and network deployment. For example, the spectrum assignment process, which currently relies on comparative selection, could be modified to include modern approaches to auctions and spectrum pricing and trading. Infrastructure sharing could lower the costs of network deployment and help expand connectivity to the unserved population.

Although digitalization has accelerated among firms during the past year as a result of the COVID-19 pandemic, the adoption of more sophisticated uses of technology would have an even more transformational impact on firms. Chilean firms use social networks, clouds, mobiles, and digital marketing quite widely, but the use of digital management tools or more advanced technologies that leverage big data or artificial intelligence is far more limited. In this sense, the deployment of 5G will be a game changer in Chile, unleashing a new series of applications, including in mining, logistics, and telemedicine. While fourth generation (4G) is the dominant mobile technology in Chile today, 5G deployment is advancing rapidly and will shape the market in coming years owing to much faster data speeds and lower latency. Building wireless links to connect mobile towers and fostering infrastructure sharing will be crucial to the successful deployment of 5G in Chile. World Bank research estimates that building wireless links to connect mobile towers is the most cost-efficient strategy to reach universal mobile coverage.

Successful Chilean flagship entrepreneurship cases have recently disrupted consumption and production patterns and have attracted attention and international capital; however, most digital ventures in Chile do not grow. One of the main challenges for start-ups to scale up is inadequate financing, with low levels of venture capital beyond the early stage and with high dependence on public support. The government has fostered entrepreneurship through the Chile Economic Development Agency (Corfo), using both direct and indirect funding, but effectiveness has been mixed. This is partly due to bureaucratic and administrative constraints, and some of the instruments might not be fit for purpose. Gaps in technical and managerial skills also hinder successful business growth. Other factors include a small domestic market size, which forces many ventures to consider internationalization from the start, combined with insufficient contestability in some sectors. In addition, limited linkages between universities, firms, international buyers, and investors make thriving in the ecosystem more challenging.

The digital entrepreneurship ecosystem could benefit from attracting private investment to Chilean venture capital (VC) from high-net-worth individuals, local institutional investors, and the growing regional VC funds. Strategies to increase risk financing include the creation of VC funds focused on strategic sectors, a fund-of-funds initiative in which the public sector could better leverage private financing as implemented in many other countries, well-promoted corporate venturing and open innovation, and increased buzz around Chile's ecosystem, especially after the consolidation of Chile's first unicorns.

Reforms that strengthen regulation and encourage private investments in local venture capital and ecosystem networking will help spur further digitalization in Chile. Regulatory changes, including in data protection, financial technology, and infrastructure sharing, could contribute to the expansion of the digital economy and infrastructure development. Setting up an independent regulator for the telecom sector would help strengthen regulatory capacities and increase the sector's efficiency. The country could also leverage the region's relative homogeneity in terms of language and culture to scale up. Investing in technical skills will take time but will be critical to expand digital entrepreneurship and the digital economy more broadly.

Advances in regulation, infrastructure maturity, and digitalization will also enable cloud market development. Cloud computing can be transformational to firms, allowing them to scale up technical resources and to gain flexibility in a cost-effective manner and increase their productivity. Chile’s competitive cloud market reached approximately US\$328 million in 2020, increasing at a strong 7 percent annually since 2018. Strengthening regulations will be key for cloud market growth, especially the approval of a bill proposal submitted to Congress in 2017 on the processing and protection of personal data (Chamber of Members and Deputies 2017). In addition, robust international connectivity, well-performing national backbones, and ample development of last-mile fiber-optic networks will be critical for cloud market development.

Reform Recommendations

The CPSD makes a series of recommendations across the themes and sectors covered in the report. Table ES.1 highlights a subset of priority recommendations to support the role of the private sector as an engine spurring greater inclusion, innovation, and resilience.

1. An analysis of plant-level data, conducted for the CPSD using the Chilean Annual Manufacturing Survey (Encuesta Nacional Industrial Annual) for the period 1996–2015, sheds new light on the factors driving changes in aggregate productivity.
2. Product market regulation (PMR) indicators for Chile stand at 1.41 versus an OECD average of 1.38.
3. The survey covers firms with sales above US\$10,000. See <https://observa.minciencia.gob.cl/datos-abiertos/base-de-datos-de-encuesta-nacional-de-innovacion-2017---2018---macrozona>.
4. According to the OECD, 53 percent of firms introduced a new product or business process in the median OECD country in 2014–16 compared with 24 percent of firms in Chile during 2015–16. See OECD 2020a.
5. The analysis in section 3.1 of this report indicates that low productivity growth in Chile is primarily explained by a negative “within-firm component” (technical efficiency) of TFP, which in turn reflects that firms are not increasing their internal capabilities, including innovation capacity, managerial skills, workforce skills, and technology-absorption capability.
6. Encuesta Nacional de Empleo, July 2021.
7. More details are available in the Chile Policy Note, “[Opportunities for a Resilient and Low-Carbon Development](#),” World Bank 2021b.

TABLE ES.1 MATRIX OF POLICY RECOMMENDATIONS

Cross-Cutting Themes			
Priority reforms	Short term (< 2 years)	Medium-long term (> 2 years)	Implementation
A. Trade			
Strengthen services and GVC trade to drive productivity-led growth.		<p>Review nontariff measures, including sanitary and phytosanitary standards and technical barriers to trade for both goods and services, to ensure that regulatory objectives, where necessary, are accomplished at the lowest possible cost to traders.</p> <p>Deepen existing trade agreements to facilitate trade in services and GVC participation by including provisions on intellectual property and competition; ease the recognition of professional titles and qualifications, which is unnecessarily burdensome to FDI in services.</p>	Ministry of Commerce
B. Competition			
Strengthen competitive neutrality in sectors with SOE presence, address regulatory gaps, and reinforce merger control and anticartel policy.	Monitor closely and assess potential implications of the proposed bill that attempts to modify the current competition system—notably, the strong investigative tools and elements such as leniency.	Separate the commercial and noncommercial activities of SOEs, at least through account separation.	Legislative bodies (National Congress); line ministries, (Ministry of Industry and Commerce; Ministry of Public Works and Communications; Ministry of Defense; and Ministry of Finance); Technical Secretary of Planning; National SOEs Council; FNE
C. Innovation			
Consolidate the new institutional framework and improve the efficiency and effectiveness of public programs.	Develop and build consensus around a long-term public innovation strategy that can provide more continuity to policy making.		Interministerial Committee of STKI National Council of Innovation STKI and Innovation; Corfo; ANID; Ministry of Economy, Development and Tourism; Ministry of STKI; Ministry of Education

Priority reforms	Short term (< 2 years)	Medium-long term (> 2 years)	Implementation
D. Education and skills			
<p>Support quality assurance and institutional accreditation and improve market relevance and digital skills.</p>	<p>Ensure that the development of new criteria and standards of institutional accreditation by the CNA (according to Law N°21186) caters to institutional diversity, is sufficiently flexible to encompass a diversity of types of students, and is able to prepare graduates for changing future scenarios in the labor market</p> <p>Evaluate the potential of incorporating microcredentials and stackable degrees into the official certification and qualification framework.</p>	<p>Establish a periodic nationwide survey to assess development of transversal and digital skills and involve students of all levels of education, as well as a representative sample of the general population, to inform public policy. Base the survey on the experience of UNESCO-Asia (2019)</p>	<p>National Commission on Accreditation, higher education associations, business associations</p> <p>Ministry of Education, Ministry of Labor</p>

Green Hydrogen

Strategic objective	Short-medium term	Potential Partners for implementation
<p>Design and deploy blended finance mechanisms to attract private investment for infrastructure.</p>	<p>Establish forecasts of expected infrastructure investments required under different GH adoption scenarios, with a focus on meeting demand niches that are closer to break-even.</p> <p>Rapidly deploy remuneration schemes under PPP mechanisms.</p> <p>Establish mechanisms for the continuous review of local technology needs.</p> <p>Develop comprehensive EHS regulation.</p>	<p>Government of Chile, Chilean agencies that promote exports and foreign investments, international financial institutions</p>
<p>Provide a stable and predictable source of revenue for GH investments through price-based mechanisms.</p>	<p>Design and implement a CfD scheme for GH and GH-derived products through an auction process that matches bankable off-takers with a competitive supply of Chilean GH.</p>	<p>GIZ, Government of Germany, Agencia de Sostenibilidad Energética, Invest Chile, and other multilateral development banks and sources of concessional funding</p>
<p>Support the aggregation of demand for GH from early movers.</p>	<p>Implement a domestic GH quota scheme combined with a tradable GH certificate scheme. Domestic end-users, retailers, or both would produce or buy a certain quota of GH defined by national GH demand targets, similar to renewable portfolio standards.</p>	<p>Partner with the EU's Fuel Cells and Hydrogen Joint Undertaking and with the HTP.</p>
<p>Leverage Article 6 of the Paris Agreement to support expansion into GH projects.</p>	<p>Launch procurement of emission reduction certificates by using funding assistance from donors and by leveraging a CfD scheme applied to greenhouse gas offsets. The purpose is to mitigate the risk of the upside (offset), reduce the viability gap for new projects, and define market signals to trigger GH demand.</p>	<p>GIZ, multilateral development banks</p>
<p>Promote GH as a long-duration energy storage (> 10 hours) medium and as a balancing asset that can enable the integration of renewables in isolated microgrids.</p>	<p>Elaborate a comprehensive assessment methodology that showcases and monetizes the advantages of this GH application, identifying the different services and their expected revenues (or avoided costs) together with a broader social and environmental cost-benefit analysis.</p>	<p>Ministry of Energy and research centers; multilateral development banks</p>

Climate-Smart Agriculture

Strategic objective	Short term (< 2 years)	Medium-long term (> 2 years)	Implementation
Improve water resource governance through comprehensive watershed management.	Establish a legal framework that defines the responsibilities and competencies of the actors involved in water management, including the roles of MINAGRI and its agencies regarding other public agencies.	Strengthen governance systems to improve the capacity to capture and use water efficiently. An integral management of hydrographic basins needs to be the main criterion to define the location of investments in infrastructure.	MMA SEGPRES MINAGRI MOP
Facilitate dissemination, financing, and adoption of existing CSA technologies, especially by small and medium farmers.	Conduct a review of available CSA financing instruments and identify opportunities for expanding access to existing instruments and for promoting new financing.	Raise awareness among farmers, especially smaller farmers, of the benefits of innovating and adopting CSA approaches. Promote collaborative knowledge networks similar to GTTs for small producers, by enhancing coordination among INDAP, FIA, and INIA.	MINAGRI INDAP INIA FIA SNA -Codesser
Promote the use of renewable energy in agriculture.		Explore PPPs, or private partnerships (such as ESCO) to facilitate farmers' access to renewable energy markets.	MINAGRI MinEnergia MMA
Expand the availability of fresh water through public investment in infrastructure.		Invest in water accumulation systems, favoring medium and minor reservoirs and considering the scarcity of public resources and the environmental and social impact of major works. Increase the coverage of technified irrigation systems.	MINAGRI CNR Corfo-ASCC Small and large-scale producers

Digital Economy

Strategic objective	Short-medium term	Potential Partners for implementation
<p>Increase competition and improve regulation.</p>	<p>Create a politically and financially independent regulator for the telecommunication sector, with strong technical capabilities.</p>	<p>Ministry of Transport and Telecommunications</p>
<p>Foster higher mobile access network mutualization and reinforce high-speed broadband access for the population.</p>	<p>Enhance the regulatory environment:</p> <ul style="list-style-type: none"> • Improve the spectrum assignment process. • Approve and enforce the bill proposal on data protection. • Enforce the bill to declare telecom services a public interest to guarantee telecom's universality and affordability. • Enforce unbundling of the local loop regulations. 	<p>SUBTEL Congress Private sector</p>
<p>Develop a fixed broadband access network in rural and underserved areas through regulatory measures that foster broader mutualization.</p>	<p>Several options could be considered:</p> <ul style="list-style-type: none"> • Issue specific licenses allowing nontelecom players to own and operate infrastructure. • Support mandatory open access for all telecom actors to active and passive infrastructure. • Build civil work regulations with mandatory obligations across industries to adhere to specific building and construction guidelines and facilitate infrastructure sharing. <p>The government could also improve regulation to</p> <ul style="list-style-type: none"> • Establish a universal access obligation for operators to increase telecom coverage in rural and low-income urban areas. • Regulate last-mile and long-distance infrastructure access. 	<p>SUBTEL Congress Private sector</p>
<p>Accelerate emerging local and regional cloud actors.</p>	<p>Approve and enforce the bill proposal on data protection.</p>	<p>SUBTEL Congress Private sector</p>

Note: ANID = National Research and Development Agency; ASCC = Sustainability and Climate Change Agency; CfD = contract-for-difference; CNA = Chile's National Accreditation Commission; CNR = National Irrigation Commission; Corfo = Chile Economic Development Agency; CSA = climate-smart agriculture; EHS = environment, health, and safety; ESCO = energy service company; EU = European Union; FDI = foreign direct investment; FIA = Foundation for Agricultural Innovation; FNE = Chile National Economic Prosecutor; GH = green hydrogen; GIZ = Deutsche Gesellschaft für Internationale Zusammenarbeit; GTT = technology transfer group; GVC = global value chain; HTP = Hydrogen Territories Platform; IDB = Inter-American Development Bank; INDAP = Institute for Agricultural and Livestock Development; INIA = Chilean Agricultural Research Institute; MINAGRI = Ministry of Agriculture; MinEnergía = Ministry of Energy; MMA = Ministry of Environment; MOP = Ministry of Public Works; PPP = public-private partnership; SEGPRES = Ministry General Secretariat of the Presidency; SNA = National Society of Agriculture; SOE = state-owned enterprise; STKI = science, technology, knowledge and innovation; SUBTEL = Undersecretary of Telecommunications.

01. COUNTRY CONTEXT: STALLING GROWTH AND PRODUCTIVITY ARE ERODING A SUCCESSFUL DEVELOPMENT STORY



Chile is going through profound changes, operating in the midst of a soul-searching exercise over its social contract and economic model that has resulted in a new Constitution and a political shakeup, all while it deals with the COVID-19 pandemic and its implications. Often hailed by observers as a shining example of market-friendly, prudent macroeconomic policy making, the country has, over the past couple of years, dealt with massive popular protests demanding a change in political and social direction. The stagnation of growth and productivity in Chile over the past decade raises questions regarding a growth trajectory that was supported by natural resource extraction rather than the generation of knowledge, increased value addition, or complexity. Decades of growth in Chile led to one of the largest reductions in poverty and highest incomes per capita in the region; however, income inequality reduction slowed after the mid-2000s. This, in addition to inequality of opportunities and access to public services, and a growing disconnect between the political system and society, led to discontent in the middle class. The COVID-19 pandemic has amplified these challenges and caused unprecedented economic loss and pain. Voters in October 2020 overwhelmingly decided to rewrite the constitution.

Chile has been largely called a success story, but growth has been on the decline in recent years

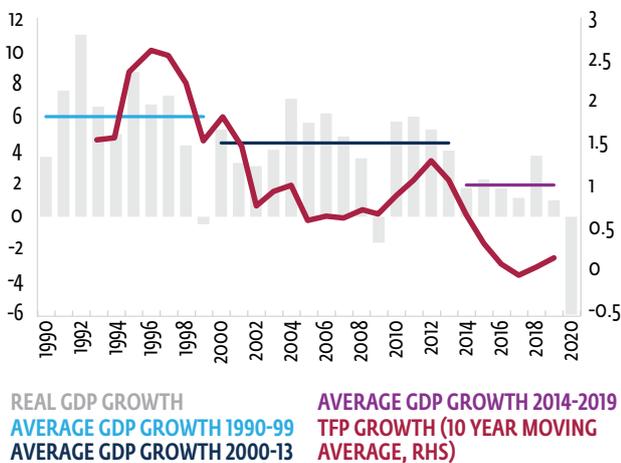
Chile has been widely hailed as a success story in the Latin America and Caribbean region in terms of sustained growth, but recently progress has stalled.¹ Macroeconomic predictability and sustainability and market-oriented policies enabled that country to attract exceptionally large foreign direct investment (FDI) flows and favorable financing, even outside the copper sector. It was the first country in Latin America to reach high-income status and joined the Organisation for Economic Co-operation and Development (OECD) in 2010. The end of the commodity cycle combined with lagging quality of education and relatively low levels of innovation resulted in lower economic growth over the past decade and impeded the shift toward a more diversified technology- and knowledge-intensive economy. Society's demands for access to better opportunities and improved public services make the need for advancing productivity-enhancing reforms in support of a better private sector even more urgent.

Structural reforms that started in the late 1970s brought steady progress and economic growth until the 2000s, but lately reform fatigue has settled in and growth has been on the decline. The market liberalization reforms initiated in the late 1970s and early 1980s, supporting a more open, private-sector-driven and price-deregulated market economy, were further deepened in the second half of the 1980s with a new banking law, the establishment of an independent Central Bank, elimination of foreign exchange controls, and adoption of a floating exchange-rate regime. In the 2000s, the sustained commodity demand from China created a favorable environment for Chile and growth averaged about 4 percent annually (Figure 1.1). Growth slowed to around 2 percent in the six years preceding the COVID-19 pandemic, however, undermined by lower dynamism among Chile's key trading partners, which reduced export demand, and by the end of the commodities boom ushering in lower copper prices. Moreover, the structural reform agenda designed to tackle some of the main shortcomings of Chile's economic system has not progressed. The social unrest that erupted in late 2019 and the COVID-19 crisis in 2020 have also led to a further slowdown in growth.

Weak productivity growth remains a key hindrance to growth

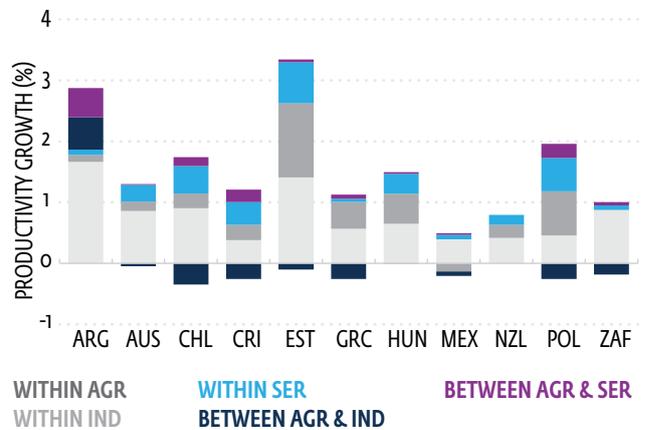
Weak or negative total factor productivity (TFP) growth has been a major driver of the growth slowdown, retarding the convergence with the average OECD income level. Throughout the past three decades growth was characterized by substantial capital deepening while TFP growth was remarkably modest, except for the 1987–97 golden period. TFP dynamics are shaped by both cyclical variables such as terms of trade and structural policies. Beyond the cycles, historical series of TFP in Chile show a clear downward trend after the peak observed at mid-1990s. This trend was temporarily interrupted toward the end of the 2000s because of the commodity boom years (Figure 1.1). As a result, Chile’s convergence with the TFP levels of other OECD peers such as Australia, Canada, and New Zealand has slowed.² Many factors have been posited as underlying the poor productivity performance in Chile. From the macroeconomic dimension, the limited diversification of the export base and its concentration in natural resource sectors as well as limited adoption of and investment in new technologies stand out. From the micro perspective, it seems that limited competition, growing challenges in the regulatory framework, and inadequate skills of the labor force are key impediments to productivity growth. The section on cross-cutting issues analyzes productivity performance, and the factors that could be holding it back, in greater detail.

FIGURE 1.1 REAL GDP GROWTH HAS BEEN ON A DECLINING TREND (PERCENT)



Source: Chile’s Central Bank, World Bank/IFC calculations.

FIGURE 1.2 DECOMPOSITION OF PRODUCTIVITY GROWTH FOR CHILE AND PEERS (1995–2018)



Source: World Bank/IFC staff calculations using World Bank World Development Indicators.

Notes: AGR=agriculture; IND=industry; SER=services. EST = Estonia; POL = Poland; CHL = Chile; CRI = Costa Rica; HUN = Hungary; AUS = Australia; NZL = New Zealand; ARG = Argentina; Mexico = Mexico; ZAF = South Africa; GRC = Greece. The “between” component is equal to the change in share in manufacturing times the difference in productivity between manufacturing and agriculture, and the change in share in services times the difference in productivity between services and agriculture (see Nayyar, Hallward-Drie-meier, and Davies 2021). The Republic of Korea is excluded because no figures for 2018 were available.

Chile experienced relatively high productivity growth within the agricultural and services sectors but relatively modest productivity growth within industry. Chile exhibits the third highest within-sector growth rate for services in comparison with its peer countries, right after Estonia and Poland (Figure 1.2).³ The share of the within-services sector productivity growth is about one-quarter, comparable with most of Chile's peers. Equally, the share of within-agricultural productivity growth rate is about half of total positive productivity growth, also comparable to some European peer countries such as Estonia and Poland.

Large but concentrated financial sector

Chile's financial sector is large and has a high level of penetration of banking products, but their use is limited.⁴ In the first half of 2021, the relative size of the financial system's assets was more than twice the gross domestic product (GDP), with banks representing 141 percent of GDP and pension funds, mutual funds, and life insurance companies amounting to 63 percent, 4 percent, and 22 percent, respectively (BCCh 2021b). There are 18 banks with the six largest concentrating close to 89 percent of total banking sector assets and the largest holding 18 percent of assets as of mid-2021. The size of the nonbank financial sector reflects the impact of the pension reform of the early 1980s, when Chile established a funded pension program managed by private companies (Administradoras de Fondos de Pensiones; AFPs). Since the introduction of the program, the annuities market developed exponentially, thus facilitating the growth of capital markets and long-term finance; total stock market capitalization reached 78 percent of GDP at the end of 2019.⁵ While account ownership has increased significantly over the past decade, there are pockets of underserved segments among those people out of the labor force or with a low level of education as well as among migrants. Cash is still the means of payment, although digitalization has increased during the COVID-19 pandemic. A well-regulated and -capitalized financial system prior to the COVID-19 pandemic and well-coordinated monetary and financial policy measures have eased the impact of the financial crisis on the financial system.

Digital finance, risk financing, and green finance remain the frontier

Financial inclusion, digital finance, and green finance remain keys to the future. The state has channeled many of its financial inclusion policies through Banco del Estado with products and services such as Cuenta RUT (a simplified demand account that can be opened with just an identification card), BEME (a subsidiary focused on micro and small enterprise lending), and Caja Vecina (a network of branches in rural areas). The national government also funds a credit guarantee program (FOGAPE), which is administered by Banco del Estado to provide credit guarantees to financial institutions for loans to microenterprises and small firms. Overall, the acceptance of digital payments is still low but has accelerated since the COVID-19 pandemic broke out. Greater digitalization of the financial sector could help address some of Chile's remaining financial inclusion challenges and enhance the efficiency of financial intermediation by lowering costs and expanding access. A fintech (financial technology) bill currently in Congress is expected to address shortcomings that have impeded the development of fintech companies. Greater availability of risk financing instruments would also facilitate the entry and growth of new firms that are more productive and more innovative.

Financial sector authorities are strengthening the enabling environment to ensure that financial sector entities adequately assess climate change risks and contribute to the country's low carbon future. The Ministry of Finance (MOF), Central Bank of Chile (BCCCh), Financial Market Commission (CMF), and Superintendency of Pensions (SP) have publicly committed to integrating climate change into their practices via the Green Agreement (MoF 2019). The BCCCh participates actively in several international organizations, including the “Task force on incorporating climate-related risks into the international reserves management framework” and regularly monitors strategic risks that may affect the BCCCh (BCCCh 2021a). The CMF has developed a “Strategy for Addressing Climate Change” in financial markets and has organized a climate change task force (CMF 2020). Chile has also adopted measures to improve the flow of finance toward greener activities in support of Chile’s Nationally Determined Contribution (NDC) and Sustainable Development Goal (SDG) commitments. Chile already hosts the region’s second largest green bond market and could build on this strength by exploring impact-oriented instruments including sustainability-linked bonds. As this area of the capital markets continues to grow, more work will be needed to develop a pipeline of future green projects to seed future green bonds (Boitreaud et al. 2021).

A vulnerable middle class despite important progress in poverty and inequality

Despite Chile’s progress in reducing poverty and inequality, the latter is still significant, and the middle class is highly vulnerable. Chile has one of the lowest poverty rates in Latin America and the Caribbean; it has also reduced extreme poverty to less than 1 percent.⁶ Increases in labor income and transitions to more productive sectors have been the dominant factors explaining Chile’s strides in poverty reduction. The middle class—the largest socioeconomic group in the country—has also experienced substantial income growth, although many in this group are vulnerable to falling back into poverty. The COVID-19 crisis has hit the incomes of both vulnerable and lower-middle class people, and while the government’s emergency social protection measures have reduced poverty significantly in the short term,⁷ this safeguard will revert as the stimulus is phased out. Inequality also has declined substantially in past decades, but while the Gini coefficient is about average compared to the rest of Latin America, it remains substantially higher than in OECD countries. Structural factors that may explain income inequality include low intergenerational mobility and limited opportunities for vulnerable groups to participate in productive activities. In addition, Chile’s market-oriented institutions have not contributed enough to integrating public service provision in education, health, and social security. The labor market is also highly segmented, with significant barriers to female labor force participation and wide use of temporary contracts that impair job protection.

Rapid growth in some sectors has been accompanied by increasing pressures on Chile’s natural capital and the environment, stresses that have been aggravated by climate change. Chile has increasingly promoted the greening of its economy and plays a key role in the region by increasing the share of renewable energy in its energy mix, including innovative fuels like green hydrogen, and by proposing ambitious emission cuts as part of its NDC. Chile’s focus on environmental sustainability was prompted by the environmental degradation that accompanied years of high economic growth. Resource-intensive industries such as mining, agriculture, forestry, and aquaculture were the key engines of growth and poverty reduction but resulted in deforestation

and biodiversity loss. Water scarcity and competition for water use have led Chile to enact greater water efficiency in some sectors, particularly the mining sector, where water reuse, desalinization, and direct use of salt water have resulted from improved technology and management practices. However, because of climate change—rising temperatures and shifting precipitation patterns in critical regions—the country is projected to move from medium water stress in 2010 to extremely high stress by 2040 and is highly vulnerable to other climate shocks.

The efficiency and effectiveness of Chile’s regulatory environment have declined over the past decade, and the system has become more complex. Issues include a duplication of permit requirements, overlapping regulations, and legal gaps that allow discretionary interpretation. An agile, modern state, capable of responding to private sector needs in a timely and efficient fashion, is required to raise productivity and investment. Yet in Chile, the time required to obtain permits and licenses is lengthy and beset by uncertainties. These problems result partly from a lack of coordination between institutions, lack of clarity regarding each institution’s jurisdiction, a low degree of digitalization of services, little use of technologies to trace the permitting and licensing process, and the absence of time limits on many procedures. Within the OECD, Chile ranks at the bottom in terms of regulatory complexity, and the World Economic Forum ranks Chile⁸ 7th of 141 countries, with a score of 3.4 out of 7 in the measure of perceived obstacles that firms face in meeting public administration requirements (WEF 2019). Chile’s Productivity Commission, in an analysis of the legal and regulatory framework affecting five strategic sectors (mining, infrastructure, energy, industry, and construction), identified 400 permits required for large investment projects in these five sectors and 53 institutions that participate in granting these permits. Many permits must be acquired more than once during a project’s lifetime: in the mining sector, a project would normally require 213 permits (CNP 2019).

Highly uncertain medium-term outlook, despite economic rebound in 2021

The medium-term outlook for Chile is highly uncertain given the wide range of possible outcomes from the constitutional process, the political turmoil, and the post-COVID economy. Social unrest and the pandemic-induced economic crisis have left many Chileans unemployed or inactive, have stretched fiscal balances, have led to a rise in public debt, and have increased vulnerabilities in the financial sector. While Chile is not the only country facing economic fallout from the COVID-19 pandemic, an additional layer of uncertainty comes with the constitutional debate and sociopolitical turmoil. A profound reform of the state, demanded by the protesters, was ratified by the constitutional referendum in October 2020, in which the Chileans overwhelmingly voted to rewrite the current constitution by mid-2022.

The economy is rebounding after the pandemic-induced recession, but significant challenges remain in returning to a sustainable and more inclusive growth path. GDP contracted 5.8 percent in 2020 but recovered strongly in 2021, driven by consumption and easing mobility restrictions. To smooth the impact of the crisis, the government implemented a large monetary and fiscal stimulus, the latter reaching more than 11 percent of GDP, and three withdrawals of private pension assets were also allowed. To support small and medium enterprises (SMEs), the government implemented subsidies, tax benefits, and credit programs such as FOGAPE and FCIC,⁹ with positive impact on survival rates and a faster recovery of firms. The different sectors of the economy adapted to operating under new restrictions, aided by the broadening use of digital services. In addition, the recovery has been uneven within sectors and among population segments. The recovery of the labor market has been slower and has lagged the economic rebound, affecting vulnerable segments of the labor market such as women and informal and low-skilled workers the most and further undermining the fragile middle class. Female labor participation fell back to 2010 levels and has not recovered after women left the labor force to dedicate themselves to home and childcare activities. Looking ahead, the country will face the challenge of unwinding the stimulus and ensuring a sustainable recovery. The post-pandemic economy is also left with the challenge of adapting to a new scenario in which digitalization has gained more relevance and a larger focus is being placed on innovation, diversification, and inclusion.

Notes

1. This report uses Latin America and the Caribbean and Organisation for Economic Co-operation and Development (OECD) as comparators for Chile in line with the Chile Systemic Country Diagnostic (SCD) (World Bank 2017). In individual sections, individual peer countries also are selected.
2. A similar pattern arises when plotting labor productivity levels in services against manufacturing: Australia, Canada, and New Zealand have higher labor productivity in both services and manufacturing.
3. After accounting for structural change that takes place in Chile and peer countries—that is, the productivity growth due to the movement of production factors from agriculture to industry and services (“between” productivity growth)—results stemming from within the sector can be properly measured.
4. A Financial Sector Assessment Program was conducted during 2021. Its findings will be available in early 2022.
5. However, as part of the COVID-19 response, Congress authorized three rounds of emergency withdrawals from pension funds during 2020 and 2021, reducing assets under management by at least 25 percent (US\$48 billion) by May 2021 and leaving over 3 million of the 11 million individual accounts without retirement funds, thus worsening future pension prospects. As of early November 2021, a fourth withdrawal was under consideration by Congress.
6. As measured by those living on less than US\$1.90 a day.
7. According to World Bank estimates, poverty (measured as percentage of the population with income below the national poverty line which is based on a local consumption basket) is expected to have dropped from 10.8 in 2020 to 2.5% in 2021 thanks to emergency social protection measures and the partial labor market recovery.
8. From 56.2 in 1985 to 44.4 in 2017, with a higher number meaning higher inequality.
9. These are, respectively, credit guarantees for SMEs and lines of credit extended by the Central Bank to financial institutions to incentivize them to continue financing and refinancing credits to households and firms.

02. STATE OF THE PRIVATE SECTOR

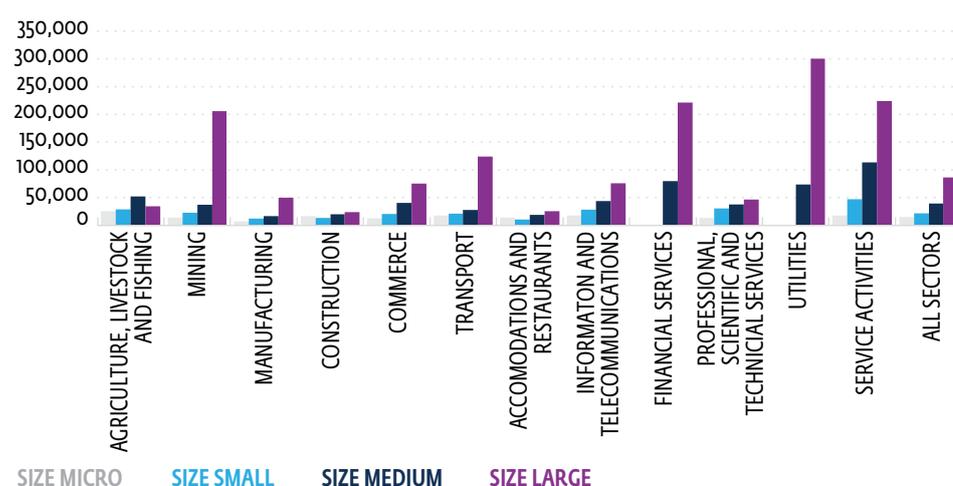


As a medium-size economy, Chile enjoys an open trade regime and one of the world's most extensive networks of preferential trade agreements and has attracted exceptionally high levels of FDI over recent decades. However, most Chilean firms remain small and focused on the domestic market and show limited productivity growth.

Formal enterprises are dominated by the services sector both in terms of value added and employment. The services sector comprises 72 percent of the value added of formal enterprises, with commerce (18 percent) and financial services (14 percent) being the largest subsectors.¹ Manufacturing contributes 18 percent of value added, and mining, agriculture, and fisheries together about 10 percent. In terms of employment, the services sector contributes about 75 percent, whereas manufacturing and the primary sectors constitute 15 percent and 10 percent, respectively. Together, commerce and construction provide one-third of employment of formal enterprises. By firm size, large enterprises constitute 54 percent of employment and microenterprises, just 6 percent.²

Productivity varies markedly by sector and firm size, with factor misallocation contributing to this pattern. The productivity of large firms is more than twice and four times that of medium and small enterprises, respectively. Within sectors, construction, accommodations, and food services are among those with the lowest productivity, whereas financial services, utilities, and mining show the highest (Figure 2.1). The average labor productivity in the OECD is nearly double that of Chile, although Chile surpasses its peers in Latin America (Brazil, Colombia, Mexico, and Peru).³ Several authors have sought to explain the causes of low firm productivity attributing it, inter alia, to limited innovation, weak managerial skills, and substantial factor misallocation (Albagli et al. 2017). The causes of low firm productivity are further analyzed in the Cross-Cutting section of this CPSD.

FIGURE 2.1 AVERAGE LABOR PRODUCTIVITY VARIES BY SECTOR, WITH THE LARGEST FIRMS MOST PRODUCTIVE, 2015 (CH\$, THOUSANDS)



Source: National Statistics Institute (INE), Longitudinal Enterprise Survey 2017, and World Bank staff estimates.

Most Chilean firms target the domestic market, while the composition of exports has not changed significantly during the past 10 years, with a strong concentration in natural resource-based products. Export markets are also highly concentrated, with 57 percent of exports in 2019 destined to three countries: China (33 percent), the United States (14 percent) and Japan (10 percent). SMEs are not internationalized. On aggregate, roughly 13 percent of total exports come from SMEs compared with 27 percent in Canada (OECD 2018a). Bravo et al. (2014) show that SMEs have a lower propensity to export and to change their export mix, and the survival of new export products is lower; introducing changes in SMEs' export mix tends to improve their productivity more relative to larger firms.

Chile has attracted extensive FDI because of its stable macroeconomic framework, openness to trade, and supportive FDI regime.⁴ The stock of inward FDI amounted to 94.1 percent of GDP in 2019 compared to 50.1 percent and 59.7 percent of GDP for Australia and Canada, respectively. FDI is concentrated in the mining sector (40.2 percent) and the financial sector (27.0 percent), followed by the manufacturing sector as a very distant third (3.8 percent).

The COVID-19 crisis has severely impaired the private sector. The negative effect of the pandemic on the performance of Chilean firms has been deep and persistent, with visible effects even a year after the initial outbreak. According to the World Bank Business Pulse Survey (BPS) conducted in June 2021, almost 49 percent of firms reported a decrease in sales in the 30 days before the interview relative to the same period in 2019. For the average firm, this corresponds to a sales contraction of 13 percent (Figure 2.2). Chilean firms appear to have been less affected in terms of decreased sales compared to other countries where the World Bank BPS was conducted, with the exception of Argentina (Figure 2.3). The negative impact on sales has been more severe among smaller firms and within service industries (Figure 2.2). While the average small firm, with less than 20 employees, saw its sales fall by 16 percent at the time of the survey relative to the same period in 2019, this figure was 10 and 4 percent for large and medium firms, respectively. Sectors have also been affected with varying degrees of intensity, influenced by various factors such as mobility restrictions, supply-chain disruptions, and the ability to sell through online platforms and to shift to home-based work. Sales declines in the services sector averaged 18 percent, followed by manufacturing at 11 percent.

Firms have used multiple mechanisms to adjust to the shock and have also benefited from government support. One important response to the shock was the adjustment of employment both at the extensive (that is, firing workers) and intensive margins (that is, cutting wages or work hours). In Chile, 24 percent of firms reported having fired employees since the beginning of the pandemic. For the average firm, this implies a reduction from 39 to 34 employees between January 2020 to June 2021. Employment adjustments over the intensive margin appear to be more important, with furloughs and reductions in workers' wages or hours being adopted by 65 percent of firms in the country. Other adjustment mechanisms commonly adopted by firms were modifying the range of products or services available (36 percent of firms) and starting or increasing the use of internet or other digital platforms for business operations (70 percent).

FIGURE 2.2 SMALL FIRMS AND THOSE IN THE SERVICES SECTOR WERE MOST AFFECTED BY THE PANDEMIC (4Q20–3Q21)

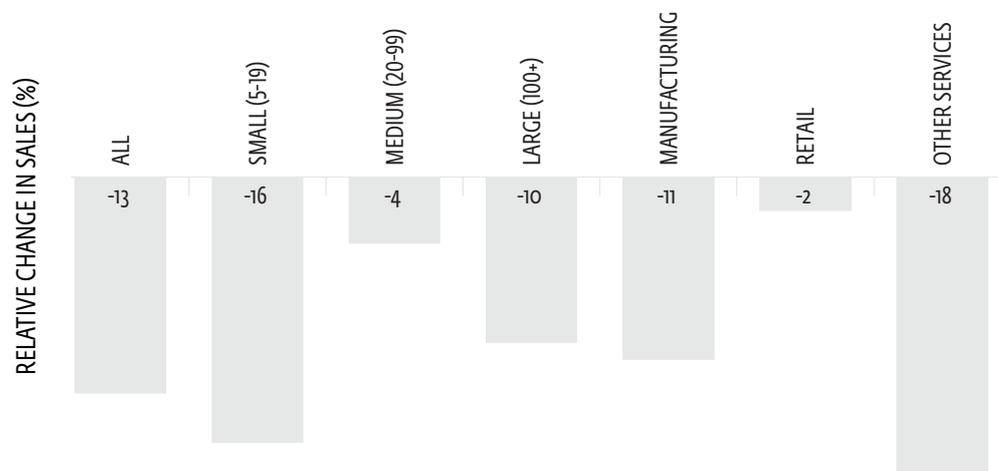
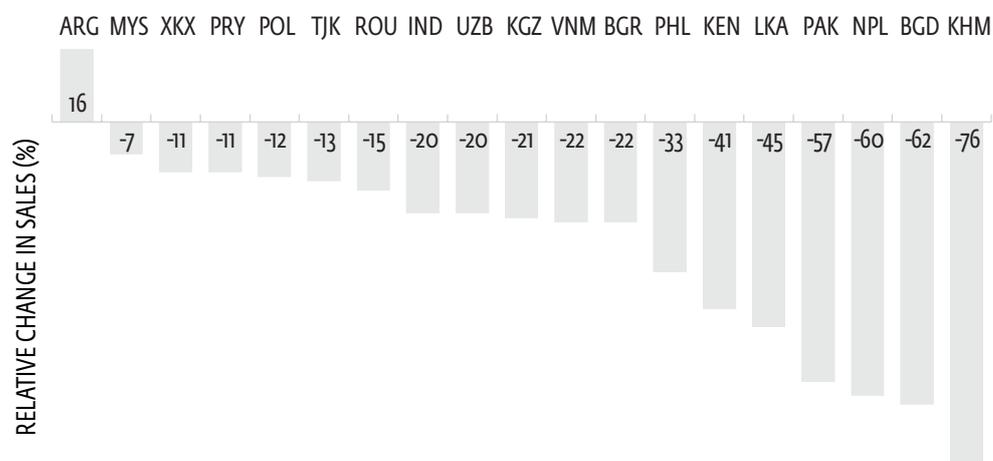


FIGURE 2.3 ALTHOUGH THE IMPACT ON CHILEAN FIRMS HAS BEEN LESS SEVERE THAN FOR MOST OTHER COUNTRIES COVERED BY THE BPS (4Q20–3Q21)



Source: Chile Business Pulse Survey (2021).

Note: This figure uses data from the Business Pulse Surveys (BPS) collected during 4Q20–3Q21 and compares it to the same period in 2019. It includes the following countries for each region considered. East Asia and Pacific: Cambodia, Indonesia, Malaysia, Mongolia, the Philippines, and Vietnam. Europe and Central Asia: Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Georgia, Greece, Hungary, Italy, Kosovo, Kyrgyzstan, Latvia, Lithuania, Moldova, Poland, Portugal, Romania, Slovak Republic, Slovenia, Tajikistan, Turkey, and Uzbekistan. Latin America and the Caribbean: Argentina, Brazil, El Salvador, Guatemala, Honduras, Nicaragua, and Paraguay. Middle East and North Africa: Jordan, Morocco, and Tunisia. South Asia: Bangladesh, India, Nepal, Pakistan, and Sri Lanka. Sub-Saharan Africa: Benin, Burkina Faso, Ghana, Kenya, Liberia, Madagascar, Malawi, Senegal, Sierra Leone, South Africa, Tanzania, Togo, and Zambia.

In addition, the government has extended support to firms to alleviate the crisis impact. According to the World Bank BPS, 47 percent of firms have had access to some form of national or local government support. Compared to other upper-middle-income and high-income countries for which comparable data are available, Chile ranks fifth of eight countries in the percentage of businesses with access to public support, behind Kosovo (91 percent), Malaysia (89 percent), Poland (83 percent), and Argentina (54 percent). The support measures most widely available to Chilean firms include access to new credit (63 percent), followed by grants (56 percent), wage subsidies (43 percent), and tax reductions (40 percent).

Despite adjustments and government support, many firms continue to face challenges. At the time of the survey, 6 percent of firms in Chile were in arrears, and an additional 12 percent expected to fall into arrears within six months of the interview. Within this same period, over 7 percent of firms expected to file for insolvency or bankruptcy. Supply chain disruptions had forced 31 percent of firms to cancel orders within the previous 30 days.

Business surveys reveal weaker prospects for 2022 amid political uncertainty and doubts regarding the direction of future economic policy. The November 2021 Central Bank Business Perception report⁵ suggests that companies have reported improvement in sales in recent months because of strong demand as the economy reopens and households make use of accumulated liquidity. They also report scarce supply of less qualified workers, which has led to wage increases. In addition, the survey shows growing concerns regarding 2022 prospects as policy stimulus is phased out and the effects of the pension fund withdrawals end, while firms face increasing costs, supply constraints, tighter financial conditions, and political uncertainty over the legislative and constitutional debates. As a result, lower investment is expected: just 30 percent of firms surveyed planned to invest in 2022, down from close to 50 percent in January 2021. Firms will need to adapt to changing conditions and new challenges ahead.

Notes

1. Data for value-added employment and productivity are World Bank staff estimates based on the fourth Longitudinal Enterprise Survey conducted in 2017 by the National Survey. The sample is representative of the economic structure.
2. In Chile, large, medium, small, and micro enterprises are defined as those with sales above 100,000 UF (Unidad de Fomento or unit of account, equivalent to about US\$37 in mid-November), between 25,000 and 100,000 UF, between 2,4,000 and 25,000 UF, and between 800 and 2,4,000 UF, respectively, as defined by the fourth Longitudinal Enterprise Survey conducted in 2017.
3. Labor productivity measured as GDP per hour worked.
4. The FDI Regulatory Restrictiveness Index measures statutory restrictions on foreign direct investment in 22 economic sectors across 69 countries, including all OECD and G20 countries. It was 0.057 for Chile versus 0.064 for the OECD in 2019.
5. Survey of 100 firms about the current situation and outlook for macro variables of the Chilean economy carried out during October.

03. TACKLING CROSS-CUTTING CONSTRAINTS THAT INHIBIT PRIVATE SECTOR PRODUCTIVITY



- 3.1. LOW PRODUCTIVITY HOLDS BACK GROWTH**
- 3.2. UNTAPPED POTENTIAL IN GVC PARTICIPATION AND SERVICES TRADE**
- 3.3. STRENGTHENING COMPETITION POLICY**
- 3.4. UNLEASHING INNOVATION**
- 3.5. EDUCATION AND SKILLS FOR AN INCLUSIVE AND INNOVATIVE ECONOMY**
- 3.6. UPDATING LABOR REGULATIONS AND REDUCING SEGMENTATION**
- 3.7. GREENING THE ECONOMY**

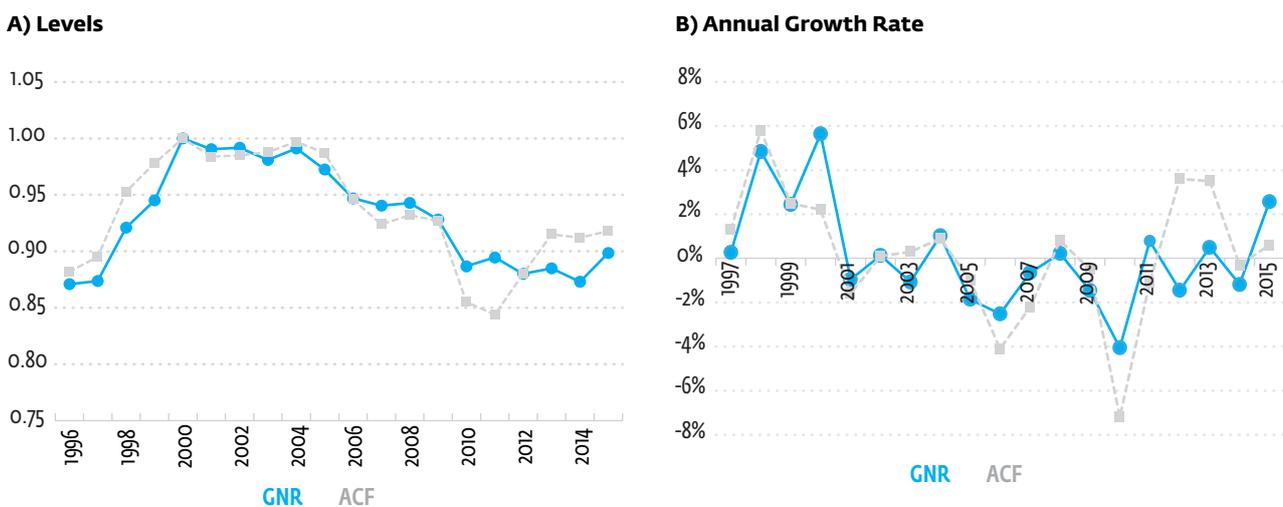
This section identifies cross-cutting constraints that impede private sector growth, focusing on problems involving (a) productivity, (b) trade, (c) competition policy, (d) innovation, (e) education and skills, (f) labor market segmentation, and (g) greening of the economy. Although these are not the only relevant constraints, the analysis conducted identifies them as the most pressing ones.

3.1. LOW PRODUCTIVITY HOLDS BACK GROWTH

Stagnating productivity growth is at the core of the low economic growth that Chile has experienced in recent years. For most years since 1998, productivity growth has been low or negative. An analysis of plant-level data using the Chilean Annual Manufacturing Survey (Encuesta Nacional Industrial Anual; ENIA) for the period 1996–2015 sheds new light on the factors driving changes in aggregate productivity.¹ Given that manufacturing productivity shows the highest correlation (0.85) with overall productivity as noted in CNP 2019, these findings are indicative of developments in other economic sectors.²

Manufacturing productivity increased rapidly in the late 1990s (around 3 to 3.3 percent on an annual basis), stagnated till the mid-2000s, and then started a gradual decline (Figure 3.1). These patterns using micro level data are broadly similar to the manufacturing productivity series estimated by the Chilean National Productivity Commission (CNP 2019) using National Accounts information.³

FIGURE 3.1 AGGREGATE MANUFACTURING PRODUCTIVITY DECLINED IN THE 2000S AND PRODUCTIVITY GROWTH HAS STAGNATED SINCE THEN

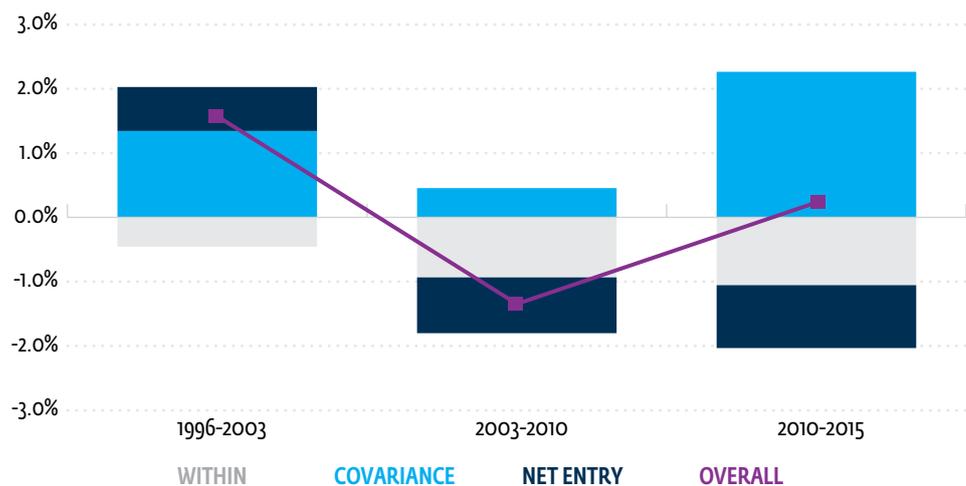


Source: Garcia-Marin 2021.

Note: For each year, the series aggregate plant-level productivity is measured by using revenue shares. The solid blue and dashed gray lines aggregate micro-level productivity following Gandhi, Navarro, and Rivers 2020 and Akerberg, Caves, and Frazer 2015, respectively.

Falling productivity appears to be the result of declining efficiency of incumbent firms and, to a lesser extent, the exit of more productive firms and entry of less productive ones. Figure decomposes aggregate productivity of incumbents on the one hand and firm entry and exit on the other hand. The contribution to productivity of the “within firm,” or technical efficiency, component is negative across all subperiods. Offsetting this, reallocation among surviving firms, or the “between firm” component, contributed positively to aggregate productivity, especially in the most recent period. The persistently negative contribution to productivity of firms’ internal efficiency, at least in manufacturing, is worrisome and is consistent with limited investment in innovation, gaps in managerial and workers’ skills, and with a failure of competition to spur efforts to improve firm efficiency (see sections 3.3–3.5). On a more positive note, more productive incumbents appear to be gaining in the reallocation process, growing in size as less productive firms shrink in comparison.

FIGURE 3.2 DECOMPOSITION OF AGGREGATE PRODUCTIVITY GROWTH IN CHILEAN MANUFACTURING



Source: Garcia-Marin 2021.

Note: Following the Melitz and Polanec (2015) methodology, aggregate productivity growth (red line) is divided into three components: “Within” indicates the change due to general changes across all surviving firms; “Covariance” captures reallocation among surviving firms due to the changes in their relative size; “Net Entry” denotes the contribution of plant exit and entry to the change in aggregate productivity.

While market forces should induce the exit of relatively unprofitable (unproductive) firms, the opposite occurred in the Chilean manufacturing industry: productive firms exited to a greater extent. The contribution of net entry to productivity turned negative from 2003 to 2010, reflecting market frictions. Further disaggregation of the net entry component indicates that in the 2003–10 period, average exiting firms were more productive than incumbents (the negative exit margin dominated; see Table 3.1). In contrast, after 2010, entering establishments were less productive than incumbents (the negative “entry” margin dominated). Creative destruction, or the exit of less productive firms to make way for more productive ones, does not seem to be happening.

There are various potential explanations for the abnormal contribution of entries and exits to aggregate productivity, as well as the consistently negative contribution of the internal efficiency of firms. Various chapters of this CPSD address some of these explanations, finding evidence for limited innovation, skills gaps and mismatches, lack of finance for new ventures, and competition-related failings.⁴

TABLE 3.1 DECOMPOSITION OF THE CHANGE IN PRODUCTIVITY, CHILEAN MANUFACTURING

	Survivors		Net entry		Total
	Δ Unweighted (1)	Δ Covariance (2)	Entry (3)	Exit (4)	Total (5)
1996–2003	-0.005	0.013	0.005	0.002	0.016
2003–2010	-0.009	0.005	-0.001	-0.007	-0.013
2010–2015	-0.011	0.023	-0.016	0.006	0.002

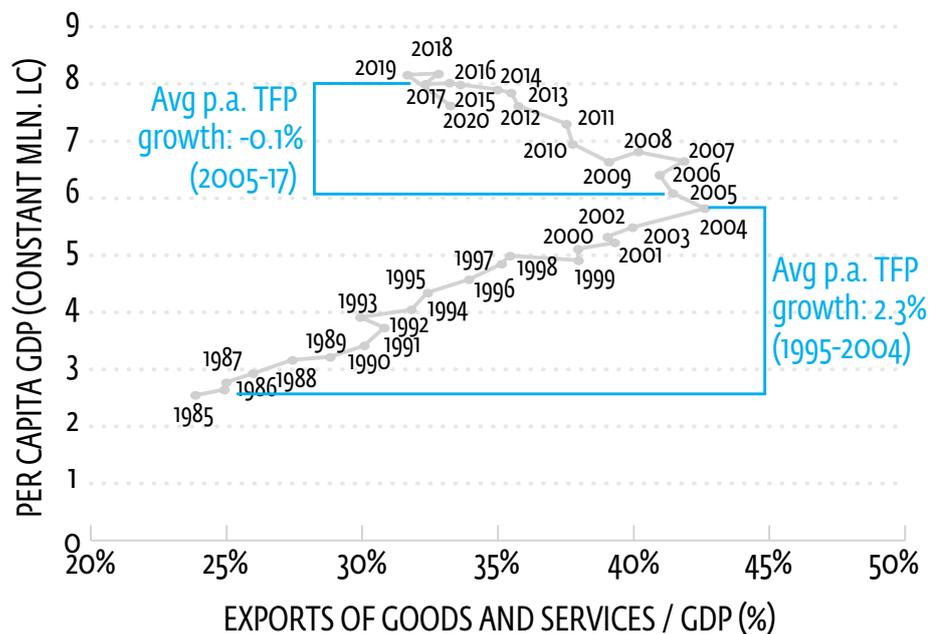
Source: Garcia-Marin 2021.

Note: Following the Melitz and Polanec (2015) methodology, aggregate (sales-weighted) productivity growth (column 5) is divided into three components: “Within” (column 1); “Covariance” (column 2); and “Entry” (column 3) and “Exit” (column 4).

3.2. UNTAPPED POTENTIAL IN GVC PARTICIPATION AND SERVICES TRADE

Trade was the main driver of growth in the 1980s and 1990s, and Chile has embraced openness like few others, but the export-led growth model has stalled over the past decades. Exports’ share of GDP increased from 24 percent in 1985 to a peak of 43 percent in 2004 but has since declined steadily (Figure 3.3). Higher export shares are correlated with higher TFP growth in Chile. Between 1985 and 2004, TFP growth contributed strongly to overall GDP growth, at approximately 2.3 percent per annum, accounting for over a third of total GDP growth (5.8 percent). Since the inflection point in 2004, the contribution of TFP growth to GDP has turned slightly negative (-0.1 percent) and with relatively unchanged contributions of factor accumulation, average GDP growth slowed to 3.4 percent between 2005 and 2017. Exports have thus not played their role as a driver of economic growth and productivity in Chile in a long time. Boosting export dynamism to promote productivity-driven growth is a priority in the recovery period.

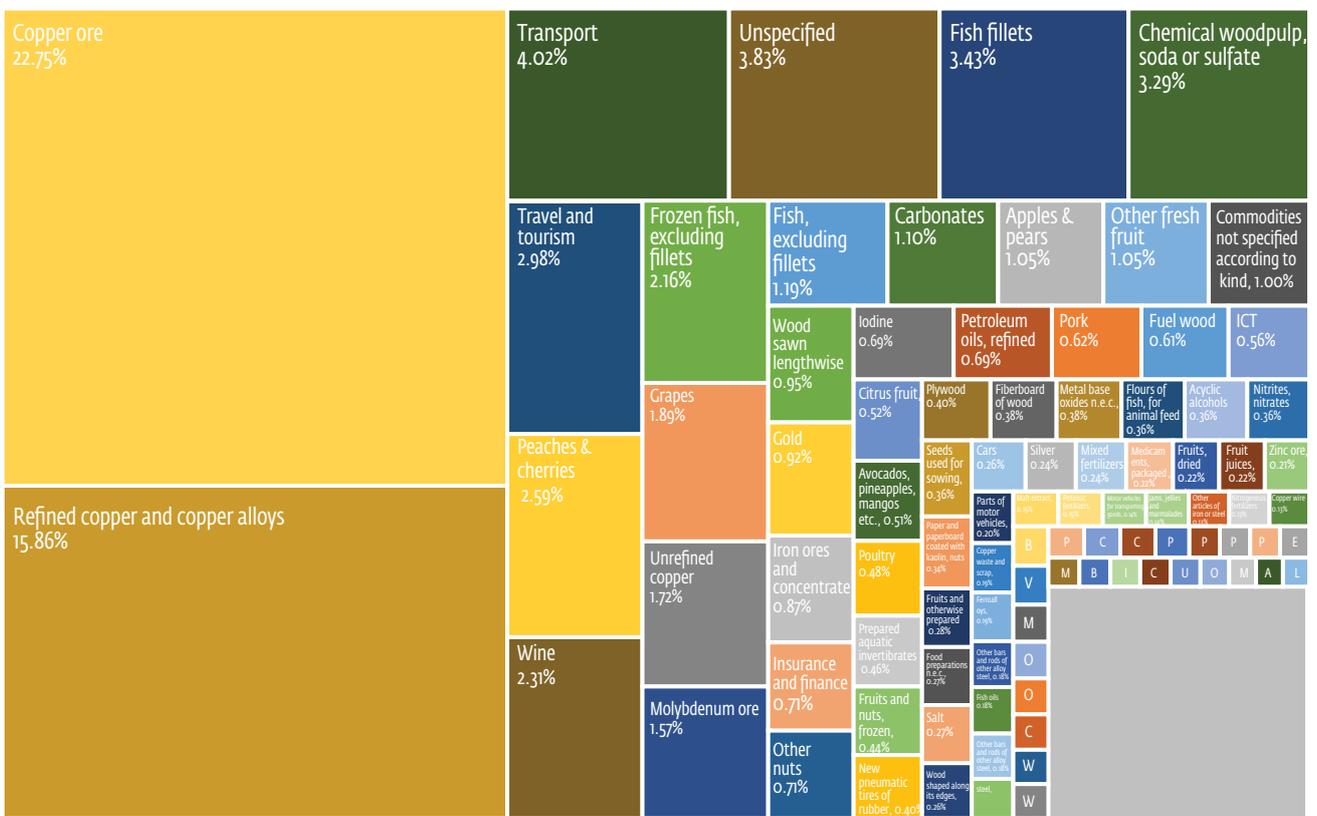
FIGURE 3.3 THE EXPORT SHARE OF GDP HAS DECLINED SUBSTANTIALLY SINCE THE MID-2000s



Source: World Bank, World Development Indicators.

Chile has diversified its export basket, particularly within natural resources. Over the past 50 years, the country has evolved from one of the most highly concentrated commodity exporters in the world to a much more diversified export basket (Figure 3.4). This includes greater domestic value addition in the traditional mining sector as well as the development of successful agro-industries, including fresh-fruits and nuts, fish, wood, and wine. Most of these products are linked to Chile’s traditional comparative advantage in natural resources, though some of them involve considerable degrees of sophisticated processing and manufacturing-based value addition.

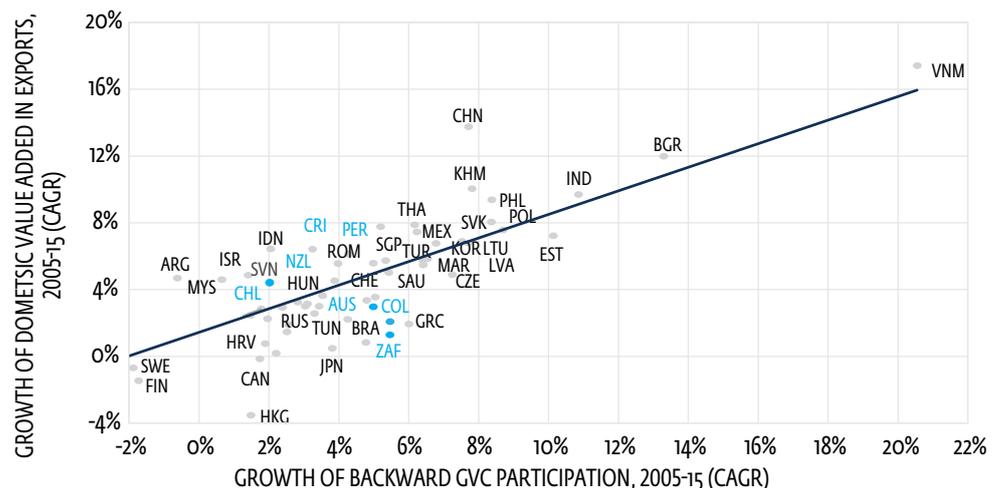
FIGURE 3.4 CHILE'S EXPORTS ARE DIVERSE, 2019



The next reform frontier is an integration policy that unleashes trade and FDI to drive productivity-led growth. While Chile benefits from strong trade-related institutions and policies, closer integration with the global economy could accelerate productivity growth in Chile through two interrelated channels: First, more engagement with global manufacturing value chains (GVCs), and second, additional steps to boost services trade. A common characteristic of GVC trade and services trade is that they are closely linked to both inward and outward FDI. FDI enables services trade through local presence (mode 3) and supports the establishment of long-term commercial relationships characteristic of GVC trade.

Participation in the production networks of global firms through GVCs promotes productivity through greater specialization and technology transfer. According to World Bank (2020b), a 1 percent increase in GVC participation is estimated to boost per capita income by more than 1 percent and significantly more so than traditional arm's length trade. GVC participation in manufacturing and services provides a channel for firms to grow and increase the sophistication of their production chain. At the micro level, firms that import and export, or that report to have longer-term relationships with trading partners, tend to be more productive and to create more jobs (World Bank 2020b). Furthermore, cross-country comparisons reveal that increased backward linkages of exports⁵ translate into more dynamic growth in export value addition as countries specialize within value chains (Figure 3.5). Chile is currently located toward the lower quadrant of growth in both backward GVC participation and domestic value addition in exports (Figure 3.5).

FIGURE 3.5 BACKWARD GVC PARTICIPATION VS. DOMESTIC VALUE ADDED IN MANUFACTURING EXPORTS, 2005–15

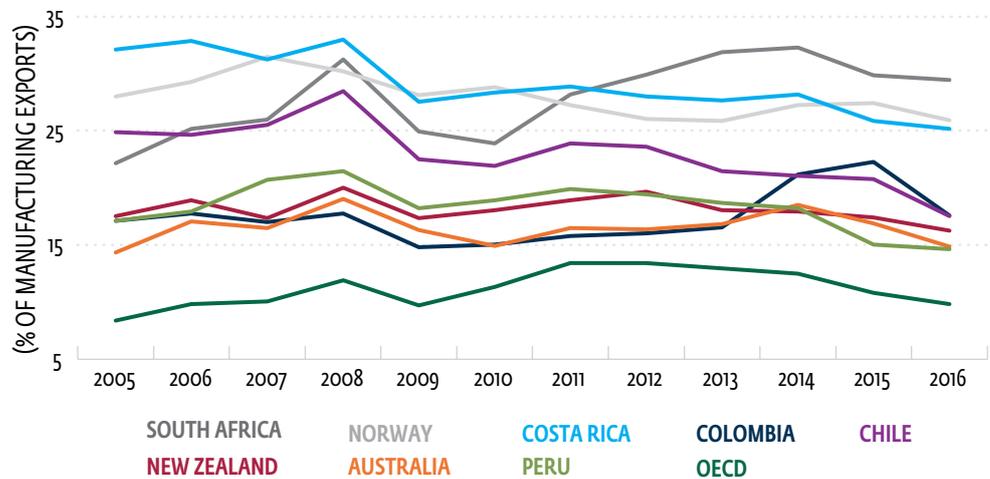


Source: Organisation for Economic Co-operation and Development, Trade in Value Added, 2018 release (OECD 2018b).

Note: Backward GVC (global value chain) participation = imported inputs in exports (in levels); CAGR = compound annual growth rate.

Chile exhibits relatively high forward linkages⁶ with GVCs, in line with its comparative advantage in natural resource-based products, but declining backward linkages relative to the country's total exports. In other words, Chile's exports, mostly of raw materials and commodity-based products, are frequently used in the production of other countries' exports. But Chile imports only limited inputs for further export-oriented processing domestically. While all commodity exporters are generally characterized by the upstream nature of their exports, Chile's export basket is even further away from the final consumer, driven as it is mostly by metals and chemicals. Even within manufacturing, forward linkages with GVCs are concentrated in commodity-intensive products like processed metals and chemicals, rather than in final assembly tasks. A sectoral decomposition reveals that Chile's backward GVC participation, as a percentage of its exports, is driven by mining, agribusiness, and business services, rather than manufacturing. And while upgrading toward manufacturing and more advanced GVCs tends to go in hand with higher backward GVC participation globally, data indicate that Chile's backward GVC participation in manufacturing relative to manufacturing exports has declined steeply since the mid-2000s (Figure 3.6), which is atypical when countries intensify their engagement in manufacturing GVCs. At the same time, Chile's goods import basket is closer to the final consumer than many of its peers, indicating a smaller relative potential to increase domestic value added.

FIGURE 3.6 BACKWARD GVC PARTICIPATION IN MANUFACTURING, CHILE VS. COMPARATORS, 2005-15

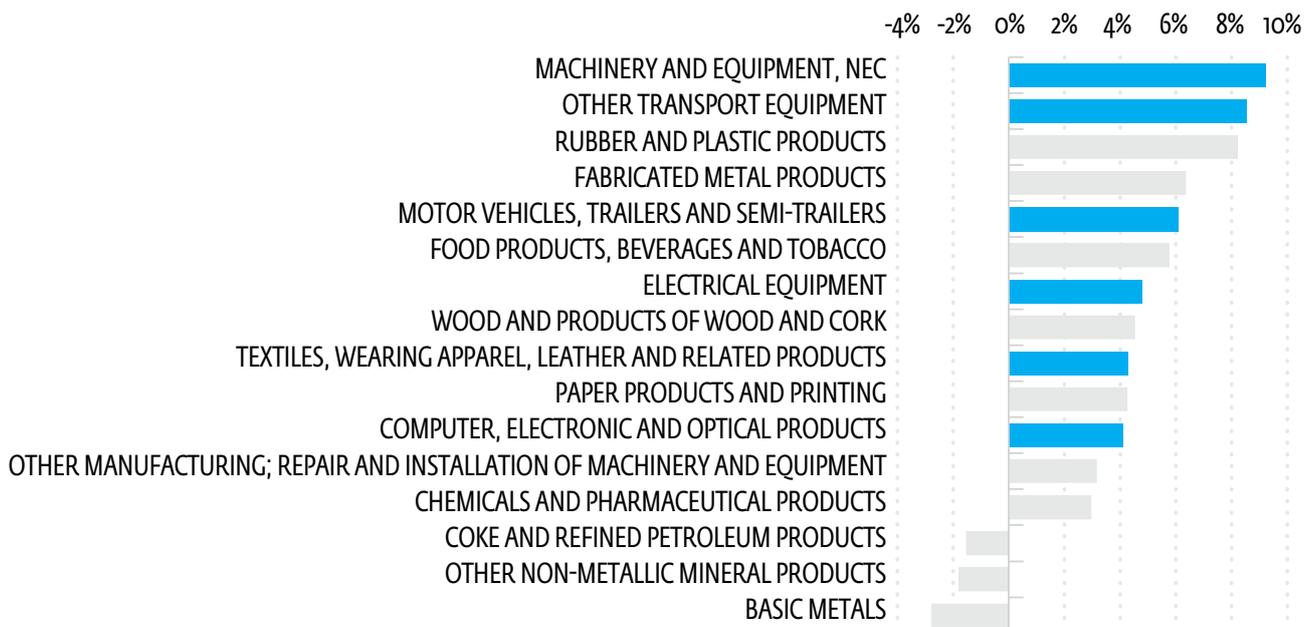


Source: Organisation for Economic Co-operation and Development, Trade in Value Added, 2018 (OECD 2018b) release.

Note: Backward GVC (global value chain) participation = imported inputs in manufacturing exports (% of manufacturing exports).

Encouragingly, some of Chile’s most dynamic export sectors are in GVC-intensive manufacturing. The opportunity exists to expand these exports to reach a scale sufficient to drive export growth and productive job creation. Several GVC-intensive sectors—in particular, machinery, transport, and electrical equipment—are among Chile’s fastest-growing export sectors (growth of over 8 percent), albeit from a relatively low base (Figure 3.7). Fabricated metal products and motor vehicles grew at over 6 percent on average every year between 2005 and 2015, while food and beverages and electrical equipment both showed growth of around 5 percent. Noncommodity manufacturing exports are concentrated in and around Santiago (63 percent of the total), and two-thirds of these exports go the Latin America and Caribbean region, underscoring Chile’s strong integration into regional GVCs. Commodity-based manufacturing exports, on the other hand, reach most key global markets.

FIGURE 3.7 SOME OF CHILE'S MOST DYNAMIC EXPORTS ARE IN GVC-INTENSIVE MANUFACTURING (CAGR %, 2005-15)

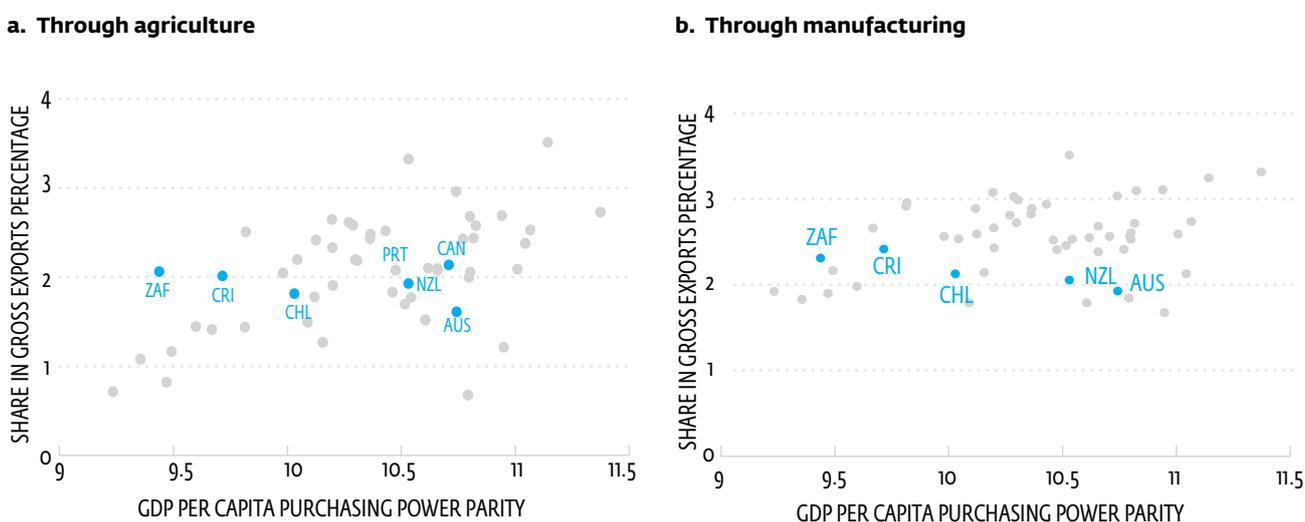


Source: Organisation for Economic Co-operation and Development, Trade in Value Added, 2018 (OECD 2018b).

Note: CAGR = compound annual growth rate. Blue bars designate GVC-intensive sectors.

The potential for greater growth of trade in services is large, both of nontraditional export services such as business services and of services imports in its manufacturing exports. Export services expanded significantly during the 2000s, reaching 14 percent of exports in 2011. Following the end of the commodity boom, they showed a declining trend by reaching 11.9 percent of total exports in 2019 because of the fall in transport services—the largest item. By contrast, business services (including consultancies, research and development, and engineering services among others) have shown a very positive trend, growing their share in total export services from 17 percent in 2003 to 27 percent in 2019. Chile could also benefit from greater import value added of services in its manufacturing exports to drive greater export productivity. For agriculture, where the country is a strong exporter, foreign services input usage is on par with its development level (Figure 3.8a). However, this is not the case for manufacturing where Chile is placed below the fitted value line, indicating that its manufacturing sector uses lower foreign service value added than expected (Figure 3.8b). Generally, GVC participation in manufacturing and services provides a positive channel for firms to grow and sophisticate their production chain. With more competitive services, firms adopt a more complex production structure and improve managerial practices. They hire more workers in nonproduction functions, including in supply chain management, product development, information and communication technology (ICT), and professional services, which in a competitive market can be sourced from abroad and from the home market.

FIGURE 3.8 FOREIGN SERVICES VALUE ADDED (INDIRECT), 2015



Source: World Bank staff calculations using Organisation for Economic Co-operation and Development’s Trade in Value Added (TiVA) data. Both panels show total services value-added used downstream (agriculture and manufacturing) using the EXGR_SERV_FVASH indicator from TiVA.

Note: GDP = gross domestic product. Countries: AUS = Australia; CAN = Canada; CHL = Chile; CRI = Costa Rica; NZL = New Zealand; ZAF = South Africa.

While its factor endowment and geographic location partially shape Chile's current pattern of GVC participation and services trade, there are several policy priorities that could help foster deeper integration. GVC participation is determined by fundamentals such as factor endowments, market size, geography, and institutional quality. Choosing the right policies can shape each one of these fundamentals and thus GVC participation (World Bank 2020b). Chile's type of GVC participation can be explained by its high share of natural resources and its remoteness from the GVC hubs (including China, Germany, and the United States). While high institutional quality seems to have helped Chile participate in GVCs, its smaller market size would encourage higher backward GVC participation. Measures to increase skills and innovation, as discussed in sections 3.4–3.5 of this report, would help gradually upgrade factor endowments toward more knowledge-intensive GVCs and services exports. The remainder of this section discusses trade-related measures, including (a) addressing existing bottlenecks in trade policies to enlarge effective market size, (b) further enhancing Chile's already-strong institutions and its market access through deeper trade agreements, (c) reducing transaction costs by aligning regulatory measures to those of key trading partners, and (d) improving connectivity and trade facilitation to overcome geographical disadvantages.

Chile has been an early mover in the pursuit of an open trade regime, but some barriers remain for services and GVC trade. Studies have confirmed the positive impact of low tariffs on GVC participation and FDI spillover because firms are less constrained by a country's market size and are able to import low-cost and high-quality inputs, and domestic firms are more exposed to international competitive pressures and the newest technologies.⁷ Chile performs in the midrange of peer countries in terms of average most-favored nation (MFN) tariffs and benefits from an extensive network of preferential trade agreements (PTAs). However, some nontariff barriers to trade remain and are particularly problematic where standards differ from those in key GVC partner countries. For services, and unlike the case of merchandise imports, Chile shows fairly high trade restriction—in particular in financial services, followed by business services and telecommunications companies. Strikingly, Chile's highest level of restrictions in services is applied to cross-border trade (known as mode 1), even though this channel of trade is usually fairly open.

However, the depth of Chile's PTAs could be increased and could serve as a vehicle to foster reform in several cross-cutting priority areas, in particular the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP). The coverage of Chile's PTAs is exceptional, reaching almost 98 percent of exports. However, increasing the depth of its agreements—for instance in the areas of intellectual property, right protection, and competition—could foster GVC upgrading, including in services sectors. One promising PTA is the CPTPP, which was signed in 2017 and besides Chile includes Australia, Brunei, Canada, Japan, Malaysia, Mexico, New Zealand, Peru, Singapore, and Vietnam. The CPTPP captures provisions that go beyond access to inputs and markets, including on services trade liberalization, competition policy, intellectual property protection, labor market regulations, and environmental laws, which are identified as cross-cutting policy priorities in this report. Engaging in deeper PTAs, such as the CPTPP, promises to foster reform in these areas and as a result to stimulate Chile's GVC and services trade.

In addition to trade restrictions, services trade in Chile is undermined by policies that, while not discriminating against foreign providers, inhibit transparency and competition. Chile stands out among OECD countries for the relatively large share of its restrictions in areas that deal with competition and domestic transparency procedures. This is particularly true for telecommunications (telecom) and transport services, activities affecting Chile's connectivity with the global economy. Such measures impose an estimated markup equivalent to about 15 percent in telecom and air transport, and about 20 percent for maritime transport and warehousing (Rouzet and Spinelli 2016). Examples include practices for spectrum regulation in telecom, the government's ability to overrule decisions of the regulator and preferential treatment for the designated postal operator in courier services, or advertising restrictions for some professions. Transparency measures refer to institutional accountability of regulations—for example, whether regulations are published or otherwise communicated to the public prior to entry into force or whether licensing agreements are publicly available.

Cross-country differences in regulatory policy frameworks for services markets are a key driver of trade costs. In the case of Chile, such differences are particularly pronounced with respect to emerging economies, but also with some OECD countries such as Mexico and the United States. Regulatory barriers are nonborder barriers and cannot be easily dismantled. The alignment of regulatory frameworks therefore becomes as essential as the reduction in the restrictiveness of services regulation itself.

Promoting connectivity and improving the quality of infrastructure touch on several dimensions of GVC participation and services trade. These include important determinants of GVC trade like securing the flow and lowering the costs of inputs and outputs, increasing speed, and reducing uncertainty. Several studies confirm the importance of connectivity for GVC participation.⁸ While Chile performs well overall, further improvements in logistics performance and digital connectivity, in particular in more remote regions, would provide further impetus to GVC integration and services trade. Digital connectivity issues are covered in section 4.3 of this report.

In light of these findings, the following recommendations would likely contribute significantly to enhanced services and GVC trade in Chile that would contribute to future productivity growth:

- Further review and, where possible, lower MFN tariffs, in particular on intermediate inputs.
- Reduce services trade restrictions, in particular in key upstream industries that drive productivity throughout the value chain, and with a special focus on mode 1 trade.
- Review nontariff measures, including sanitary and phytosanitary standards and technical barriers to trade for both goods and services to ensure that regulatory objectives, where necessary, are accomplished at the lowest possible cost to traders.
- Deepen existing trade agreements to facilitate trade in services and GVC participation by including provisions on intellectual property and competition and easing the recognition of professional titles and qualifications, which are unnecessarily burdensome to FDI in services.
- Reduce regulatory heterogeneity and converge toward the regulatory environment of main trading partners, which could be an important source of cost savings.
- Further invest in trade facilitation to reduce waiting times and trade costs, as well as in trade related infrastructure.

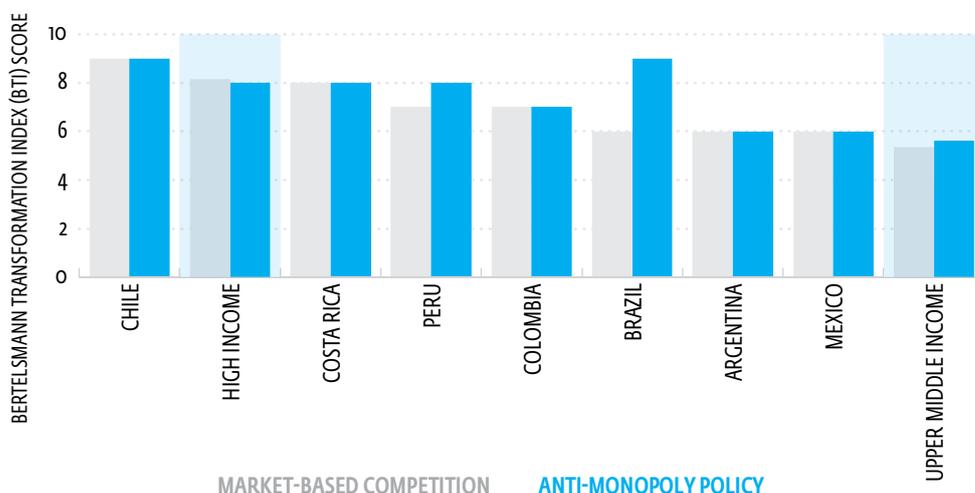
3.3 STRENGTHENING COMPETITION POLICY

Enhancing competition in Chile is critical to increase productivity and efficiency for the benefit of private sector development. Competition fosters innovation when coupled with sound firm capabilities and cost reductions and promotes productivity growth (Acemoglu and Ozdaglar 2007).⁹ Two mechanisms contribute to this result. First, competition shifts market share toward more efficient producers; second, it induces firms to become more efficient in order to survive (Kitzmuller and Licetti 2013). Empirical evidence shows that the degree of competition in the domestic market is a key determinant of international competitiveness (Goodwin and Pierola 2015). Firms typically acquire many of their inputs—transport, energy, telecommunications, and financial services—in local markets. If these upstream markets lack competition, firms may be less competitive than their foreign rivals.

Various measures of product market concentration and markups point to increased market power in the manufacturing sector, especially among high-markup establishments. While perception-based indicators on market-based competition and anti-monopoly policy (Figure 3.9) show high marks, an analysis of the Chilean Annual Manufacturing Survey for the period 1996–2015 suggest increased market power. Product market concentration has been rising as measured by both the unweighted and sales-weighted Herfindahl-Hirschman Index (HHI), with the latter taking off after the mid-2000s (Figure 3.10). Aggregate industry markups, a traditional measure of market power, show a similar trajectory to market concentration patterns. Using the methodology of De Loecker and Warzynski (2012), Figure 3.11 displays a substantial rise in aggregate markups from approximately 2008 on. Moreover, while markups rose for all percentiles, they increased by more in high-markup establishments and sectors, consistent with the increase in product market concentration observed. Changes in productivity among incumbents and the negative “entry margin” (Figure 3.2) seem to have provided top manufacturing high-markup establishments a stronger ability to charge higher markups. While market concentration can result from natural barriers, small market size, or firms operating more efficiently because of scale economies, it may also be associated with government regulations and interventions that disrupt the marketplace by increasing the cost of entry, facilitating dominance, or un-leveling the playing field through as discussed below.

State-owned enterprises (SOEs) are present in key enabling sectors, including sectors typically served by private operators. As of 2021, Chile had 32 SOEs with aggregate revenues accounting for approximately 7.7 percent of GDP, mainly the National Copper Corporation of Chile (CODELCO) and the National Petroleum Company (ENAP) (MoF 2021a). In this sense, 20 of 32 SOEs in operation were created by Law 20.285, including the mining company CODELCO, or Corporación Nacional del Cobre. Ownership control remains dispersed. While the control and supervision of the majority of SOEs (20 of 32 SOEs) reside in the State-Owned Enterprises System (Sistema de Empresas Públicas; SEP), the largest Chilean SOEs—CODELCO, ENAP, and Banco del Estado—operate in a decentralized and autonomous way.

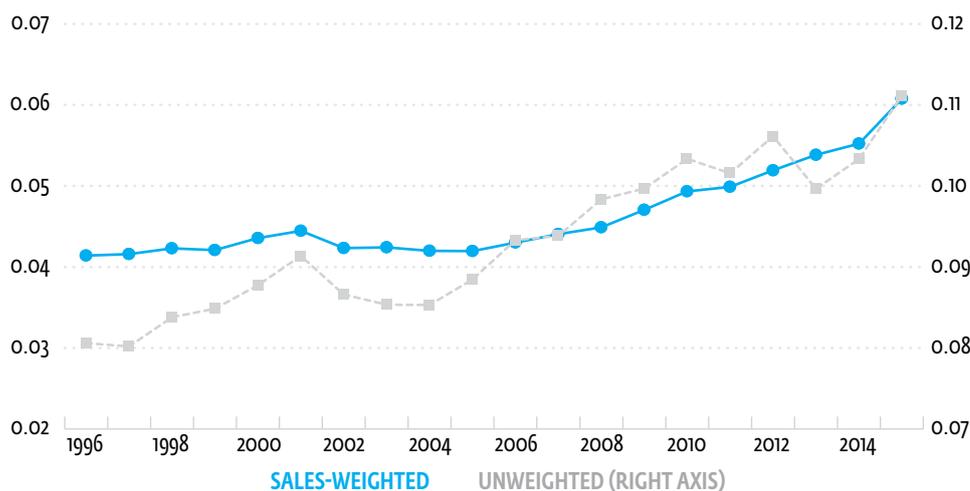
FIGURE 3.9 PERCEIVED MARKET-BASED COMPETITION AND ANTITRUST POLICY IN CHILE AND COMPARATOR COUNTRIES, 2020



Source: World Bank staff elaborations based on Bertelsmann Transformation Index (BTI) 2020.

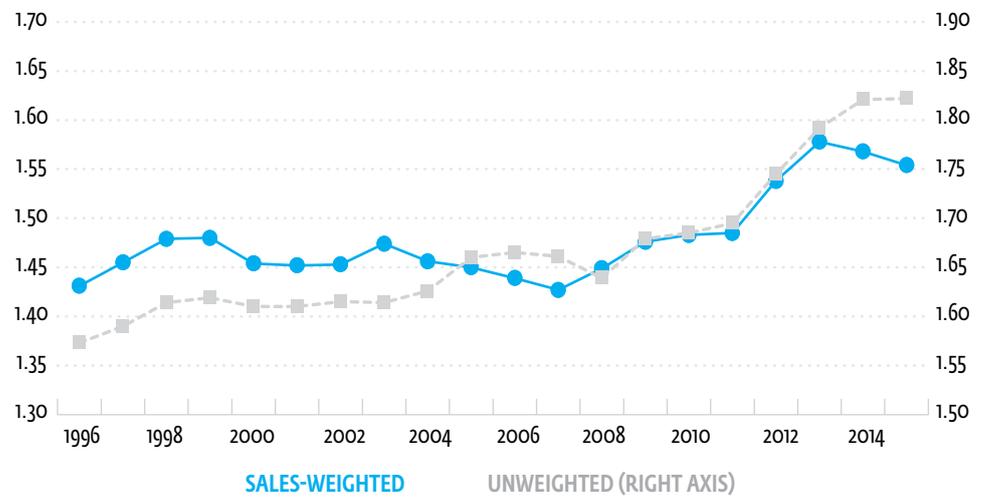
Note: The BTI is a perception indicator based on in-depth assessments of countries by Bertelsmann Stiftung. The scores vary from 1 (worst) to 10 (best).

FIGURE 3.10 MANUFACTURING HERFINDAHL-HIRSCHMAN INDEX (HHI), CHILEAN MANUFACTURING, 1996–2015



Source: Garcia-Marin 2021.

Note: To compute the aggregate HHI, the figure averages industry-level HHI (at the 3-digit ISIC level) weighting by sales (blue line) and taking unweighted averages (gray-dashed line).

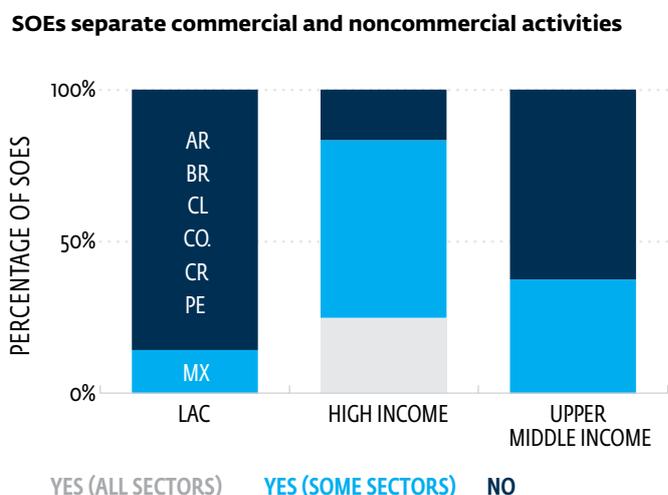
FIGURE 3.11 AGGREGATE MANUFACTURING MARKUPS IN CHILE, 1996–2015

Source: Garcia-Marin 2021.

Note: The blue line computes aggregate markups weighting plant-level markups by plants' sales, while the gray-dashed line shows unweighted average markups across all manufacturing establishments in each year. Plant-level markups are computed using the methodology by De Loecker and Warzynski (2012).

In this context, limited implementation of the competitive neutrality principle might unlevel the playing field for private operators. Competitive neutrality is a principle by which all enterprises, public or private, domestic or foreign, face the same set of rules, and by which government's ownership or involvement in the marketplace does not confer an undue competitive advantage on any actual or potential market participants (OECD 2015). The effective implementation of competitive neutrality is important to decrease the risk of anticompetitive behavior and economic distortions from SOEs. In Chile, product market regulation (PMR) data show a number of regulatory gaps that challenge the competitive neutrality principles. First, SOEs in Chile are not required to separate their commercial from their noncommercial activities, which is critical to identify the costs and revenues of various activities (Figure 3.12) (Rodriguez-Ferrand 2009). Second, Chile has SOEs that are not incorporated as limited liability companies, and some of those are not subject to private law.

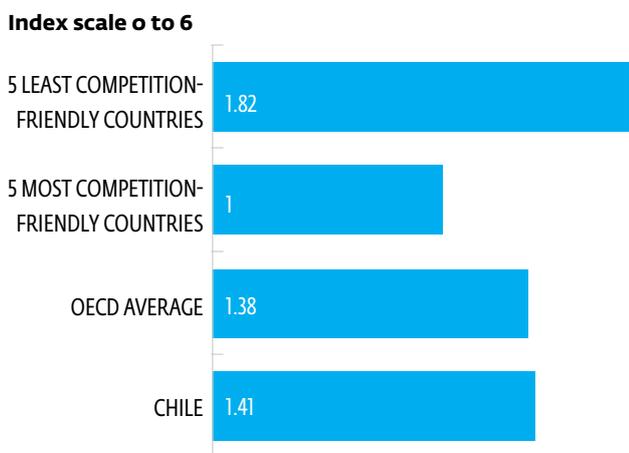
FIGURE 3.12 TREATMENT OF CHILEAN SOES AND COMPARATORS, 2018-20



Source: WBG-OECD Product Market Regulation database, 2018–20.
 Note: AR=Argentina; BR=Brazil; CL=Chile; CO=Colombia; CR= Costa Rica; LAC = Latin America and Caribbean; MX=Mexico; PE= Peru.

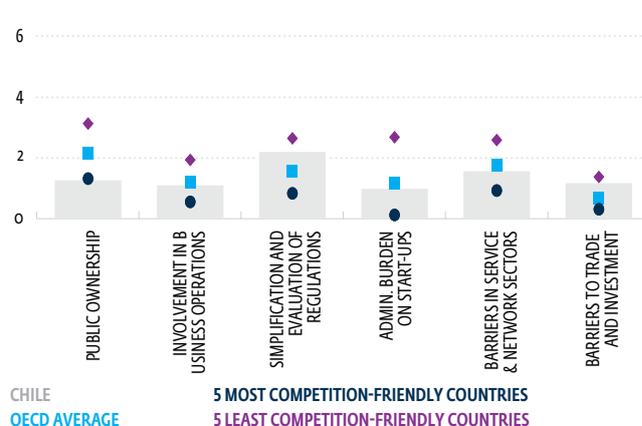
While the Chilean regulatory framework compares well with peers in terms of its ability to promote competition, certain gaps in key enabling sectors may be affecting market outcomes. Overall, PMR indicators for Chile are only slightly more restrictive than the OECD average (Figure 3.13), with simplification and evaluation of regulations, barriers in services and network sectors, and barriers to trade and investment being the dimensions in which Chile diverges the most from top performers (Figure 3.14).

FIGURE 3.13 OVERALL PMR INDICATOR FOR CHILE AND COMPARATORS, 2018



Source: OECD 2018c
 Note: The PMR indicators range from 0 to 6. A lower value represents a more competition friendly regulatory regime

FIGURE 3.14 ECONOMYWIDE PMR INDICATORS FOR CHILE AND MAJOR COMPARATORS



Source: OECD 2018c
 Note: The PMR indicators range from 0 to 6. A lower value represents a more competition friendly regulatory regime

In network industries, regulation appears to protect incumbents, hindering market contestability (OECD 2020c).¹⁰ While competition has increased in the telecommunication sector over the years, some challenges remain. Operators have market power in mobile call origination services, but prices are not regulated. Similarly, operators have market power in wholesale fixed local access but are not required to separate local access from downstream retail services. In addition, switching operators seems to be difficult—although it improved with the approval of the numerical portability law in 2009—and the regulator is not as independent as it could be, raising the risk of conflict of interest and regulatory uncertainty (OECD 2018c). The latter is also the case for the water regulator. In the gas sector, the public operator remains vertically integrated with no separation between transmission and distribution, production, or retail supply. In addition, third-party access (TPA) to the transmission grid and to the distribution networks is negotiated and not regulated. In financial services, where nonbank financial institutions are not always able to compete on a level playing field with major banks (such as in accessing public sector credit guarantee lines) (FNE 2017), a fintech bill currently in Congress is expected to address shortcomings that have affected the business model and development of fintech companies (CMF 2021).

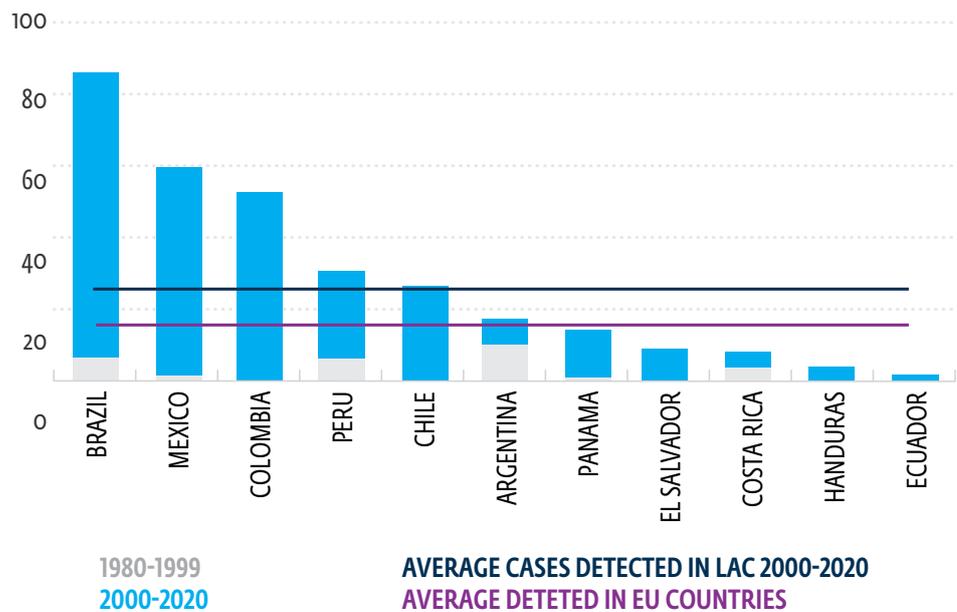
In some regulated professional services, there is a perception of excessive charges. In particular, notaries and customs brokers are perceived to overcharge for services, indicating some competition shortcomings. For example, PMR data indicate significant entry and conduct restrictions for notaries. The number of notaries is limited by law, and notaries have exclusivity over a significant number of tasks.

Overall, the competition system is robust with competent institutions that have gained more power to enforce the law over time. Chile's competition system, enshrined in the Competition Act (D.L. 211), is designed to prevent abuses of dominant position, concerted parties, and, in general, any acts that restrict competition or could produce such effects. The legal framework was further strengthened in 2016 by reinstating criminal penalties for concerted practices, establishing the per se illegality of hardcore cartels, and including additional sanctions. Moreover, this amendment established a premerger control regime, making it mandatory to notify any projected transaction when certain turnover thresholds are surpassed. Chile's Competition Authorities are the Chile National Economic Prosecutor (Fiscalía Nacional Económica; FNE), an independent competition agency whose main responsibility is the enforcement of the competition law, and the Competition Tribunal (Tribunal de Defensa de la Libre Competencia; TDLC), an independent judicial body with exclusive jurisdiction to decide competition lawsuits.¹¹ Both institutions are highly technical.

Recent changes to the merger control framework will bring greater legal certainty and streamline notification requirements to benefit both private parties and the competition authority. Although the procedure for merger control has worked efficiently since its implementation in 2017, the new regulations further improve it by (a) establishing a simplified mechanism for transactions with no horizontal or vertical overlaps and expanding the scope of transactions that are eligible for the simplified notification; (b) streamlining notification requirements and establishing adapted standards for concentrations in digital markets; and (c) formalizing prenotification contacts between the merging parties and the FNE.

New proposals that would allow parallel investigations on cartel cases by the public prosecutor could derail efforts to strengthen anticartel policy. Between 2010 and 2020, the FNE presented 23 cartel lawsuits to the TDLC. While the number of hardcore cartels sanctioned in Chile remains relatively modest compared with regional peers (Figure 3.15), the FNE has obtained convictions for collusion in 100 percent of the cases filed since 2010 and more than 200 individuals and legal entities have been convicted with fines of almost US\$200 million. Cartels were criminalized back in 2016. No jail sanctions have been issued yet, as no decisions on cartel conduct that took place after 2016 have been delivered to date.¹² A bill is being discussed in Congress that could open the possibility for the public prosecutor to investigate cases of cartels.¹³ This could hinder the effectiveness of the existing leniency policy, which has been critical in uncovering and sanctioning cartels in 7 out of 23 cases. The proposed bill could discourage leniency applicants because they may fear parallel investigations by different institutional bodies, which could end with contradictory decisions.

FIGURE 3.15 NUMBER OF HARDCORE CARTELS SANCTIONED IN CHILE AND OTHER LATIN AMERICA AND CARIBBEAN COUNTRIES, 1980–2020



Source: Adapted from World Bank 2021c.

Note: The average number of cases detected in EU countries are estimated from the OECD Cartels database (2020). The average number of LAC countries are estimated from the WBG ACED database.

Potential areas of reform to foster competition in Chilean markets for the benefit of the private sector

Enhancing competition policy in Chile would require focusing on three priority areas: (a) strengthening the competitive neutrality framework in sectors with SOE presence; (b) addressing regulatory gaps that may hinder competition in key sectors, notably network industries; and (c) reinforcing merger control and anticartel policy, especially considering emerging laws and regulations:

- **Strengthening the implementation of the competitive neutrality framework in sectors with SOE presence** calls for (a) an evaluation of the need for the state to directly participate in markets that are being catered by the private sector; and (b) consideration of separating the commercial and noncommercial activities of SOEs, at least through account separation.
- **Addressing regulatory gaps that may hinder competition in key sectors, notably network industries** would require (a) **introducing key regulatory tools in network industries**, such as TPA access to transmission and distribution segments, price regulations in mobile call origination services, and separation of local access from downstream retail services; and (b) setting lower entry and conduct barriers in the regulated professional services of notaries.
- **Reinforcing merger control and anticartel policy, especially in light of laws and regulations that are new or under consideration** implies (a) supporting the implementation of the recently adopted regulation, namely Decree No. 41, which provides a simplified mechanism for transitions and a notification system as well as adapted standards for concentrations in digital markets, among other reforms; (b) monitoring closely and assessing potential implications from the proposed bill, which attempts to modify the current competition system—notably, the strong investigative tools and elements such as leniency.

3.4 UNLEASHING INNOVATION

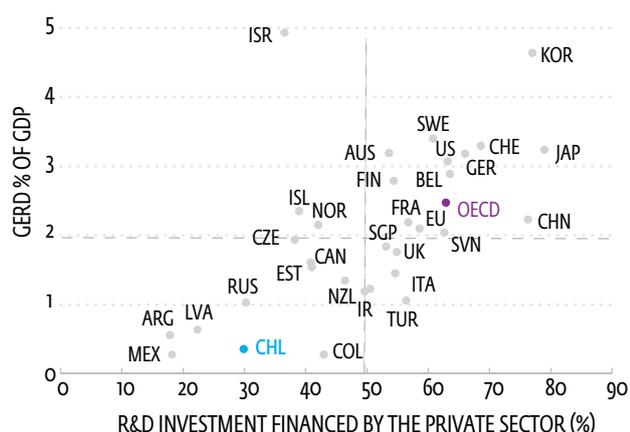
A rich body of empirical literature has shown that innovation can improve firm productivity, but innovation in Chile remains at a low level.¹⁴ The analysis in section 3.1 (in particular, Figure 3.2) indicates that low productivity growth in Chile is primarily explained by a negative within-firm component (technical efficiency) of TFP, which in turn reflects that firms are not increasing their internal capabilities, including managerial skills, workforce skills, innovation capacity, and technology-absorption capability. Despite this pattern, some studies have documented a positive effect of innovation on labor productivity for manufacturing and services in Chile (Bravo et al. 2014). This linkage is, however, weaker than for other high-income countries.

Although younger and exporting firms display higher levels of innovation, Chile's investment in innovation seems to have broadly stagnated (or possibly declined by some measures). According to the XI National Innovation Survey,¹⁵ 14 percent of firms innovated during the 2017–18 period, a steady decline from 23.7 percent in 2011–12 and substantially below levels prevalent in OECD countries (OECD 2020a).¹⁶ Firms innovate more in business processes (13 percent) than in products (five products). Innovation tends to be incremental and mostly catches up with competitors, with less than one-fifth of innovations being completely new to the market. In line with this finding, acquisition of machinery, equipment, and software is by far the most frequent innovation activity, while research and development (R&D) investment is

significantly smaller and requests for Intellectual Protection Rights (largely trademarks with few patents) are low compared with structural peers.¹⁷ Innovation incidence is also concentrated, with SMEs and firms outside Santiago displaying much lower rates. The adoption of digital technologies by firms, however, appears to have accelerated substantially during the COVID-19 pandemic (see section 4.3). Younger companies (less than five years old) innovate more than older companies (older than 20 years) and derive a higher percentage of sales from product innovations, highlighting the importance to productivity of easing entry restrictions and fostering innovative entrepreneurship. As expected, exporting firms show higher innovation inter alia because they are more exposed to international competitive pressures (Havranek and Irsova 2011) and the newest technologies (Meyer and Sinani 2009). Still, innovation incidence among firms that operate in international markets lags the levels found in most OECD countries and in Chile’s structural peers, suggesting that important barriers to innovation remain (OECD 2020a).

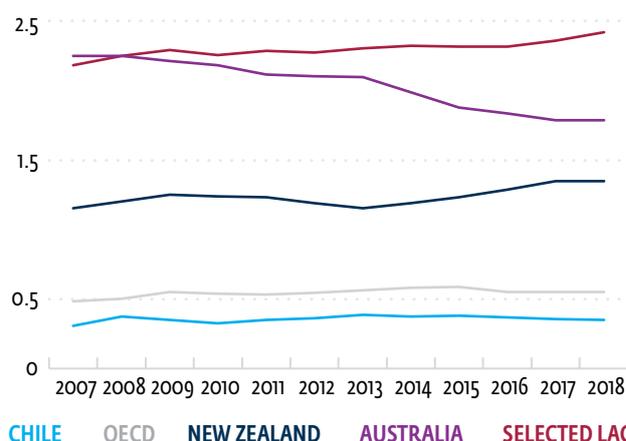
Chile spends less on R&D than would be expected for its level of development, even after adjusting for its economic structure, and only a small share is financed by the private sector.¹⁸ Chile only spends 0.35 percent of GDP on R&D, compared with 2.4 percent in the OECD and 0.7 percent in Latin America and the Caribbean (Figure 3.16). In contrast, structural peers such as Australia and New Zealand, countries with a strong natural resource base, invest 1.8 percent and 1.3 percent of GDP on R&D, respectively. Furthermore, spending on R&D as a percentage of GDP has not increased in Chile since 2007 (Figure 3.17), and the private sector’s contribution, about a third of the total R&D expenditure, remains significantly below the OECD average of 63 percent and has been on a declining trend since before the global financial crisis, when it had peaked at 44 percent of the total.

FIGURE 3.16 R&D EXPENDITURE IN CHILE REMAINS AT A LOW LEVEL (2019 OR LATEST AVAILABLE)



Source: OECD (MSTI database).
 Note: Median at y-axis (2) and x-axis (50). GDP = gross domestic product; GERD = gross domestic expenditure on research and experimental development; R&D = research and development.

FIGURE 3.17 R&D EXPENDITURE HAS STAGNATED FOR MORE THAN A DECADE (PERCENT OF GDP)

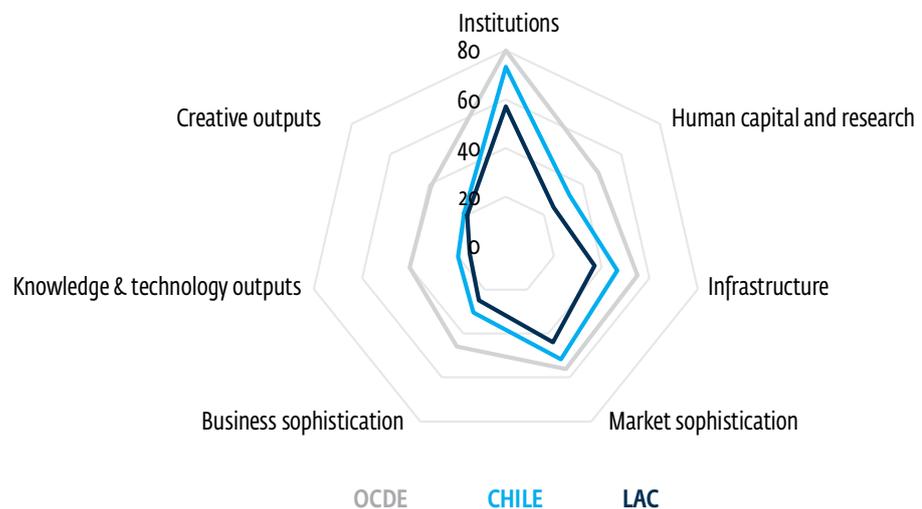


Source: OECD (MSTI database).
 Note: Selected LAC is average of Argentina, Colombia, and Mexico.

Barriers to innovation

The quality of Chile's institutions, its open economy and overall business environment have generally been conducive to innovation, but other factors seem to be hindering innovation efforts. The Global Innovation Index (GII) highlights that Chile performs strongly on institutions but needs to catch up substantially on human capital and research as well as on business sophistication (especially linkages within the innovation system) relative to the OECD average (Figure 3.18). Chile's financial system—an important ingredient to support innovation—is quite mature on many fronts, but risk financing instruments are still scarce.¹⁹ Inadequate competition in some sectors seems to have also depressed innovation efforts.

FIGURE 3.18 CHILE SCORES ABOVE OTHER LATIN AMERICAN AND CARIBBEAN COUNTRIES IN THE GII BUT BELOW THE OECD MEAN IN ALL OF ITS PILLARS, 2020

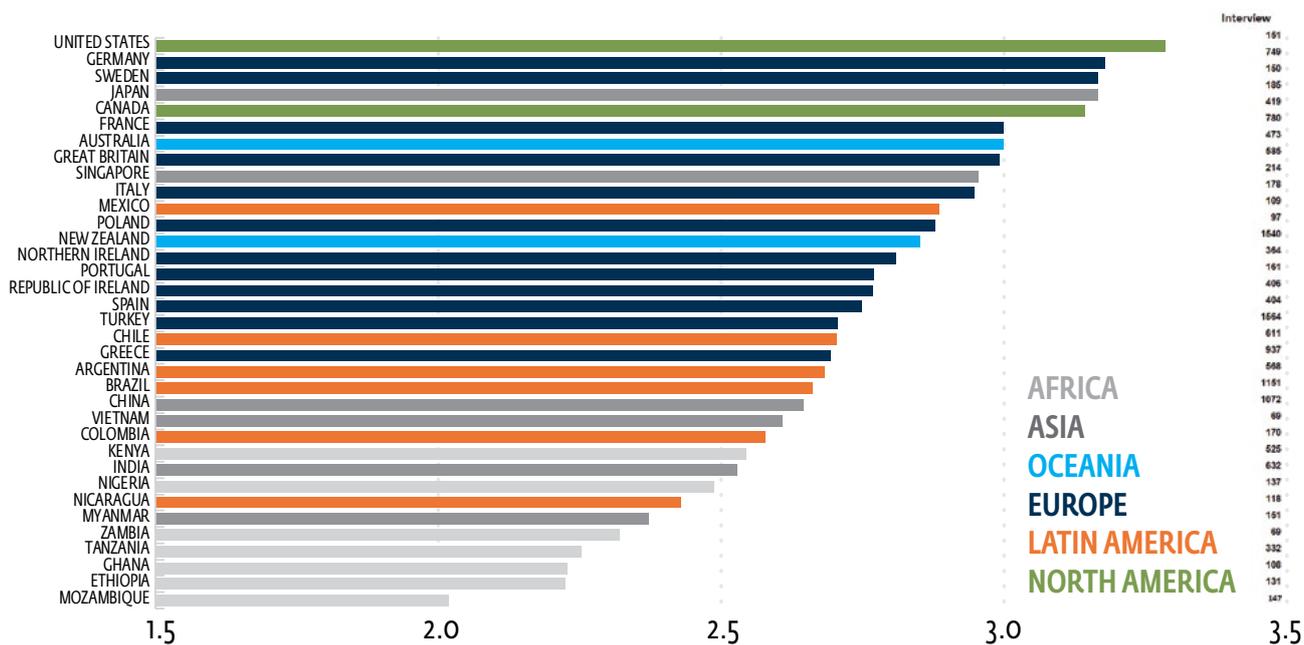


Source: Global Innovation Index 2020.

Note: LAC = Latin America and Caribbean; OECD = Organisation for Economic Co-operation and Development.

Addressing the gap in managerial skills and in human capital in scientific and technological areas could facilitate firms’ innovative activities. Chile ranks 55th in the human capital and research pillar of the GII, which presents the lowest score among innovation inputs (Cornell University, INSEAD, and WIPI 2020). The country has only 493 researchers in R&D per million people, compared with 580 in the Latin America and Caribbean region and 4,080 among OECD members. At the firm level, according to the National Innovation Survey of 2020, almost 60 percent of firms mention the lack of qualified staff as an obstacle to innovation. A growing number of Chileans pursue graduate degrees, but few do so in science, technology, engineering, and mathematics (STEM) areas: 7.3 percent of graduates are in natural sciences, mathematics and statistics, information and communication technologies, and engineering, compared with an average of 22.6 percent in the rest of OECD countries. Lack of technical skills is the main challenge that firms face filling positions (SENCE 2021).²⁰ Empirical studies have shown that besides being a key driver of productivity, strong managerial skills lead firms to pursue innovation and improve their technological capabilities (Dieppe et al. 2021). The latest management survey conducted in Chile, however, indicates that management skills remain below those of its structural peers and most OECD countries (Figure 3.19).

FIGURE 3.19 AVERAGE MANAGEMENT SCORE BY COUNTRY, 2004-15



Source: World Management Survey Database

Note: Unweighted management scores. The number of interviews is shown in the right column (total = 15,798); all waves pooled (2004–15).

Linkages across the innovation system, especially between universities and firms, can be enhanced to foster the transfer of technology and much broader learning spillovers. While a significant part of the execution of R&D resources is concentrated in universities (46 percent versus the OECD average of 18 percent), these resources have limited linkages to industry, especially SMEs. The XI National Innovation Survey shows that, among innovative firms in Chile, less than 4 percent collaborated with a university and only 8 percent collaborated with national institutions. Collaboration among innovative firms is barely 10 percent and when it occurs, it is mainly with suppliers and clients—even though empirical evidence on Chile shows that firms that cooperate with each other conduct more innovative activities compared to those that do not.²¹

A few innovative clusters, however, have emerged in exporting sectors. Since the mid-2000s, the wine industry has made an important leap with the launch of the Consorcio I+D Vinos de Chile. This R&D consortium, which encompasses 79 wineries, universities, and other institutions, has developed an ambitious program to foster the competitiveness and sustainability of the industry.²² The consortium has benefited from funding from the Chile Economic Development Agency (Corporacion de Fomento; Corfo). The fruit industry, the largest exporter in the southern hemisphere, has also undertaken innovations on a number of fronts to improve logistics and reduce travel times; to develop smart packing to preserve the freshness of products and the satisfaction of the final consumer; to extend the life of fruits; and to increase the resilience of plants to changing climatic conditions.

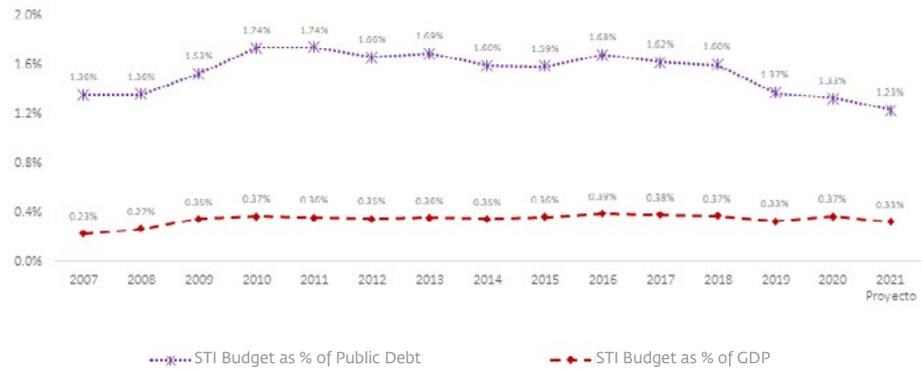
International collaboration, which can provide access to a broader pool of knowledge at lower costs, is still small but growing. Chile's International Centers of Excellence program launched by Corfo is a positive step in that direction, having attracted premier research institutions from around the world (such as Franhoufer and University of California, Davis) in a wide range of fields, including digital technologies, solar energy, biotechnology, genetic improvement and adaptation to climate change, and mining. Their future, however, appears uncertain.

Insufficient competition in some sectors might have discouraged innovation efforts, but greater competition without building firms' capabilities will not induce innovation. Cusolito, Garcia-Marin, and Maloney (2021) have shown that greater competition following trade liberalization only increased innovation in establishments close to the technology frontier ("the leaders"), highlighting the need for complementary innovation policies to reap the benefits of greater competition.²³ For most plants, higher competition depressed most measures of innovation.²⁴ These results point to the need to improve plant capabilities and managerial practices—which drive the leaders—as an important innovation policy complementing efforts to increase competition. Risk financing instruments, also important to support investments in intangibles and innovative entrepreneurship, are not adequately developed in Chile. The size of the venture capital industry barely reached US\$147 million in 2020²⁵, and most early-stage funds are publicly sponsored.

Policies and programs

The institutional framework supporting innovation has evolved over the past 15 years in pursuit of a long-term strategic vision and greater collaboration, but reforms have not always yielded the expected results. The effectiveness of previous national councils on innovation (high-level advisory bodies to the president) and inter-ministerial committees on innovation fluctuated with changes in leadership and administrations. Overall, consensus on a long-term vision for innovation was not attained, and coordination among ministries and agencies has needed to be enhanced. In addition, budgetary support did not change substantially over the past decade even though the innovation system is still young and capabilities within the private sector as well as research and technology institutions need to rise significantly (Balbontín, Roeschmann, and Zahler 2018). International experience shows that it will take time to develop such capabilities (Figure 3.20). Budgetary support for science, technology, and innovation (STI) by the central government as a percent of GDP rose from 0.23 percent in 2007 to 0.37 percent in 2011 and saw fluctuations after this, often responding to changes in the priorities of different administrations.

FIGURE 3.20 CHILE BUDGETARY EXPENDITURES ON STI (2007-2021)



Source: Zahler and Balbontin, 2020.

Note: STI = Science, Technology, and Innovation

Recent institutional changes have sought to further enhance collaboration and strategic policy directions, but it is premature to assess their overall effectiveness. In 2018, a new law was approved creating the National Council of Innovation for Science, Technology, Knowledge, and Innovation (STKI) for Development, the Ministry of STKI (MSTKI), and the Interministerial Committee on STKI. The National STKI Council is an autonomous body that seeks to advise the president and develop a long-term strategic vision on innovation. The new legal structure seeks to provide greater legitimacy to the council and to clarify further its roles and responsibilities, because the previous two councils were created by decree.²⁶ The role of the new MSTKI includes fostering science, technology, and technology-based innovations and coordinating the overall STI system through the Inter-ministerial Committee on STKI.²⁷ In collaboration with other ministries, the MSTKI issued a national policy on STKI in 2020 and an action plan for 2020–22 that seek to strengthen the STI ecosystem and institutional capabilities and to enhance linkages between science and technology and society. While these are positive steps, the aforementioned action plan did not have a corresponding medium-term budget, and budgetary support for STI has generally fallen as a percent of GDP and of the central government’s budget in recent years. Fostering innovation needs a long-term strategy with targets, which is still to be prepared.

Chile already offers a wide range of programs to support innovation. Corfo and the Agencia Nacional de Investigación y Desarrollo (ANID), reporting to two different ministries, are the primary but not the sole agencies implementing STI programs. That the programs are scattered underscores the importance of the Inter-ministerial Committee of STKI in fostering coordination and ensuring that the policy mix is holistic and consistent with long-term objectives.²⁸ Corfo (with budgetary transfers equivalent to 0.15 percent of GDP in 2020) focuses on innovation, entrepreneurship, and productive development, while ANID supports research, technological development, and science-based innovation. Together, these two agencies manage a wide range of STI instruments to foster advanced human capital formation, science-based research, R&D incentives, technological innovation and commercialization, and technology diffusion. Over the years, Corfo has been increasing its focus on innovative entrepreneurship, providing seed, start-up, and growth capital along with some funding for incubation. The programs—Centros de Desarrollo de Negocios and Centros de Extensionismo Tecnológico—by SERCOTEC and Corfo, respectively, also support the development of managerial capabilities, which are important not only for short-term productivity enhancements but also to induce the growth of business-led R&D.²⁹

R&D tax incentives remain one of the largest innovation programs under Corfo, but very few companies leverage them despite the 2012 reform aimed at making them more attractive. Incentives are equivalent to a tax credit for 35 percent of the investment (capped at US\$1 million per year) and an income tax deduction for the remaining expenditure. Benefits are overly concentrated on large firms, and research is largely conducted within the firms. In 2019, for example, 61 projects were approved for a total of US\$50 million, all of which were undertaken within the firms. Large firms obtained 85 percent of the projects and 94 percent of resources, and half of the total corresponds to one big paper company. A few examples of outside linkages have emerged, such as the Microsoft and Clean Technologies Centers.³⁰ Besides limited SME capabilities, factors that seem to constrain take-up of the R&D tax incentive include lack of knowledge of the program, administrative barriers, and, reportedly, concerns about audits by the tax authorities.³¹

Recommendations

The new institutional framework is still under consolidation, and a top priority will be to develop and build consensus around a long-term innovation strategy that provides more continuity to policymaking. Closing the gap on managerial, technological, and scientific skills; increasing cooperation among firms and between firms and universities; upgrading regional capacities while building international linkages all will be key to generate a fertile innovation ecosystem, and they need to be central to Chile's long-term innovation strategy. While Chile's regulatory environment has generally been conducive to innovation, stronger competition together with more robust firm capabilities could provide better foundations for innovation. The strategy will also need to consider the process of decentralization underway in Chile and the role that the regions will progressively assume in the design and implementation of innovation initiatives.

The strategy could be the compass for conducting a deeper review of the coherence of the current mix of innovation programs, their efficiency, and their effectiveness. Greater effectiveness of public policies will also entail stronger coordination among public institutions under the leadership of the new Inter-ministerial Committee of STKI. While the process for designing, monitoring, and evaluating policy instruments has improved over time within the major STI agencies, there are opportunities for further strengthening using logic models more systematically and explicitly to present how interventions will achieve results; enhancing post-program beneficiary data collection; and designing impact evaluations ex ante (rather than ex post) to better measure program effectiveness. As the budget of some programs remains small, integration, rationalization, or scaling up of instruments could be considered after revising the instruments' impact. Nearly a decade after the R&D tax incentive reform was approved, it is an opportune time to examine the instrument's additionality and the scope for reaching a broader set of firms and creating greater linkages within the innovation system. Besides direct transfers and tax incentives, regulatory standards and public procurement could be better leveraged as instruments to foster innovation as implemented in other OECD countries. These instruments have been overlooked and underutilized to date.

3.5 EDUCATION AND SKILLS FOR AN INCLUSIVE AND INNOVATIVE ECONOMY

Overview of Higher Education

Higher education in Chile has benefited from a steady evolution in governance, quality assurance, and funding schemes during the 1990s and early 2000s that placed the country in a leading regional position in terms of education quality. A demand-based student aid funding mechanism, now moving to a tuition-free model, has allowed for significant inclusion of previously excluded segments of the population. As access has expanded, a new set of reforms to consolidate quality has been put in place. This section evaluates some of the remaining challenges facing tertiary education and technical and vocational education and training (TVET), particularly regarding the provision of high-quality, labor-market-relevant higher education. The objective is to arrive at a more efficient and equitable system that supports Chile's need to match acquired skills to labor market demands and to jump-start innovation in support of productivity.

The private sector has played an important role in the expansion of higher education, which continues to be a profitable investment for Chileans. Policies such as student loans and scholarships have facilitated access to private higher education institutions (Ferreira et al. 2017; OECD 2018d). Higher education programs and institutions, especially private ones, have proliferated; today, 85 percent of students in Chile are enrolled at private institutions (Delisle and Bernasconi 2018). And although tuition costs in Chile are high in comparison to OECD countries overall and in relation to average income, higher education is still a profitable investment. In 2017, people ages 25 to 64 years old with a tertiary degree and with income from full-time, full-year employment earned 141 percent more than full-time, full-year workers of that age group with only upper-secondary education; this compares with a 54 percent premium on average across OECD countries (OECD 2020e).

However, for a substantial portion of students—close to 10 percent—returns to education are negative. They may fail to graduate and become saddled with debt. Another segment, although successfully graduated, does not attain gainful employment. This is particularly true for those enrolled in the fields of education or the humanities (Ferreira et al. 2017) (Box 3.1). Still others, even if they do graduate and receive higher incomes, do not join the ranks of the elite—which was the culturally driven expectation—leaving many graduates disappointed with higher education. Higher education has thus become a flashpoint for Chileans dissatisfied with equality of access to economic opportunity in the country. An implicit social contract, whereby a tertiary or technical-professional degree would open doors to higher-quality jobs and rising incomes, is perceived by many to have been broken. Indeed, tuition in Chile is among the highest in the world, about US\$7,600 (purchasing power parity) on average at public universities and is equivalent to approximately half of median family income, although government grant and scholarship aid can significantly reduce the net price that students pay. Only American private universities and British universities have higher prices relative to per capita income (Delisle and Bernasconi 2018). Students from different backgrounds and income groups continue to have unequal access to quality tertiary education.

The perception of a crisis in Chilean higher education has led to a series of reforms over the past two decades that have targeted a stronger regulatory role for the state. Trust in higher education had been eroded by high levels of debt from state-guaranteed loans (CAE), a corruption scandal at the National Accreditation Commission (CNA), and the failure of a number of higher education institutions.³² These events gave rise to a student movement demanding that higher education be considered a social right, resulting in a new law for higher education in 2018 and the establishment of the free tuition policy.³³ Earlier reforms were also implemented to create quality assurance bodies and the CNA.³⁴

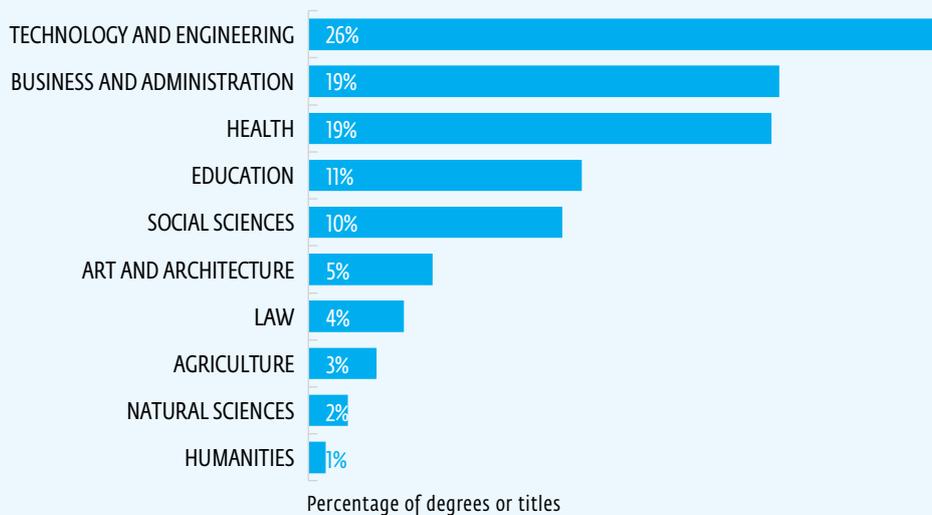
More recent and ongoing reforms are moving toward greater regulation of higher education, transforming the system's governance, quality assurance, funding, and admissions. The changes include an overall strengthening of the regulatory capabilities of the government and other autonomous public bodies and increased control over admission and funding schemes.³⁵ While accreditation has been voluntary since 2007—incentivized by access to student funding—higher education institutions (both universities and TVET institutions) will now be subject to mandatory accreditation under stricter quality assurance standards. Institutions must fulfill standards not only in teaching and management, but also in outreach and research (even for TVET institutions). It remains to be seen where the balance between greater regulatory control and flexibility will fall.

BOX 3.1 FIELD OF STUDY AND EMPLOYABILITY

Employability and expected income vary widely by type of institution, area of study, and type of program. University graduates in the humanities and education tend to have lower expected income at the fifth year after graduation, while technology and health (including mining, engineering, and medicine) show higher expected returns. The highest-paid graduates are medical doctors, mining engineers, and industrial engineers, all of whom graduated from universities and who earn on average roughly US\$2,500 in their first year on the market (SIES 2021). At the technology and vocational training and education level, graduates

tend to have lower expected outcomes, with more homogenous income levels across fields of study. This holds for graduates from both professional institutes and from vocational training centers. The latter concentrate their graduates in the areas of education, law, social sciences, and agriculture, all programs with the lowest range of expected returns. Of the 240,000 graduates each year, 26 percent have degrees or titles in business and administration and 22 percent in engineering and technology. A little over 11 percent graduate with a social science major (figure B3.1.1).

FIGURE 3.1.1 TECHNOLOGY AND ENGINEERING ARE THE MOST POPULAR PROGRAMS

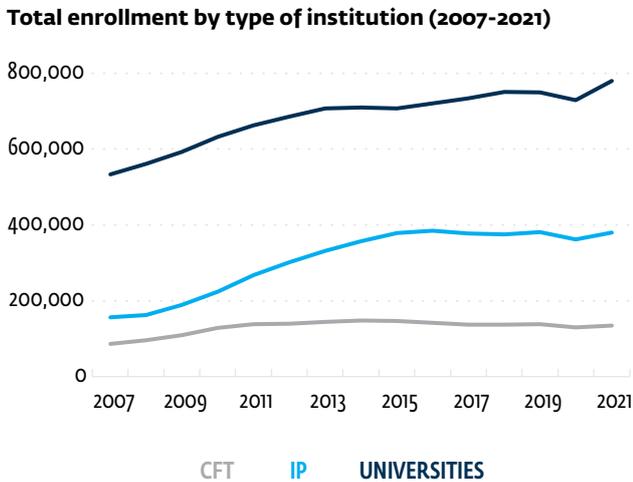


Source: SIES 2021

Chile's free tuition policy, known as *gratuidad*, may be generating rigidities for education providers—especially private ones—and leading to a more segmented higher education system rather than providing the intended equal opportunity regardless of income. The state today exerts significant control on enrollment and budgets through its free tuition policy. Demand-based funding mechanisms are still predominant but a shift toward a free tuition policy and an eventual change in student loan schemes is underway. Free tuition consists of transfers to an eligible educational institution to cover the cost of providing tuition for students receiving financial assistance. The government also regulates the growth in the number of students receiving the free tuition benefit at every institution. The program now represents roughly half of all student aid granted by the government, and together with scholarships and loans benefits two-thirds of higher education students (over 760,000 students). *Gratuidad* is mandatory for all public universities, and private universities can join voluntarily. The system is structured so that the government allocates funding to universities that participate in the program and whose tuition levels are limited under the program. In the case of many private universities, however, these remittances are not sufficient to cover their costs. Low-ability students, especially those from low-income backgrounds, are thus relegated to poorer-quality private institutions, while the wealthy have access to expensive, selective private and public institutions. As argued below, *gratuidad* may also exacerbate the challenge of raising quality in higher education. Reforms have also given the Ministry of Education control of the centralized admissions process—which now includes the TVET sector, which had traditionally not been selective—previously administered by the Council of Rectors of Chilean Universities.

As in the case of university education, TVET is characterized by broad coverage and a wide dispersion in the quality of institutions and programs. A large proportion³⁶ of students in higher education attend technical-professional institutions (*institutos profesionales*, or IPs, and *centros de formación técnica*, or CFTs) and receive formal technical degrees or diplomas (Figure 3.21). Unlike the situation in the majority of peers in Latin American and the Caribbean, most of these institutions are private, for profit, and are financed through state vouchers, although as the free tuition policy applies only to nonprofit institutions, many have moved toward non-profit status.³⁷ The formal TVET system suffers from problems typical of systems in other countries: poor connections between the programs offered at the secondary and tertiary levels, as well as between tertiary TVET and academic university programs. Students can, in theory, pass from one program to another, although few do in practice. As in the case of university education, TVET is characterized by broad coverage and quality shortcomings, with low participation of the business sector, although the latter constraint is beginning to be addressed by pilot qualifications frameworks being designed jointly with the private sector.

FIGURE 3.21 HIGHER EDUCATION STUDENTS ARE DIVIDED ACROSS THREE FORMAL TYPES OF INSTITUTIONS

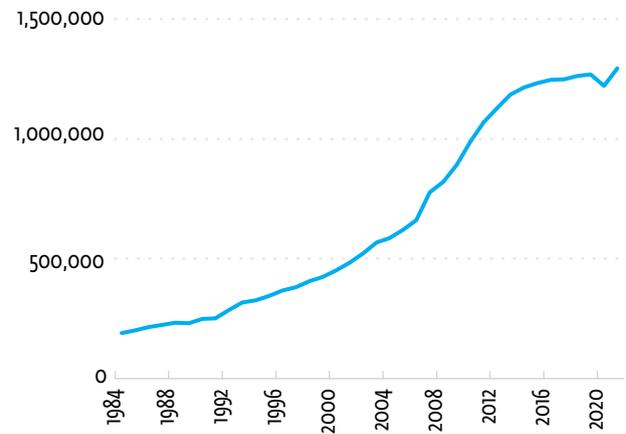


Source: SIES 2021.

Note: TVET = technical and vocational education and training; CFT= Vocational Training Centers (2-Year TVET); IP=Professional Institutes (4-Year TVET)

FIGURE 3.22 ACCESS TO HIGHER EDUCATION HAS EXPANDED RAPIDLY

Total Higher Education Enrollment (1984-2021)



Source: SIES 2021.

Many of the best TVET institutions, however, are nimble and responsive to market signals in developing and structuring the programs and degrees that they offer, often more so than typical university degree programs. A historically low participation of the business sector in defining these programs is being addressed by the design of pilot qualifications frameworks jointly with the private sector. On average, indications are that these formal TVET programs work relative to alternatives or to a high school diploma, although public information on returns is scarce. The wide dispersion in quality has led to some stigma associated with TVET programs—although this is changing gradually—and that may be affecting demand, both from students and from the job market. This dispersion is partly due to regulation of formal programs having been largely financial rather than outcomes based. To address access and quality issues, the government in January 2018 passed a wide-ranging higher education and TVET reform, signaling a shift in policy focus toward the sector, which has been a historically neglected segment of higher education.³⁸ Quality requirements for TVET institutions have been raised, and institutions now need to fulfill outreach and innovation standards.

An important policy question is how to harness the power of the high-performing TVET programs—particularly short-cycle programs—to help meet the need to upskill workers for the rapidly evolving demands of the labor market, including increasing digitalization. Because many TVET students come from relatively lower income groups, recourse to debt may not be a sustainable alternative. Other sources of financing, including public financing, are needed. In Europe, massive funding for short-cycle programs comes from employers. For this to be replicated in Chile, a prerequisite would be closer collaboration with the business sector in the design and perhaps in the delivery of programs, including the participation of the private sector in supporting the incorporation of digital education in traditional tertiary institutions.

A Rapidly Evolving Landscape

The rapid growth of access to higher education has transformed the profile of students, challenging the higher education system to find the flexibility and market relevance that these new types of students need. The 1981 reform that allowed the creation of private universities and TVET institutions led to the expansion of enrollment from 120,000 to 250,000 in 1990, and to 1.1 million today (Figure 3.22). This expansion has opened access to higher education for groups that were previously excluded. Today, roughly 60 percent of students in higher education are part of the first generation to access universities or TVET institutions. Many come with significant educational deficiencies from high school and primary school. Some are entering higher education for the first time many years after leaving high school: they are older and already working, many are women, some have families and pay for themselves, they are more likely to live in remote locations, and most face greater responsibilities and time constraints. The system also receives more migrant students. These students require a tertiary education system that is sufficiently flexible and relevant to cater to their needs. While traditional students demanded higher levels of academic qualifications (masters and doctoral programs³⁹), nontraditional students have generated the need for a diversification of undergraduate and TVET programs.

While there is broad consensus regarding the importance of flexibility and meeting new emerging needs, this is not yet reflected in policy priorities. Digital disruption, for instance, has already reached the job markets, but not necessarily education and training. Technological change is transforming labor markets faster than the educational system is training people—this gap, if not addressed, will perpetuate inequality and exclusion for significant segments of the population. Efforts to advance policy in these areas—such as the Transferable Academic Credit System, which has been in place since 2003—have not been able to move the needle or to meet expectations.

Funding schemes tend to be rigid. Virtually all student aid targets the traditional segment of 18- to 24-year-old students enrolling in accredited full-time higher education programs directly from high school. There is little recognition that nontraditional students—a key growth segment in the market—require flexible alternatives and, frequently, more financial aid. Limited funding is available for part-time students, distance learners, or those wanting to pursue a second degree. Gratuidad requires students to complete their courses of study on time. For instance, a traditional two-year degree must be completed in that time. Yet students in Chile take 10–30 percent longer than the prescribed time, on average, to finish their degrees. Tens of thousands of students who had been enjoying free tuition come to the end of their eligibility before graduation.

The current structure of academic degrees and professional titles is narrow and designed without full consideration of the growing needs for life-long learning. The structure tends to generate roadblocks and dead ends for students starting in lower TVET levels and defines qualifications by hours of training rather than by the skills developed. Educational credentials continue to play a stronger role than actual skills, generating a mismatch between workers' skills and the skill requirements of their jobs (see next section).⁴⁰ The current structure also contributes to unfair market competition, as only universities have the advantage of providing all available degrees and titles. Quality assurance mechanisms, in some cases, deter innovation, tending to prevent the diversification of modes of education provision and the granting of new credentials.

Nevertheless, some higher education institutions are innovating to improve flexibility and linkages within the system, as a response to diversifying student needs and labor market requirements. A recent study by CNED (2021) noted that flexible learning initiatives are being developed in various types of institutions, which are innovating in alternative access mechanisms—evening courses, flexible programs, and distance learning or blended alternatives—recognition of prior learning, transfer opportunities, continuing education options, and better links between training and jobs. Higher education institutions have also responded to the rapidly growing demand for life-long learning—enrollment in continuing education has tripled since 2007—with a broad array of programs. Yet continuing education still lacks legal definition or a clear place and role in educational trajectories.⁴¹ Some of these innovating institutions have recently obtained accreditation. The new criteria and standards of accreditation that the CNA will approve in the coming months will set the stage in terms of the ability of institutions to innovate

Higher education in Chile has the opportunity to increase its focus on promoting greater inclusion, flexibility, and curricular innovation and to increase its relevance by decisively engaging the private sector in shaping its offerings. Bolder public-private partnership initiatives and more fluid ways to obtain and update qualifications will be crucial to prepare Chilean higher education for the challenges of the future and to prevent a widening of the skills gap. A move toward a more flexible regulatory framework, a renewed credential structure, and quality assurance mechanisms that encourage innovation toward flexible learning pathways are needed. An overarching national qualification framework and transferable academic credit systems are among the tools the system needs to be more flexible and comprehensive. Higher education also needs to strengthen its incipient coordination with the productive sector, continuing to learn from successful initiatives—some led by the mining sector—and jointly implemented between the public and private sectors, to tackle the skill gap.

Skills and workplace training

A skilled workforce is important for innovation and technology adoption, and while Chile has made significant progress in education coverage and in quality, the skill levels among the population remain relatively low. A 2018 review of workplace training in Chile conducted by the National Commission of Productivity (CNP 2018) concluded that there is no functional system for competencies in place in Chile. The assessment notes that the fragmented set of public institutions involved in workplace training are unable to anticipate the skills required by the labor market. Another 2020 study (Accenture 2020) concluded that the current education and corporate training systems are not equipped to face the impending revolution in demand for digital skills. Long-lasting effects of the COVID-19 pandemic in education are also projected, posing specific challenges to closing the skills gap. Widespread shortcomings in skills undermine the capacity of Chilean firms to innovate and thus reduce the productivity of the economy.

According to the OECD's 2018 Survey of Adult Skills (PIAAC), a significant gap exists in Chile between acquired skills and those in demand in the labor market. The share of adults who achieve high levels of proficiency in literacy, numeracy, and problem solving in technology-rich environments is relatively low. Only 1.6 percent of adults reach the highest levels of proficiency in reading comprehension, compared with 10.6 percent on average in participating OECD countries. About 62 percent of adults have difficulty

performing more than basic mathematical operations like counting and sorting. Most also fare relatively poorly in problem solving in technology-rich environments. This poor performance applies at all skill levels, and differences among sociodemographic groups, notably between men and women, are sharp (OECD 2019). And while internet penetration is high, at over 80 percent, a significant portion of the population lacks basic digital skills.

Surveys, although partial, point to employers' difficulties in finding the skilled workers they need (ENADEL 2019; MINECON 2019). A majority of firms surveyed, across most sectors (including 60 percent of manufacturing firms and 65 percent in construction), reported difficulties in filling open positions, with the top reason cited being a lack of technical skills, but also a lack of work experience and limited socioemotional skills. Larger companies express having greater difficulties in hiring staff than smaller firms. Other efforts to assess the skills gap have been conducted by the mining sector, which concluded that technical training is deficient and weakly linked to the sector's requirements.

Assessments of Chile's nonformal, publicly funded training programs⁴² have concluded that these are ineffective in skilling workers for jobs and are poorly targeted at those who need them most. Spending on workplace training reached 0.2 percent of GDP in 2016 (US\$570 million)—mostly channeled through the national training and employment service institution (SENCE)—and is spread across programs for supporting basic labor skills, workforce reinsertion for vulnerable populations, continuing education for upskilling or reskilling, and training in entrepreneurial competencies for small business owners. Duplication is not uncommon, most programs are purely theoretical, cost per hour varies greatly, success is measured by hours of training rather than by learning outcomes, and there is no certification of competencies. Assessments have shown that SENCE's largest program, which grants tax credits for on-the-job training, mostly benefits large firms, which tend to have less vulnerable, better educated workers; they do not reach the self-employed, who account for a large share of job creation.⁴³ Information is often absent on the type of skills demanded by the market as well as on the variety and quality of the courses offered by providers. Although efforts are being made to increase SENCE's technical capability and the relevance of its courses, there is no formal mechanism to evaluate its programs, and it is difficult for users to assess the quality of the courses (OECD 2018e).

Skills to prepare workers for a green and circular economy, sustainability, climate change, and a technology-rich marketplace will become a predominant need in the near future. That need, along with the economic impact of the COVID-19 crisis, the dramatic increase in unemployment, and the push for reskilling because of the increased use of digital platforms for work, makes it urgent for Chile to assess the severity and potential negative impact of the widening skills gap that will affect large portions of the workforce in the post-pandemic era. Opportunities are available for quality assurance, funding mechanisms, and governance structure to promote flexibility and curricular innovation. Fit-for-purpose education requires not only rapid adoption, but also flexible learning pathways and study-work fluidity. Chile has the opportunity to focus more determinedly on flexibility and life-long learning in order to narrow its skills gap. Boosting innovation and coordination between the academic and government sector on the one hand and the private sector on the other hand is critical for success.

Recommendations

The opportunity provided by the discussion of new criteria and standards of accreditation should be seized to move toward a consensus for a flexible approach to quality that involves private sector stakeholders. Finalizing the definition of new criteria and accreditation standards for higher education is urgent because it is an essential element to determining the financing of institutions of higher education and students. Standards could focus on the need to measure relevant results such as skills attainment or employability, rather than on infrastructure or time spent in a program. Ensuring that the new criteria and standards of accreditation are flexible enough to allow for institutional diversity is important, because stricter mandatory accreditation can deter innovation and threaten flexibility, which are essential to prepare learners for changing scenarios and skill needs.

More flexibility in the financing of higher education institutions can be considered. State control of student fees and their growth via the gratuidad system have led to a weakening of the financial position and a significant reduction in revenues for higher education institutions, particularly—though not exclusively—private ones. A financing system based on institutional performance may be more appropriate, using indicators related to the quality of graduates, research, and employability, among others. More flexible rules for financing students are also needed, including financing for continuing education, modular programs, part-time study, and other programs.

To support student success and greater equity in access to higher education, curricula need to be more attuned to the needs of students, particularly nontraditional students. Curricula need to become more flexible, with a menu of delivery modes, more modular courses, and easier recognition of a range of titles and degrees. To reduce the gap between skills obtained and skills demanded by the labor market, information on labor demand should be made more consistent and comprehensive. Financing for education needs to cater to the needs of nontraditional students, including those pursuing continuing education, modular, or online programs.

Higher education programs must be more market relevant. This relevance can be achieved through encouraging flexible training programs with multiple entry and exit between different types of institutions (universities, Ips, and CFTs) and the labor market, and a greater recognition of knowledge and competencies acquired previously. Developing a comprehensive qualifications framework is also essential, although today it is limited to TVET. This gap makes it difficult to link TVET qualifications with high schools and universities.

There is a need to harness the power of high-performing TVET programs, especially short-cycle ones, to upskill and re-skill workers and to bridge the skills gap. Innovative financing solutions, both public and private (from employers) need to be structured to avoid the trap of increasing student debt. Closing down the worst-performing institutions would help reduce the stigma associated with TVET. Access to data on program returns would help with transparency and would inform students on programs most likely to meet job market demands. And as with the rest of the higher education system, providing intermediate credentials (such as certificates for partial completion and modularity within programs) would meet the needs of the growing number of nontraditional students.

3.6 UPDATING LABOR REGULATIONS AND REDUCING SEGMENTATION

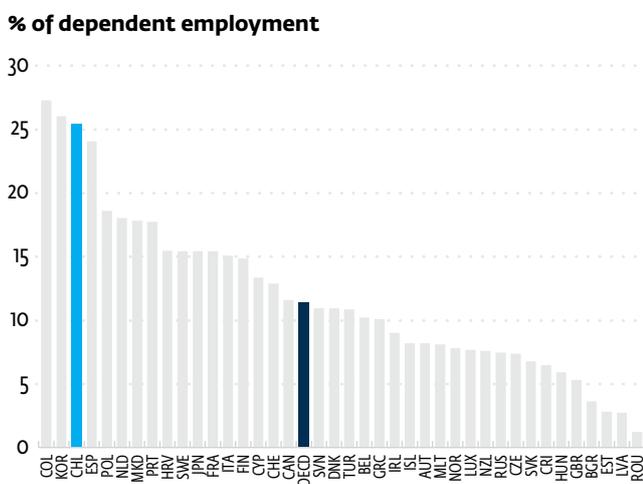
Chile's labor market presents characteristics that are a source of inequality and a constraint to productivity. This section will focus on four key aspects: female labor force participation, fixed-term contracts, informality, and telework. These are areas in which Chile lags the OECD average and that have an impact on inequality and productivity. Furthermore, these areas have been profoundly affected by the COVID-19 pandemic, deepening preexisting inequalities. Addressing segmentation will not only reduce inequality but will also increase productivity, thus making for a better private sector.

Despite some improvements over the past decade, differences between the labor participation rates of women and men remain significant. Female labor force participation increased by 6 percentage points from 2010 to 2019. However, differences between female and male labor force participation are still large. In 2020, 45.2 percent of women of working age participated in the labor market, compared with 67.2 percent of working-age men. This compares with 51.7 percent and 68 percent, respectively, in OECD countries. Unemployment among women has also been historically higher than among men. The gap between female and male unemployment is reflected in differences in the probability of finding a job and of staying employed. Indeed, at least one study (BCCh 2018) found that unemployed women have a lower probability of moving toward employment⁴⁴ than men have (33 percent versus 55 percent, respectively). Furthermore, once employed, women have a lower probability of remaining employed than men have (81 percent and 91 percent, respectively) and a greater probability of transitioning to inactivity (16 percent versus 5 percent, respectively).

The impact of COVID-19 was felt more strongly by women than by men, with potential long-term effects. The destruction of jobs held by women during the 2020 health crisis was almost double that of men.⁴⁵ This is because the pandemic had a particularly severe impact on the services sectors where female work is more concentrated, and because the decline in the labor force participation was also more pronounced for women than for men. Indeed, female labor force participation fell from 53 percent to 45 percent between 2019 and 2020, reversing more than a decade's worth of growth. The fall in women's labor force participation is largely explained by the greater likelihood that women will leave work to care for children as schools and daycare facilities closed owing to health restrictions; women are also the primary caretakers for elderly or disabled family members. Before the pandemic, surveys showed that while 96 percent of mothers stated that they take care of their children frequently, only 63 percent of men do.⁴⁶ The pandemic has exacerbated this gap with potential long-term impacts if the temporary separation leads to a more permanent disconnection of women from the labor market.

Differences in contract types have contributed to labor market segmentation. In Chile, 25 percent of private sector salaried workers are on temporary contracts.⁴⁷ Chile has the third-highest proportion of temporary contracts in the OECD after Colombia and Republic of Korea (Figure 3.23). Legislation provides little security to workers under temporary contracts, who are not entitled to severance pay. Chile's labor market is characterized by high labor rotation, low average duration in a job (41 months), and rapid transitions between jobs compared with the OECD median.⁴⁸

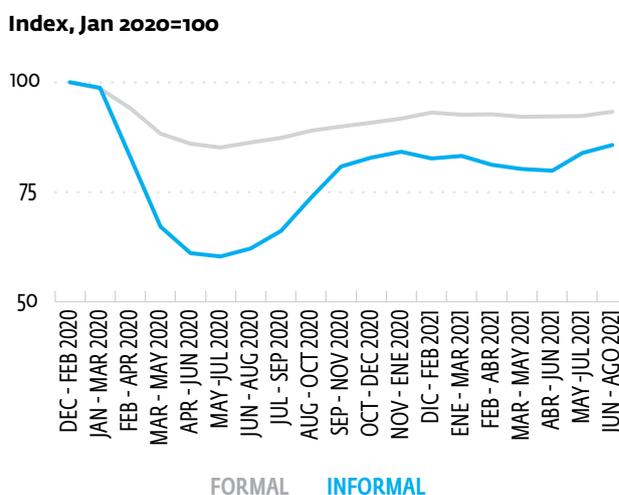
FIGURE 3.23 TEMPORARY EMPLOYMENT, 2020 OR LATEST AVAILABLE



Source: OECD.

Note: OECD’s definition of temporary employment includes wage and salary workers whose job has a predetermined termination date. OECD = Organisation for Economic Co-operation and Development.

FIGURE 3.24 FORMAL AND INFORMAL EMPLOYMENT, LATE 2019–MID 2021



Source: INE.

Note: data correspond to moving quarters.

Informal jobs lack social benefits and are associated with lower levels of income for workers and with lower productivity. Informality⁴⁹ had declined significantly since 2010 in Chile, falling from 40 percent to 28 percent, although in the past three years the improvement stagnated. While the informality rate in Chile is below that of Latin American and Caribbean peers, except for Uruguay, it is higher than the OECD average of 12 percent. During the COVID-19 pandemic, and in contrast to previous cycles, job losses were larger in the informal than in the formal sector (Figure 3.24), likely because of mobility restrictions. Women have a strong presence in informal sectors that were hurt by the pandemic, such as domestic workers. In addition, Barrero, Fuentes, and Mena (2018) show that informal workers, besides being less educated on average, earn lower wages than those in the formal sector, controlling for their education. Formal workers also remain in their jobs twice as long as informal workers (BCCh 2018). In turn, informality can imply a deterioration in the quality and productivity of a job, with long-term costs that include reducing aggregate productivity.

Telework was crucial during the COVID-19 pandemic, allowing for more flexibility and may have had a positive impact on productivity. During COVID-19, teleworking helped mitigate the impact of social distancing measures on the operation of firms and on employment. During the lockdown months of 2020, 27 percent of workers were teleworking in Chile,⁵⁰ particularly in some sectors such as education, information and communications, financial activities, and insurance. Over the longer term, promoting telework could provide greater flexibility in working hours. This flexibility is an advantage given that Chile has the sixth-longest working hours among countries in the OECD,⁵¹ to which commuting time must be added. Greater flexibility in working hours can be an opportunity to increase the participation of women in the labor force. In fact, a higher proportion of women telework compared with men: 32 percent of employed

women and 23 percent of employed men. In addition, telework is usually associated with result-driven methods, which have been found to increase employee's productivity (Rubio 2010). Other studies argue that, under normal circumstances and for specific occupations, productivity increases because employees who telework dedicate more time to work (Bloom et.al. 2013). Finally, it has been found that companies with a larger number of employees who telework show higher levels of innovation and better financial performance (Allen, Golden, and Shockley 2015).

However, gaps in access to infrastructure and digital skills limit the potential adoption and impact of telework. The “skills gap” section of this CPSD (section 3.5) addresses digital competencies in Chile. A study by Observatorio Laboral de la Region Metropolitana, SENCE, Centro de Políticas Públicas UC, and OTIC SOFOFA (OLM 2021) estimated that employees who can telework have more education (15 years versus 11 years, on average) and receive, on average, double the income. The same study estimates that the probability of being employed in an occupation in which teleworking is feasible is five times higher for those who have completed professional studies compared to people who have a high school education. The results also show that, compared to employees from the bottom quintile of the income distribution, the probability of teleworking is higher for employees from the rest of the quintiles, with those in the top quintile having 2.72 times greater probability of teleworking than employees in the bottom quintile in the Metropolitan Region of Santiago. Furthermore, employees with a written and an open-ended contract are also more likely to telework than those who are informal or on a fixed-term contract. Finally, it is worth noting that while internet penetration in Chile is high, as shown in the digital economy section (section 4.3), there are significant heterogeneities within the country among regions and also between rural and urban locations.

Challenges

The main barriers to female labor force participation are the lack of access to affordable childcare and eldercare, cultural norms, and rigid regulations regarding working hours. Having cheaper or easier access to childcare (and eldercare) increases female labor force participation.⁵² Cultural norms also explain low female labor force participation in Chile despite relatively high education levels (Contreras, Puentes, and Sanhueza 2007). Survey data for Chile⁵³ shows that 32 percent of women out of the labor force mention housework as the main cause of inactivity, against 1.6 percent among men. Besides childcare, women also care for other dependent persons: 46 percent of people over 60 years old with functional dependency rely on a caregiver who lives in the same home, most of whom are women (OLM 2021).⁵⁴ Part-time work could be a tool to increase female labor force participation. However, there are some constraints that prevent it from being more widely accessible. The cost of hiring a part-time worker for Chilean firms is proportionally higher than that of hiring a full-time worker in terms of both fixed and variable costs, affecting demand for this type of employee. For the worker, it also represents higher costs relative to salary—for example, regarding transportation—affecting the supply for this type of job. Finally, part-time work is characterized by high levels of informality and instability, and by more precarious working conditions (Rau 2008).

Women’s access to childcare is constrained by COVID-19 in the short term and, more structurally, by regulation. In Chile there are 4,468 kindergartens that receive state funding⁵⁵ and that support lower-income families with small children. Many of these institutions remain closed due to COVID-19. Reopening them requires that the institutions have sufficient personnel and supplies as well as adequate infrastructure to comply with COVID-19 protocols and operate safely. Longer term, access to nursery schools and kindergartens is a benefit that is guaranteed for women in the bottom 60 percent of the most vulnerable population.⁵⁶ In addition, the Ley de Salas Cuna obligates firms that hire 20 females or more to provide childcare until the child is two years of age. Firms can create and maintain childcare centers annexed to the workplace, share childcare facilities with other establishments, or pay directly to external day care centers. A shortcoming of the policy is that only 14.6 percent of firms have 20 or more women workers (ENCLA 2019), so the law excludes a large proportion of women. In addition, studies have found that because this policy increases the cost for companies of hiring women, it drives some firms to stop hiring once they are close to the threshold (Escobar Salcedo, Lafortune, and Tessada 2016).

The government has introduced financial incentives to help female labor force participation, but their impact has been limited. The women’s work benefit (Bono al Trabajo de la Mujer) is a program that consists of a cash incentive for working women in vulnerable households. It is paid to those who keep their pension and health contributions up to date, and the amount varies according to salary.⁵⁷ Two-thirds of the amount of the subsidy is received by the employee for four years and one-third by the employer for two years. In 2020, amid the pandemic, the government announced that the beneficiary group will be widened from 40 percent to 60 percent of vulnerable women. Studies that evaluated the impact of the program found that it was underused by the targeted population (Centro de Políticas Públicas UC 2020). The reasons cited were lack of information about the subsidy and its requirements, and high paperwork costs. It was also found that demand has been higher among workers than companies, thus the policy is more successful in stimulating labor supply of low-income workers than in generating new jobs.

Chile’s dynamic labor market provides flexibility to adapt to cycles, but the high proportion of temporary jobs reduces job quality, human capital accumulation, and productivity. Chile ranks near the middle in flexibility indexes compared with European Union (EU) and OECD countries (LFMI 2020). Aspects of labor market flexibility include low unionization rates and decentralized and fragmented bargaining. Indeed, Chile stands out relative to other countries by virtue of the small percentage of workers who are covered by collective bargaining agreements. Fixed-term contracts are flexible in nature. The job turnover rate in Chile is high in international comparisons,⁵⁸ and rapid employment reallocation is important for an economy to adjust to cycles (Albagli et al. 2017). However, fixed-term contracts are often used to circumvent labor legislation. Workers on fixed-term contracts lose out on many work benefits, as they usually receive less training, have less job security, and do not have provisions such as childcare access. Workers who rotate more have a higher probability of losing their job, a lower probability of finding new ones, and lower income levels (Ruiz-Tagle and Sehnbrunch 2015). This reflects, for example, the reduced development of specific human capital with an employer. It reduces incentives for specialization and accumulation of human capital. In turn, the high proportion of temporary jobs impairs both innovation efforts and overall firm productivity.

The rapid expansion of the gig economy in Chile intensified during the COVID-19 pandemic, highlighting the need to regulate this industry and provide social protection for its workers. As stated in the “digital economy” section of this CPSD (section 4.3), the growth of this type of nonstandard job, working via a technology platform, has accelerated during the COVID-19 pandemic. More than 300,000 people provide a variety of services through platforms, including transport, food delivery, and purchases of all kinds of goods (Comision de Trabajo y Prevision Social 2013). Services through digital platforms have allowed more people to enter the labor force, while providing flexibility to the worker. However, workers under this modality are left out of the traditional social protection systems. In this sense, the gig economy presents trade-offs similar to those of informal or fixed-term workers. Chilean legislation does not currently regulate this modality of work, although there are three legal initiatives in Congress to address it. The objective is to improve the working conditions of people performing these services by formally recognizing their classification as workers or by providing minimum guarantees such as access to health coverage, pensions, and compensation for workplace accidents. The executive branch supports the proposal sent to Congress in May 2020⁵⁹ to regulate the contracts of digital platforms workers by creating a new chapter in the Labor Code to include them as workers while allowing them to decide if they will be dependent or independent. Advancing this legislation will be a step forward in the regulation of these working arrangements to protect workers, although enforcement will be challenging. The gig economy is a dynamic and rapidly changing market, with recurrent entrance and exit of new actors through new platforms and services. Keeping up with the evolution of this market will require constant efforts and innovative approaches, but a policy will be important to extend social and labor protections to these workers and reduce labor inequalities.

Recommendations

Access to childcare could be enhanced to support female employment. The government has sent a bill to guarantee the universal right to a nursery care for all the children of working parents, but the bill has not been able to pass Congress. Alternatively, the requirement that firms must provide childcare when they exceed a minimum number of female employees could be modified to apply to a minimum number of employees independently of their gender, to discourage discrimination when hiring workers. Escobar Salcedo et al. (2020) propose that forcing all firms, not only those with more than 19 women, to provide for childcare would have substantial welfare benefits, suggesting that the size-dependence of the policy is largely generating the negative outcomes observed.

Reinforcing support for the care of elderly and dependent people could contribute to the reincorporation of women into the workplace. Strengthening the program Sistema Nacional de Apoyos y Cuidados could help women return to the labor force, although doing so might carry additional fiscal costs. The program—which benefits the most vulnerable 60 percent of the population that has declared a moderate or severe dependency, according to the Household Social Registry—provides specialized services to facilitate care, such as therapy and home care, to reduce the burden on the caregivers. However, the program excludes part of the population that has not requested inclusion, largely because of lack of information about the program. Outreach to the potential beneficiaries would increase coverage (SUBSIDES 2017). Subsidies for caregivers of people with disabilities and elderly people also help women return to the labor force. In the end, the decision regarding whether a woman will join the labor force is a family calculation of costs and returns.

The government could improve the design of the Bono al Trabajo de la Mujer. To improve its impact, the subsidy could be distributed more evenly between workers and employers in terms of amount and duration. Its amount could also be increased, or requirements streamlined, so that companies are encouraged to hire women and collect the subsidy. Increasing the maximum age for eligibility from 59 to 65 years could also incentivize the hiring of older women (Huneus and Repetto 2013).

Promoting more flexible working arrangements, such as telework and part-time work, as well as training can help women return to the labor force. Qualitative analysis of reform experiences from France, Germany, and Portugal show that labor flexibility could raise workers' well-being and optimize productive resources. The development of telework, in all occupations where possible, can facilitate balancing work with family responsibilities. Part-time work also can be made more accessible by correcting the asymmetry in the labor costs of hiring a part-time or full-time worker. An example of such reform would be to modify article 203 of the Labor Code that requires firms with 20 or more female workers to provide childcare and apply it to firms independent of the number of women hired, or at least reduce the weight of part-time workers in the calculation of the 20 female employees to be proportional to the workday. Subsidizing public transportation for part-time workers—although implying higher fiscal costs—and making labor hours more flexible also could help promote part-time work (Rau 2008). Finally, training programs have proved effective in improving access to formal employment among women (Attanasio, Kugler, and Meghir 2011). Programs could benefit from including microentrepreneurs to inform them about the formalization of their businesses or from adapting current programs to improve the incorporation of women to the labor market, which has been reshaped by the COVID-19 crisis (OLM 2021). SENCE for example is currently running the program Digital Talent, which provides training in STEM subjects, and “Mujer Digital 2021.” These initiatives could help women increase and diversify their opportunities to participate in the labor market and telework if they are well designed, which is assessed in the “skills gap” section, 3.5.

Disincentivizing the repeated use of short-term contracts could reduce labor market segmentation and improve job quality. On the supply side, enhancing unemployment insurance provisions could help support workers while they seek higher-quality jobs. This assistance would also facilitate a better matching of workers and jobs. While many affiliates need only access to the funds in their unemployment savings accounts to sustain their job search and find work, a significant number exhaust their savings and require support from the solidarity fund. The government has increased the amount of the unemployment insurance and made requirements more flexible for the duration of the COVID-19 crisis, but these actions will need to be reviewed depending on the evolution of the labor market recovery. In addition, the government could strengthen active job-search assistance. Bolsa Nacional de Empleo, an electronic job registry platform, is a useful government tool to allow workers to search online for work in the public and private sector. On the demand side, a policy to disincentivize the abuse of short-term contracts would be to enforce the regulation that limits the practice of *multirut*,⁶⁰ which allows firms to exceed the limits of temporary contracts. Finally, Ruiz-Tagle and Sehnbruch (2015) propose alternative policies that could be considered to discourage the abuse of fixed-term contracts. One option is charging employers a higher rate of contribution to the unemployment insurance system at the beginning of any new employment relationship and reducing the rate over time in line with employment

duration. In addition, dismissing a permanent worker is very costly in Chile and comes with high severance payments.⁶¹ Reducing these costs would increase the chance that workers would become permanent employees, obtain training, and experience increases in productivity and wages. Therefore, another alternative could be partially replacing severance pay with higher social security contributions—particularly for pensions and unemployment insurance—that would be mandatory regardless of the type of contract.

Policy measures are needed to ensure that telework endures the pandemic as a new welfare-improving working method. To maximize the gains for productivity and welfare inherent in the use of more widespread telework, three elements appear to be key: reinforcing regulation, expanding digital infrastructure across the country, and increasing training. Regarding regulation, working from home makes it difficult to oversee compliance of the law⁶². For example, it is difficult to supervise work environments in terms of health and safety or of overtime hours worked. This is true especially when there is a high level of informality. To strengthen implementation and enforcement of telework regulations, third parties such as organizations that cover labor accidents could monitor compliance with the law, especially for smaller firms. Preventing informality and the precariousness that may be generated through this mode of work, especially by supervising that there is a contract or its corresponding extension to regulate remote work, will also be important. In addition, it will be key to assess the outcome of the law after a year of its implementation and to evaluate potential improvements to it.

Closing the infrastructure and digital gap could help turn telework into a tool to increase homogeneity in the labor market. Telework could help reduce geographical segmentation, but this requires improving technological infrastructure and connectivity in lagged regions. Further, SENCE has made available free online courses to train people for telework, including strategies to optimize working from home, manage time, and increase productivity. These courses, together with others in digital marketing and basics of programming and leadership, which are framed in the “Entrepreneurship, IT and 21st Century Skills” program, can be helpful to promote a wider access to telework opportunities. Given that in Chile women are 1.57 times more likely to work in occupations that can be performed remotely than men at the national level (SENCE 2021), these courses could be especially targeted to women. Similarly, training could be designed to include people with disabilities in the labor force and to help the younger population, who have more access and ability to use technology, improve their job opportunities.

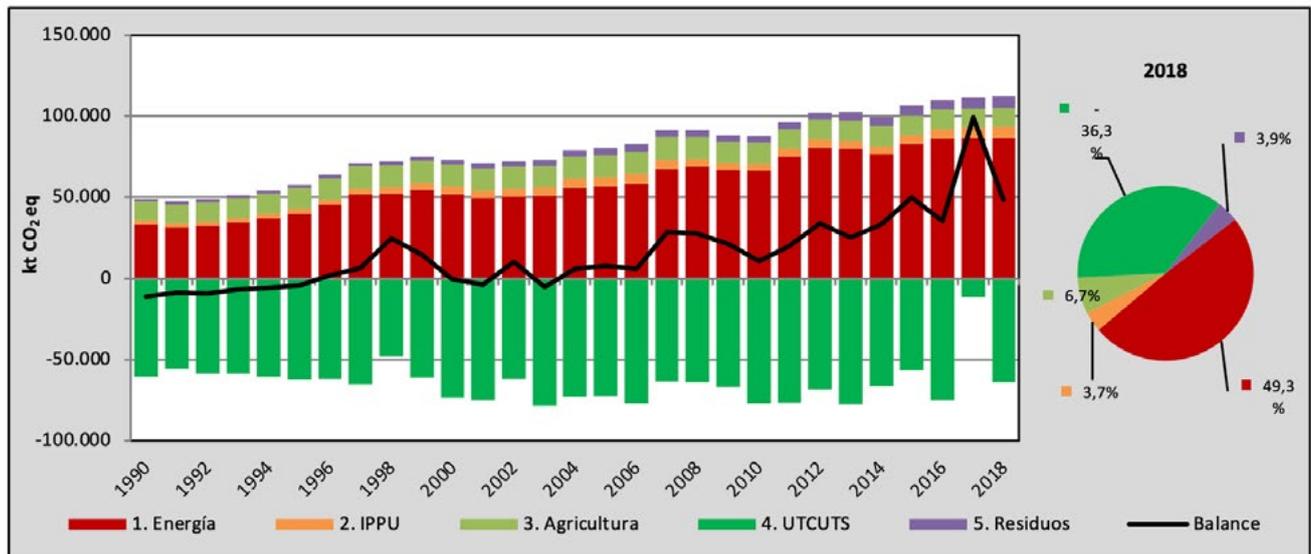
3.7 NEED FOR GREENING THE ECONOMY

Chile is vulnerable to the effects of climate change. Over the past decade, the intensity and frequency of extreme weather events have caused a significant increase in natural disasters in the country. The increase in these climatic events, combined with unsustainable management of ecosystems and natural resources, amplify the vulnerability to the impacts of both society and the Chilean economy, its development, and its competitiveness in various productive sectors. The mega droughts that continue to affect the central region of Chile since 2010 are partially associated with global warming.⁶³ Likewise, Chile's glaciers have retreated during the past decades, with a differential rate of about -0.72 meters for the period 2004–19 due to the increase in temperatures and a considerable reduction of precipitation in the region. Being a country abundant in natural resources that provide essential services to the development of society and the economy, the increase in intensity and frequency of these climatic events not only increase the vulnerability of Chilean society and economy, but also put the country's competitiveness in various productive sectors at risk.

Chile is committed to implementing actions to reach carbon neutrality by 2050 and to promoting green and resilient development. This can be achieved by decarbonizing the economy, especially the most polluting productive activities, and promoting those natural ecosystems that contribute to be greenhouse gas (GHG) sinks. Through its NDC and its Long-Term Climate Strategy, commitments aim to integrate climate actions promoting risk reduction and adaptation to climate impacts with the reduction of GHG emissions in energy and production systems and the long-term protection of natural carbon sinks. Chile is also committed to reaching its green and resilient development goals by improving and maintaining long-term economic competitiveness through sectoral management in an inclusive and affordable manner, avoiding the widening of gaps between members of society.

The energy sector is responsible for 76 percent of total GHG emissions, which have increased over the last decade (Figure 3.25) following the country's economic growth (MINAMB 2020). Within energy emissions, the electricity and heat generation subsectors (industrial and heating) are responsible for 37.5 percent of emissions and the transport sector for 32.9 percent. In addition, improving the capacity of the country's natural sinks, such as forests and the forestry sector, to absorb GHGs is essential to achieve green development, low in emissions. Reducing emissions in these important sectors, increasing absorption capacity through natural ecosystems, and decoupling economic growth from them will be essential to migrate to a carbon-neutral economy and to meet the commitments made.

For Chile to achieve its commitments it must deepen the decarbonization of major GHG sources and improve the absorptive capacity of natural sinks to achieve low-carbon and resilient economic development. This includes (a) making changes to the regulatory framework and improvements to the transmission infrastructure to allow the massification of renewable energy and greater electrification of the economy, (b) promoting electromobility and use of clean fuels in the transport sector, (c) reducing emissions from the mining industry through the use of green hydrogen (see section 4.1), (d) strengthening sustainable management of terrestrial and marine-coastal ecosystems to improve GHG absorption capacity, and (e) consolidating carbon pricing instruments as a climate action tool.⁶⁴

FIGURE 3.25 CHILE'S GHG INVENTORY: GHG BALANCE (KT CO₂EQ) BY SECTOR, 1990–2018

Source: Coordinating Technical Team of Ministry of Environment (MMA) : <https://snichile.mma.gob.cl/principales-resultados/>

Note: GHG = greenhouse gas; IPPU = Industrial Processes and Product Use; ktCO₂eq = kilotons of carbon dioxide equivalent; UTCUTS = LULUCF=land use, land-use change, and forestry.

The path to resilient, low-carbon development, which includes carbon neutrality by 2050, must contemplate an inclusive process, avoiding the widening of social inequality gaps. In particular, the management of an energy transition to net zero emissions will lead to structural changes both in the skills required by industries and in the prices of products, both of which will directly affect members of the most vulnerable population, depending on their social, geographical, specific, and labor integration circumstances. Energy poverty, especially in terms of having access to clean and sustainable heating, is still needed with important co-benefits in reduced air pollution. In order to achieve a just transition, actions should include making policies to reduce energy poverty and providing opportunities for vulnerable populations affected by decarbonization measures.

Table 3.2 outlines recommendations to remedy cross-cutting constraints in Chile.

TABLE 3.2 MATRIX POLICY RECOMMENDATIONS FOR CROSS-CUTTING CONSTRAINTS

Priority reforms	Short term (< 2 years)	Medium-long term (> 2 years)	Implementation
Unleash services and GVC trade as a driver of productivity-led growth.	<p>Draft law and regulations to introduce a mandatory regulatory procedure—to enhance transparency and due regulatory processes across all regulatory agencies and require use of standard general procedures for designing and implementing regulations. The new legislation should be approved by Congress within a two-year period.</p> <p>Create a politically and financially independent regulator for the telecommunication sector, with strong technical capabilities. The regulatory agency should be responsible for ensuring a modern, high-quality, transparent, and efficient market and a world-standard digital infrastructure aiming at facilitating the introduction of new technologies and wider adoption of information technologies, especially by SMEs.</p>	<p>Gradually introduce, in critically regulatory agencies, the new binding regulatory framework, including an impact assessment mechanism and creation of an institution to coordinate across regulatory agencies and promote good practices, perform reviews of regulations and procedures, assess regulations, and suggest improvement in regulatory procedures.</p>	<p>Interministerial committee integrated by, among others, ministries of Finance, Economy, Agriculture, Health, Education, and other regulatory bodies, including the National Competitiveness Commission.</p> <p>Ministry of Transport and Telecommunications</p>
	Competition		
Foster market competition for the benefit of the private sector by strengthening competitive neutrality in sectors with SOE presence, addressing regulatory gaps, and reinforcing merger control and anticartel policy.	<p>Evaluate the need for the government to directly participate in markets through SOEs when the private sector can cater to those markets.</p> <p>Monitor closely and assess potential implications from the proposed bill, which attempts to modify the current competition system, notably the strong investigative tools and elements such as leniency.</p>	<p>Separate the commercial and noncommercial activities of SOEs, at least through account separation.</p> <p>Progressively limit the ability of SOEs to access financing at better conditions than private operators, except when justified by public service obligations.</p> <p>Establish restrictions to disclose reference prices of goods and services tenders.</p> <p>Set entry requirements for bidders that are proportional to the size or value of the tender in goods and services.</p>	<p>Legislative bodies (National Congress); Line ministries, Ministry of Public Works; Ministry of Transport and Telecommunications; Ministry of National Defense; and Ministry of Finance; Technical Secretary of Planning; National SOEs Council; FNE.</p>

Priority reforms	Short term (< 2 years)	Medium-long term (> 2 years)	Implementation
Foster competition among notaries.		Lower entry and conduct barriers in the regulated professional services of notaries.	Legislative bodies (National Congress), Supreme Court of Justice, professional bodies, FNE.
Innovation			
Consolidate the new institutional framework and improve the efficiency and effectiveness of public programs.	<p>Develop and build consensus around a long-term public innovation strategy that can provide more continuity to policy-making.</p> <p>Conduct a deeper review of the coherence of the current mix of innovation programs, their efficiency, and their effectiveness.</p> <p>Strengthen coordination among public institutions under the leadership of the new Inter-ministerial Committee of STKI.</p> <p>Enhance post-program beneficiary data collection.</p> <p>Design impact evaluations ex ante (rather than ex post) to better measure program effectiveness.</p> <p>Examine the additionality of the R&D tax incentive and the scope for reaching a broader set of firms and creating greater linkages within the innovation system.</p> <p>Besides direct transfers and tax incentives, regulatory standards and public procurement could be better leveraged as instruments to foster innovation, as implemented in other OECD countries.</p>	<p>Further strengthen the process for designing, monitoring, and evaluating policy instruments using logic models more systematically and explicitly to present how interventions will achieve results.</p> <p>Because the budgets of some programs remain small, consider integration, rationalization, or scaling up of instruments after revising the instruments' impact.</p>	<p>Interministerial Committee of STKI National Council of Innovation STKI and Innovation Corfo ANID Ministry of Economy, Development and Tourism Ministry of STKI Ministry of Education</p>

Priority reforms	Short term (< 2 years)	Medium-long term (> 2 years)	Implementation
Education and skills			
Establish quality assurance and institutional accreditation.	Participate and influence the ongoing process of development of new criteria and standards of institutional accreditation that the CNA is currently conducting according to Law N°21186, to ensure that they cater to institutional diversity, are flexible enough for the different types of students, and prepare graduates for changing future scenarios of the labor market.		National Commission on Accreditation, higher education associations, business associations
Assure that programs focus on market relevance and digital skills.	<p>Commission the research center of the Ministry of Education to conduct a prospective study of the emerging market of self-learning and alternative credentials and certifications in Chile.</p> <p>Explore the subject of microcredentials and stackable degrees, assessing its relevance for the higher education system and evaluate its potential incorporation in official certification and the qualification framework. Results should be shared and discussed with all higher education stakeholders and employers.</p> <p>Harness the power of high-performing TVET programs, especially short-cycle ones, to upskill and re-skill workers and bridge the skills gap.</p> <p>Explore innovative financing solutions, both public (such as reallocation of funding within the tertiary education system) and private (funding by employers) to avoid the trap of increasing student debt.</p> <p>Close down the worst-performing institutions to help reduce the stigma associated with TVET.</p>	Establish a periodic nationwide survey to assess transversal and digital skills development, involving students of all levels of education, as well as a representative sample of the general population, to inform public policy. Base the survey on the experience of UNESCO-Asia (2014)	Ministry of Education, Ministry of Labor and Social Welfare

Priority reforms	Short term (< 2 years)	Medium-long term (> 2 years)	Implementation
	<p>Require TVET institutions to calculate and publish returns to their degrees and assist them in processing the information and creating summary indicators.</p> <p>Review the possibility of providing intermediate credentials, such as certificates for partial completion and modularity within programs, to meet the needs of the growing number of nontraditional students.</p>		
<p>Make financing available to students.</p>	<p>Include greater flexibility in student loans and push forward law No. 366 of June 2018, which created a new unified student loan but is currently stagnating in Congress.</p> <p>Create new financing mechanisms to balance the types and levels of funding accessible to TVET institutions, including a fund specifically targeted to allow them to cover improvements in outreach to the productive sector and applied research, which are currently assessed areas in institutional accreditation.</p>	<p>Review the conditions established by Law No. 21091 for the free tuition policy, to cater to the needs of nontraditional students, including different provision modes, transfers, and life-long learning, among other flexibility measures.</p> <p>Revise and reconsider the common admission system's link to student financing, as it may not be flexible enough for nontraditional students entering such as at different times of the year. Include programs with alternative provision modes. This revision should ensure participation of TVET institutions and universities in consultations to avoid the negative impacts of regulating enrollment growth and fees on institutional autonomy or on innovation, or investments in improvement in educational quality.</p>	<p>Ministry of Education</p> <p>Higher education institutions</p> <p>Ministry of Education, National Commission on Accreditation, TVET higher education institutions</p>

Priority reforms	Short term (< 2 years)	Medium-long term (> 2 years)	Implementation
Labor			
<p>Increase female participation in the labor force.</p>	<p>Increase access to childcare. Modify article 203 of the Labor Code, which requires firms with 20 or more female workers to provide childcare so that it applies to a minimum number of employees independently of their gender or apply the requirement to all firms independently of the number of employees.</p> <p>Increase support for the care of elderly and dependent people. Strengthen the program Sistema Nacional de Apoyos y Cuidados, increasing information and outreach to potential beneficiaries to increase coverage or increasing subsidies.</p> <p>Improve the design of Bono al Trabajo de la Mujer to distribute funds more evenly between workers and employers in terms of amount and duration; increase the amount or streamline requirements to incentivize employers; increase the age for eligibility to hire older women.</p> <p>Promote more flexible working arrangements such as telework and part-time work. Correct the asymmetry in labor costs of hiring a part- or full-time worker (for example by modifying article 203 of the Labor Code to at least reduce the weight of part-time workers in the calculations for the 20 female employees to be proportional to the workday), subsidizing public transportation for part-time workers, and making labor hours more flexible.</p> <p>Promote training programs that inform microentrepreneurs about the formalization of their business or adapting and improving the design of current programs provided by SENCE such as Digital Talent that provides training in STEM subjects and Mujer Digital 2021 so that women can diversify their opportunities and telework.</p>		<p>Congress Labor Ministry Social Development and Household Ministry SENCE Ministry of Women and Gender Equity</p>

Priority reforms	Short term (< 2 years)	Medium-long term (> 2 years)	Implementation
Disincentivize repeated use of fixed-term contracts.	<p>Enhance unemployment insurance provisions to support workers while they seek higher-quality jobs and facilitate a better matching of workers and jobs.</p> <p>Strengthen active job-search assistance, for example by promoting Bolsa Nacional de Empleo.</p> <p>Enforce regulation that limits the practice of multirut.</p>	<p>new employment relationship and reduce the rate over time in line with employment duration.</p> <p>Reduce severance payments or partially replace it with higher social security contributions—particularly for pensions and unemployment insurance—that would be mandatory regardless of the type of contract.</p>	AFC Ministry of Labor and Social Welfare
Ensure telework endures after the pandemic as a new welfare-improving working method.	<p>Strengthen implementation and enforcement of telework regulation.</p> <ul style="list-style-type: none"> Engage third parties such as organizations that cover labor accidents to monitor compliance with the law regarding health and safety of jobs performed at a distance, especially for smaller firms. Prevent informality and precariousness by supervising the existence of a contract or extension. Assess the outcome of the law after a year of its implementation and evaluate potential improvements to it. <p>Promote training. Reinforce SENCE's free online courses to train people for telework and programs such as "Entrepreneurship, IT and 21st Century Skills" with courses including Digital Marketing and Introduction to Programming. These courses could be especially targeted to women or the younger population to improve their job opportunities.</p>	<p>Close the infrastructure and digital gap to help turn telework into a tool to decrease homogeneity in the labor market. Improve digital infrastructure and connectivity in lagged regions.</p>	Ministry of Labor and Social Forecast SUBTEL SENCE

Priority reforms	Short term (< 2 years)	Medium-long term (> 2 years)	Implementation
Greening the economy			
Generate and implement long-term participatory public policies in line with the NDC.	Accelerate the approval of the Framework Law on Climate Change and the completion of the Long-Term Climate Strategy		
Deepen the energy transition.	Change the regulatory framework with adequate incentives to ensure a flexible, reliable, and affordable electricity system, and review the transmission infrastructure.		
Decarbonize the transport sector.	Promote electromobility in urban and suburban public transport at the national level and the production and use of clean fuels such as hydrogen for freight and long-distance transport.		
Decarbonize the industrial sector—with a focus on mining.	Promote the decarbonization of the industrial sector, particularly mining, through the use of green hydrogen and its derivatives in mining operations.		
Maintain and improve the GHG retention capacity threatened by degradation of native forests and unsustainable management of marine-coastal ecosystems.	Promote sustainable management of terrestrial and marine-coastal ecosystems—for example, by prioritizing the bill for the creation of the Biodiversity and Protected Areas Service and expanding the registry of ecosystems (marine, peatlands, and others) in the national inventory of greenhouse gases.		
Combat energy poverty through policies that provide clean and sustainable heating.	Promote the electrification of heating, with energy efficiency measures in homes, to provide sustainable, nonpolluting heating at an affordable cost in cities in the south-central zone.		

Note: AFC = Administradora de Fondos de Cesantia de Chile; ANID = National Research and Development Agency; Corfo = Chile Economic Development Agency; FNE = Chile National Economic Prosecutor; GVC = global value chain; NDC = Nationally Determined Contribution; OECD = Organisation for Economic Co-operation and Development; R&D = research and development; SENSE = National Training and Employment Service Institute; SME = small and medium enterprise; SOE = state-owned enterprise; STEM = science, technology, engineering, and mathematics; STKI = Science, Technology, Knowledge and Innovation; SUBTEL = Undersecretary of Telecommunications; TVET = technical and vocational education and training; UNESCO = United Nations Educational, Scientific and Cultural Organization.

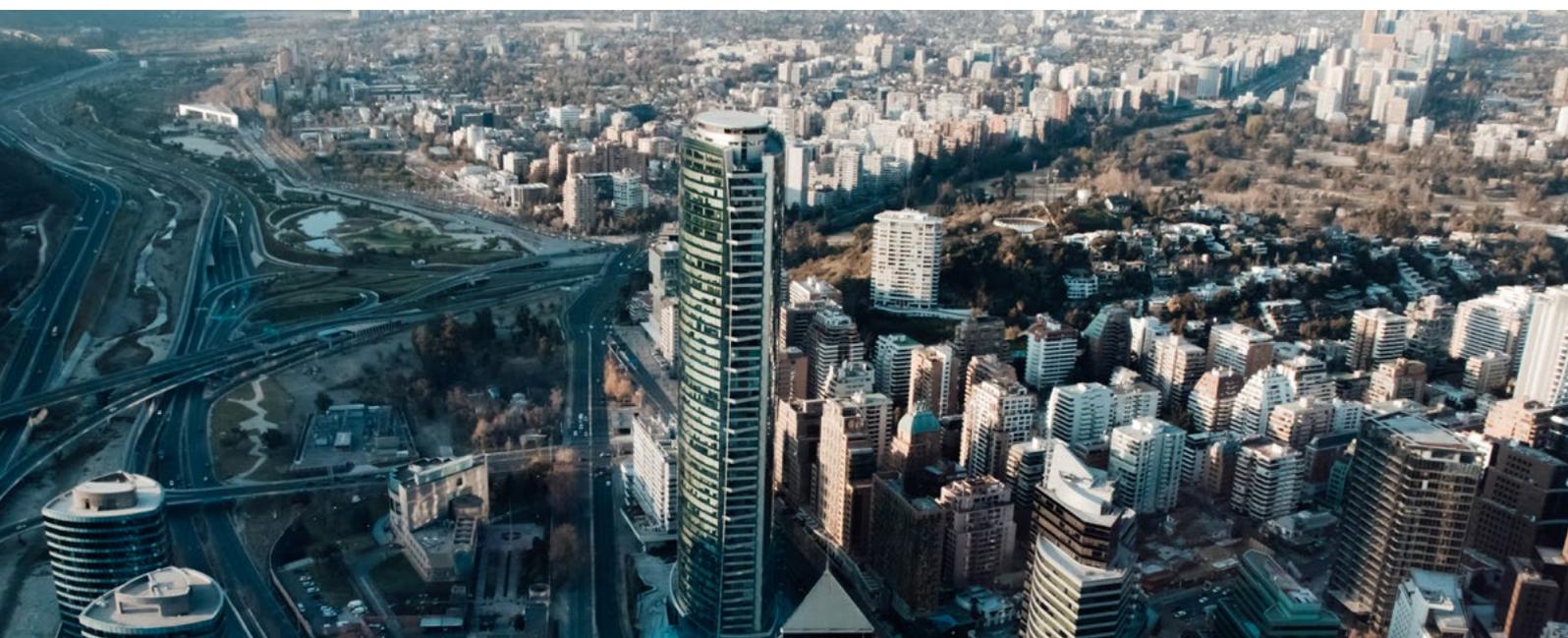
Notes

1. The analysis only covers 1996–2015 because of data limitations.
2. The ENIA is produced by the Chilean National Statistical Agency and provides annual production information for the universe of Chilean manufacturing plants with 10 or more employees, approximately 5,000 manufacturing plants per year. While manufacturing only represents one-fifth of the gross production value, it is highly connected to the rest of the economy, demanding inputs from the primary sector and supplying goods that are later commercialized by the retail and other service sectors.
3. Some differences, however, arise, with a smaller acceleration in Chilean National Productivity Commission (CNP)-measured productivity (1.8 percent per year) during the first phase, a decline in the CNP productivity series that starts later in 2006, and a partial reversal in the downward trend after the subprime crisis from 2009 to 2011.
4. The digital assessment in section 4.3, for instance, provides evidence of inadequate finance for start-ups.
5. Backward GVC participation is the portion of imported inputs used in export production and can be measured in levels and as percent of gross exports.
6. Forward GVC participation is the portion of domestic value added that is re-exported by third countries and can be measured in levels and as a percentage of gross exports.
7. See Crespo and Fontoura 2007; Fernandes, Kee, and Winkler 2021; Havranek and Irsova 2011; and Meyer and Sinani 2009.
8. Hummels et al. 2007; Christ and Ferrantino 2011; Arvis et al. 2010; and Fernandes, Kee, and Winkler 2021.
9. Cusolito, Garcia-Marin, and Maloney (2021) show that greater competition needs to be complemented with the building of firms' capabilities to induce innovation (see section 3.4).
10. In this note, network industries are defined as industries in which a fixed infrastructure is needed to deliver the goods or services to end users, e.g., telephone and rail track.
11. The TDLC's rulings and decisions can be challenged before the Supreme Court of Justice.
12. The introduction of the bill may have been prompted by the public perception that collusion crimes go unpunished because after five years of reintroducing criminal penalties, nobody has been sanctioned with prison. All lawsuits brought by the FNE, however, concern cartel conduct that took place before the 2016 amendment reinstated prison as a penalty for collusion.
13. Regarding criminal sanctions, the bill proposes to increase these for cartels involving basic goods and services from the current range of 3 to 10 years of jail to a range of 5 to 10 years.
14. Among others, see Foster Grim, Haltiwanger, Wolf, 2018 and Hall 2011, Mohnen and Hall 2013, Raffo et al. 2008 for developing countries.
15. The survey covers firms with sales above US\$10,000. See Observa, XI National Innovation Survey, 2017–18 dataset, <https://observa.minciencia.gob.cl/datos-abiertos/base-de-datos-de-encuesta-nacional-de-innovacion-2017---2018---macrozon> 2018.
16. According to the OECD, 53 percent of firms introduced a new product or business process in the median OECD country in 2014–16 compared to 24 percent of firms in Chile during 2015–16. Part of the decline could represent a change in methodology.
17. The percentage of firms participating in the innovation survey of 2015–16 that requested patents and trademarks in Chile were 1 percent and 2 percent, respectively, compared with 13 and 28 percent in New Zealand during a similar period. See OECD 2020a.
18. A specialization in natural resources partly explains the R&D gap. While Chile does not specialize in R&D intensive industries, the level of investment in R&D has traditionally fallen below the level expected, after controlling for its pattern of specialization (Maloney and Rodriguez-Clare, 2007).
19. The pillar on “market sophistication” covers inter alia (a) credit, (b) investments (including risk financing instruments), and (c) trade, competition, and market scale.
20. See section 3.4 for further information on higher education and its relationship with the labor market.
21. See Chavez Bustamante 2018; Serrano-Bedia et al. 2018.
22. For example, the Investment and Innovation Center of Concha y Toro is conducting research on the presence of pathogens in plants and applying a biological reinforcement treatment to increase the productivity of plants.
23. Their findings indicate that increased competition from China following trade liberalization only raised product quality for the 10 percent most productive industrial plants (‘the leaders’) to escape competition. These accounted for roughly a quarter of industrial value added.
24. The authors find that rises in rents induce ‘the leaders’ close to the technology frontier to spend more in R&D and product innovation. For ‘the laggards’, the fall in rents depresses innovation efforts and the rise moderates their decline. However, rising rents never increase the innovation efforts of ‘the laggards’ above the average change for the sector.
25. Startupeable based on Pitchbook and LAVCA. Venture Capital Chile: Mapa del Ecosistema (2021). <https://startupeable.com/venture-capital-chile/>

26. The first council was the National Council of Innovation for Competitiveness (2005), which subsequently became the National Council of Innovation for Development.
27. The inter-ministerial committee is chaired by MSTKI and includes the ministries of finance, education, and economy, development and tourism.
28. Corfo and ANID (formerly known as CONACYT) report to the Ministry of Economy, Tourism and Development and the Ministry of STKI, respectively.
29. The Servicio de Cooperación Técnica (SERCOTEC), under the Ministry of Economy, Tourism and Development, fosters the development of microentrepreneurs.
30. A new Institute of Clean Technologies, led by a US consortium, was awarded at the beginning of 2021 to conduct R&D activities in solar energy, lithium and other minerals, and advanced materials for battery storage and green hydrogen, with an investment worth US\$265 million. In December 2020, Microsoft announced the establishment of a data research center in Chile as part of a \$11.3 billion investment estimated to add 51,000 new jobs over four years.
31. According to the XI National Innovation Survey, only 20.8 percent of firms that engaged in R&D are aware of the existence of the tax benefit, and of those, 21.6 percent applied to make use of it.
32. Cases include Universidad del Mar and, more recently, Universidad del Pacífico and Universidad ARCIS. All these cases involved for-profit universities, which have since been forbidden by law in Chile. Several TVET institutions were also implicated.
33. For TVET institutions profit is allowed, but because the free tuition policy applies only to nonprofit institutions, many have moved toward nonprofit status.
34. Laws N°20,370 and Law N°20,129 (2007).
35. Law N°21,091 of 2018.
36. In 2020, 54 percent of first-year students and 40 percent of all students.
37. Public TVET centers, one in each region (15 in all, 10 of which have been created to date) are also being established to increase the role of government in higher education.
38. A Technical and Vocational Training Division within the new Undersecretary of Higher Education has been created, and reforms mandate the development of a National TVET Strategy and require the adherence of public TVET institutions to a TVET National Qualification Framework—developed with the participation of the business community—which is currently being piloted, Law N°21,091
39. Masters and PhD levels have also grown substantially since 2007, reaching over 45,000 students today. PhD students doubled over this period to reach enrollment over 6,000 students, while masters students grew from nearly 18,000 to over 40,000 today.
40. For technical and professional titles, a mandatory minimum of 1,600 hours is required. While universities can impart all kinds of recognized degrees and titles, professional institutes can only offer professional or technical titles, and vocational formation centers can only impart technical titles. There are 18 programs that can only be imparted in universities and not in TVET institutions. To obtain the professional title of these programs, the university must also issue a bachelor's degree in the area. This list includes architecture, several engineering programs, psychology, school pedagogy, journalism, pharmaceutical, medicine, and many others.
41. Although Law N°20.129, which created the accreditation system in 2006, allowed for continuing education programs to be accredited, the certificates from these programs are not recognized in the law, adding to the confusion in the higher education system.
42. These include workplace training, apprenticeship programs, among others.
43. A key shortcoming of the program is that courses are extremely short. Internationally, a minimum of 200 hours is deemed necessary to make a significant impact on upskilling, particularly for the vulnerable populations they aim to serve, while the overwhelming majority of SENCE trainings are shorter than 40 hours, with an average of close to 20 hours.
44. The probability of finding a job within three months.
45. Total female employment levels fell 15 percent year-on-year by December 2020, while the decline was 8 percent for men, according to data from INE.
46. World Bank based on data from Encuesta Longitudinal de Primera Infancia (ELPI 2017).
47. INE (National Statistics Institute), “Encuesta Nacional de Empleo (database),” 2021, <http://bancodatosene.ine.cl/>.
48. It takes six months on average for a worker to find a new formal salaried job, below the median in OECD countries of 12 months (BCC 2018).
49. INE's definition of informal workers includes self-employed, employers who own an informal economic unit, nonremunerated family members of a household, and salaried employees and domestic service workers who do not receive health contributions (Isapre or Fonasa), social security (AFP or other), or both.
50. UC 2020.
51. OECD data: hours worked, <https://data.oecd.org/emp/hours-worked.htm>.

52. See Baker, Gruber, and Milligan 2008; Berlinski, Galiani, and McEwan 2011; Blau and Currie 2006; Cascio 2009; Gelbach 2002; Mateo Díaz and Rodríguez-Chamussy 2016; and Morrissey 2016.
53. Encuesta Casen 2017
54. OLM 2021 based on Encuesta Casen 2017
55. Subsecretaría de Educación Parvularia, 2019.
56. Socioeconomic categories are determined by the Registro Social de Hogares according to income, household members, and their characteristics (elderly, children, people with disabilities), and their properties, health plans, education, and other indicators.
57. Maximum amount is the equivalent to USD 735 annually.
58. Albagli et al. (2017) define rates of entry and exit of workers who are the employees who work for the first or last time in a year in a company as a percentage of total workers in the company; the turnover rate is the average of both. Between 2005 and 2016 the turnover rate for Chile was 40.6 percent, according to their calculations.
59. Boletín 13496-13 at <https://www.senado.cl/appsenado/templates/tramitacion/index.php>.
60. Multirrut consists of the artificial subdivision of a company in a multiplicity of tax identification numbers to avoid legal labor and social security obligations and allows firms to hire workers on a fixed-term contract without complying with duration restrictions prescribed by law (one renewal and both periods should not exceed a year).
61. OECD 2020d; data are available at <https://stat.link/brk4sa>
62. In March 2020 Congress enacted Law 21220 to regulate telework. It authorizes the worker to provide services from another place different from the firm. It requires a new contract or an annex to the current one that specifies the place and workday(s) agreed. It includes the right to disconnect, personal protection elements, labor risk management, and the provision of materials from the employer. Workers who telework benefit from all the same rights established in the Work Code for face-to-face workers. See BCN 2020; DT 2020a, 2020b.
63. According to the latest report of the Intergovernmental Panel for Climate Change (IPCC) on the physical changes expected due to climate change.
64. Find more details in the Chile Policy Note (World Bank 2021b).

04. TRANSITIONING TO A GREENER CHILE: OPPORTUNITIES IN GREEN HYDROGEN, CLIMATE-SMART AGRICULTURE, AND THE DIGITAL ECONOMY



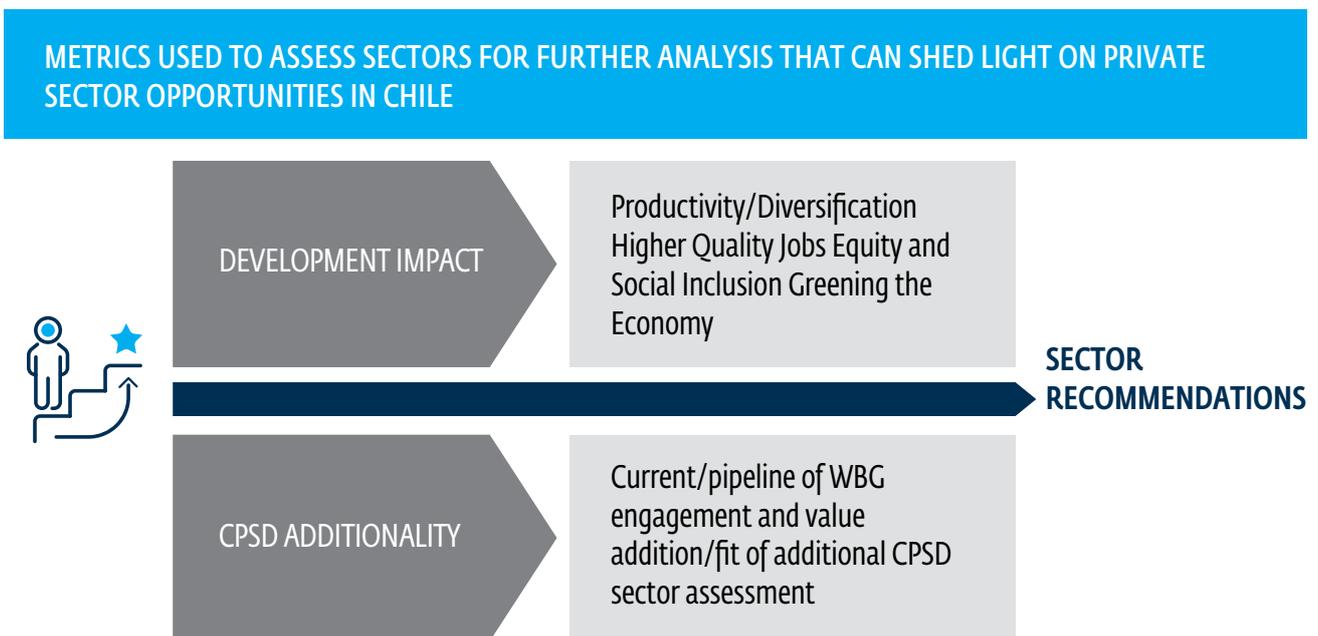
4.1 GREEN HYDROGEN AS A SOURCE OF FUTURE GROWTH

4.2 ENHANCING RESILIENCE AND COMPETITIVENESS THROUGH CLIMATE-SMART AGRICULTURE

4.3 ENHANCING PRODUCTIVITY AND ENTREPRENEURSHIP THROUGH THE DIGITAL ECONOMY

The Chile CPSD conducts out sector assessments in **Green Hydrogen, Digital Economy, and Agribusiness**. The challenges of Chile’s growth model, the 2019 social unrest, the upcoming constitutional changes, and the COVID-19 crisis encapsulate what the country and the private sector have to contend with in the coming years. Four criteria were used to select sectors for deeper assessments: (a) potential to support enhanced productivity and diversification, (b) capacity to create high-quality jobs, (c) potential to contribute toward equity and social inclusion, and (d) contribution to sustainability and greening the economy (Figure 4.1). Green hydrogen could have potential as a new industry for increasing economic diversification, creating new jobs, and contributing to greening the economy. In turn, the incorporation of green hydrogen-based technologies into mining would contribute to significantly reducing the climate footprint of the mining sector and may aid in increasing its productivity. The digital economy was selected given its contribution to all four criteria and its increasing importance as a result of COVID-19. Climate-smart agribusiness also contributes to all criteria, being an important sector in Chile that contributes to diversification and employment but also with an important regional development angle (hence inclusion).

FIGURE 4.1 SECTOR SELECTION FRAMEWORK



Source: WBG staff.

Note: CPSD = Country Private Sector Diagnostic; WBG = World Bank Group.



4.1 GREEN HYDROGEN AS A SOURCE OF FUTURE GROWTH

Zero-emission hydrogen (green hydrogen; GH) is likely to be a core component of a low-carbon future. Hydrogen as a chemical reactant and a feedstock for production of other chemicals has been in use for over 100 years. Its potential as a fuel has also been well known, but its production from fossil fuels (gray hydrogen) has made it unattractive. Recently, the possibility of producing GH from renewable energy has sparked new interest with many ideas for its use in decarbonization; but its future, the end-use applications that may be the first adopters, and the speed at which this could happen all remain unclear. Hydrogen and its derivatives, ammonia and methanol, can be thought of as energy carriers and a means of energy storage because they can be burned to regenerate energy, much like gasoline or diesel.

To manufacture green hydrogen, electrolyzers (reactors that carry out chemical reactions using electrical energy) use renewable energy (solar, wind, and similar) to separate water into oxygen and hydrogen, an expensive and inefficient process today, although technology is evolving and costs are falling.¹ Production costs for gray hydrogen in Chile today are in the range of US\$0.80–\$1.20/kilogram (kg), while the estimated costs of producing GH range between US\$2.30–\$2.70/kg. By 2030, however, GH production costs are expected to fall below US\$2.00/kg, and below US\$1.50/kg by 2050. Because of Chile's abundant low-cost renewable energy potential, the government of Chile has estimated that GH could create 100,000 associated jobs by 2030 and that the industry could lead to investment opportunities worth US\$200 billion and to exports of US\$30 billion in 2030, representing 10 percent of GDP and rivaling Chile's copper exports (MinEnergía 2020a; S&P Global 2020). This sector assessment contributes to the understanding of the potential of green hydrogen production in Chile, enumerating the challenges to its development and outlining what it would take to realize the sector's potential in the country.

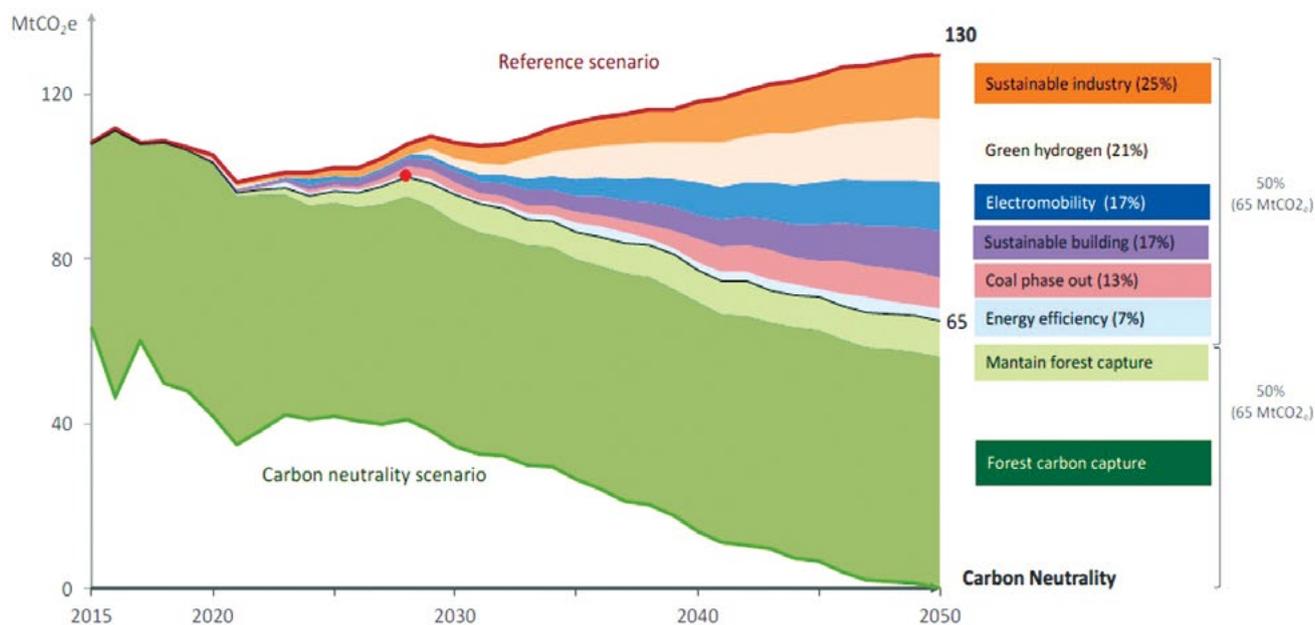
Why green hydrogen in Chile?

Interest and investment in the production, storage, and use of GH and its derivatives is growing rapidly. Excitement around GH is explained by the prospects for a clean fuel that can reduce GHG emissions in hard-to-abate sectors, including heavy industry and heavy-duty and long-haul transportation, making it a potentially important part of the overall fuel mix needed to decarbonize economies. GH has the capacity to reduce GHG emissions in these sectors, where renewable energy cannot directly replace fossil fuels because of complex chemical processes and the need for high temperatures that are still difficult to achieve with electricity. Long-haul commercial transport, where the scope for batteries remains limited, is another potential application, and hydrogen-derived fuels may also be useful in aviation and shipping.² GH, either as a gas or in easier-to-handle derivatives such as ammonia or methanol, may also be used for large-scale, long-duration storage and transport of renewable energy and then converted back to electricity on demand; it can thus help even out the intermittency of solar and wind. GH may also extend the capability of renewable energy in remote applications owing to its portability and storability, and by balancing peak and off-peak supply. Future technological advances are likely to expand the list of uses for GH.

Chile hopes to become a global leader in this nascent industry by leveraging the abundance and low cost of its renewable energy resources, key to the production of GH. Chile today has the potential to be one of the most competitive countries for GH production in the world, with the capability to produce GH at costs of US\$1.60/kgGH or lower in the long term.³ The Chilean electricity market has been transformed in the past decade by the introduction of various renewables, mainly solar and wind. These two technologies represent close to 80 percent of new-build generation projects, and account for 6 gigawatts (GW) of installed capacity, a five-fold growth over the past six years and with an additional 5 GW to be commissioned by 2022 (CEN 2021).⁴ Chile has had an unsubsidized approach to developing its renewable energy market, strengthened by long-term competitive tenders for power purchase agreements (PPAs), which has led to a reduction in electricity prices from US\$128.20/megawatt-hour (MWh) in 2013 to US\$32.50 in 2017 in optimal sites in Chile. Large-scale solar and wind have a levelized cost of energy (LCOE) of US\$25/MWh (CEN 2021).

Green hydrogen plays an important role in Chile's updated nationally determined contributions, in which it commits to reach carbon neutrality by 2050 (figure 4.2). According to the Ministry of Energy's projections, GH has the potential to become the second-largest contributor to emissions reductions after sustainable industry. The contribution of GH to decarbonization can be further broken down by sector: GH is expected to contribute to a 71 percent reduction in the GHG emissions of heavy-duty transport (such as long-haul transport where plug-in electric trucks are not viable); 12 percent reduction of emissions in the mining sector (replacement of diesel-based combustion system for mining, or CAEX, trucks); 7 percent reduction in buildings; and a 2 percent reduction in GHG emission by industry (MINAMB 2020b).⁵

FIGURE 4.2 PATHWAY TO CARBON NEUTRALITY BY 2050



Source: Chilean Ministry of Energy (MinEnergía) 2020b.

Note: The figure considers a capture of 57 million metric (MM) tons per year from the forestry sector, plus an increase of 8 MM tons in 2050. The reduction percentages represent the aggregate for the period 2020–50.

The Chilean government’s aspirations for GH are ambitious. The National Green Hydrogen Strategy, launched in November 2020, aims to have 5 GW of electrolysis capacity under development by 2025, to produce the cheapest GH on the planet—and create 100,000 associated jobs—by 2030, and to be among the top three GH exporters by 2040 (MinEnergía 2020a). The strategy states that the GH industry could lead to US\$200 billion worth of investment opportunities and to exports of US\$30 billion in 2030, representing 10 percent of GDP and rivalling Chile’s copper exports (MinEnergía 2020a; S&P Global 2020). These aspirations rely heavily on yet-to-be proven cost-reduction assumptions and technology adoption forecasts. From a regulatory perspective, the Chilean government has already given GH, and other GH-based fuels, legal recognition through the Energy Efficiency Law 21 305, issued in February 2021. As a complement, the Economic Development Agency recently launched a US\$50 million fund to finance GH projects selected through competitive bidding (Corfo 2021), and the Ministry of Energy, the Chilean Agency for International Cooperation for Development (AGCID), and the EU launched a similar fund to finance preinvestment studies (AGCID 2021).

There remain significant challenges, however, to reaching the economies of scale outlined in Chile's strategy. For instance, while the strategy anticipates that the first phase of GH adoption (2020–25) will mainly target domestic consumption—by replacing existing gray hydrogen demand in oil refineries and ammonia production—the most consistent business models that have been put in place to date by private sponsors and investors target international off-takers for GH-derived products—that is, they rely on export demand. In addition, for the industry to mature, gaps in environmental and safety regulations need to be addressed (Schröer 2020). Moreover, today the GH market is still not profitable, and Chile will have to compete with other economies to establish itself as a leading GH producer. These and other challenges are reviewed in the next section.

What are the constraints to development of green hydrogen in Chile?

Green hydrogen projects are risky for investors: they are capital intensive, have high upfront costs, and are not profitable when competing against gray hydrogen unless sufficient carbon taxes or subsidies are in place. Chile enjoys a number of key advantages that support its bet on GH despite these uncertainties: (a) it boasts an abundant supply of low-cost renewable energy; (b) its investment climate is strong, as are its market-friendly trade and investment policies; and (c) it is moving early to become a leader and adopter, seeking memorandums of understanding (MoUs) with relevant actors to take initial steps and open markets (such as signing MoUs with the port of Rotterdam, and another in Germany, for importing GH). Nevertheless, not knowing when investments in GH could become profitable is an obstacle for potential investors and for policymakers who are considering deploying financial instruments. Other key risks include (a) the uncertainties surrounding the scale of global demand and supply of GH; (b) the potential for competing technologies to outperform GH on costs; (c) the need to develop, and rely on, export markets for the development of GH because of limited scale in the domestic market; and (d) the importance of concessional financial resources to incentivize investment in costly, front-loaded projects, among other risks. These challenges are detailed in the paragraphs that follow.

The strength of the Chilean wager on GH relies on the cheap electricity provided by solar and wind energy. Although low energy costs are a necessary condition for GH to compete with fossil fuels, they are not sufficient. Low energy costs must be complemented with technologies that ensure a continuous supply of electricity—difficult to achieve with solar or wind—to support rapid amortization of the cost of electrolyzers through high utilization rates. Electrolyzers are a major component in the cost of GH production (electricity provision and electrolyzer cost represent 95 percent of total costs), and their continuous operation would reduce the unit cost of GH. While a combination of falling costs for solar and wind power, improved performance, and economies of scale for electrolyzers could make it possible for green hydrogen to be cost-competitive with fossil fuel alternatives by 2030 (IRENA 2020b), this combination of events is not assured⁶—and if it does take place, investments based on today's technologies may not be competitive in 2030.

A related risk involves the potential of blue hydrogen, which may lead to the displacement of green hydrogen or to the postponement of its development. Blue hydrogen is produced as a “bridging fuel” using fossil fuels (natural gas) whose emissions (carbon dioxide; CO₂) are captured and stored (IRENA 2019). If carbon capture technologies become increasingly successful and cost-effective, or if policymakers prioritize the oil and gas industry's interests, blue hydrogen would be

more attractive, with investments in GH potentially turning into stranded assets. The attractiveness of blue hydrogen will also depend on the ability to verify that the hydrogen produced is, in fact, blue (the same challenge applies to verification of green hydrogen). Because there is currently no global trade in green or blue hydrogen, no industry or regulatory body has taken the step of providing an express standard or definition. Nevertheless, stiff competition from blue hydrogen is to be expected. Similarly, there are other technologies in development that could compete with GH: production of hydrogen from natural gas where the carbon is isolated as a solid and is prevented from entering the atmosphere (methane pyrolysis), and production of hydrogen from landfills by capturing the gases emitted, which could be greener than GH because it also prevents GHG emissions in addition to producing GH. Extending the concept, for any application in which GH is being considered, alternate ways of decarbonizing the application would pose a threat to the potential for GH (such as development of higher-capacity batteries for long-haul transportation).

The dependence on export markets for the early development of GH is a risk. In Chile's nascent GH market, export-oriented projects have gained more traction than projects targeting domestic consumption. The most likely development for this first stage in GH development is therefore the production of easier-to-transport hydrogen derivatives for export (because hydrogen needs to be under high pressure and very low temperatures to be efficiently transported), relying on developed country targets that will need to be supplied, at least partially, from abroad. These targets can sustain the long-term investments needed in the production process and in infrastructure that will support the hydrogen economy. Export markets can provide the economies of scale needed to develop GH infrastructure, create the incentives to innovate and invest in cost-reducing technologies, and facilitate the creation of GH production and use hubs, or valleys, in Chile. Nevertheless, reliance on export markets that Chile cannot influence, and which could switch suppliers and shift needs and standards, represents a significant risk, although one that seems difficult to avoid. Chile's geographic location presents a challenge in this sense, because other potential producers are closer to export markets such as Europe and the United States (including Brazil, Colombia, Morocco, Saudi Arabia, among others; see Box 4.1). For Chile to remain competitive, it needs to reach the cheapest GH locally to compensate for higher transportation costs to supply European or American markets.

Structuring the financing for costly, front-loaded projects with high uncertainties in demand growth and technologies is challenging. In the short and medium term, the commitment of an off-taker with solid financing, at prices that ensure project profitability and demand, is critical. The market in Chile is developing rapidly, with a growing pipeline of projects and new market actors willing to explore business opportunities. In this environment, projects producing GH for export (such as green methanol or green ammonia-based products) are more likely to match with an international off-taker willing to enter into long-term commitments and pay a green premium for GH-derived products. Vertical integration in the value chain could also help reduce uncertainty, and some companies are designing strategies in this direction. Consortia, or joint ventures, in which each partner supports the project with its capabilities and financial contribution, can contribute to the development of GH projects with efficient, distributed risk management. Because Chile is no longer an Official Development Assistance recipient, concessional finance is more difficult to obtain, placing the country at a disadvantage relative to some others, and innovative solutions to tap climate-related funds are needed.

BOX 4.1 INTEREST IN GREEN HYDROGEN IN LATIN AMERICAN AND THE CARIBBEAN AND BEYOND

Around the world, countries are betting on green hydrogen (GH) as a viable clean energy carrier. In Latin American and the Caribbean, many countries are either building roadmaps or updating their regulatory frameworks to promote green or blue hydrogen, although none has an enabling environment as developed as Chile's. Compared with Chile, regional comparators tend to be less holistic in their approach, focusing on specific subsectors (such as Costa Rica on transport and Panama on energy storage). In some countries, where the national strategy is under development, strong municipal programs are in progress at the subnational level (for example, Port of Ceara in Brazil).

In terms of energy profile, some Latin American and the Caribbean countries are better positioned to compete in the green and blue hydrogen production markets because of their natural or technological endowments. The countries with the highest percentages of fuel exports—thus having the best profile for blue hydrogen production—are Colombia (54.7 percent of fuel exports as a share of total exports), Brazil (13.4 percent), Ecuador (39.2 percent), and Paraguay (20.5 percent) (World Bank 2021b). The countries with the highest percentages of renewable electricity output, and with major potential for GH production, are Argentina (28.1 percent), Brazil (74.0 percent), Chile (43.6 percent), and Colombia (68.2 percent).

Beyond Latin American and the Caribbean, others are also trying to catch the GH wave, taking advantage of the opportunities arising from its promotion worldwide. Saudi Arabia has some of the world's cheapest wind and solar power and is positioning itself to be a major player. Morocco launched its Green Hydrogen Cluster in March 2021, aiming to position the country as a leading exporter in the regional context, especially to European partners. It signed a cooperation declaration with Portugal in February 2021 to enhance investment opportunities for both countries in the GH field. The European Union has issued its Green Hydrogen Strategy and drafted a strategy for large-scale GH expansion (yet to be adopted). Japan recently opened one of the world's largest GH plants near Fukushima. Australia launched its Green Hydrogen Strategy in November 2019, with the objective of becoming a major global player in this market by 2030 and has announced plans to build an "Asian Renewable Energy Hub" that would use 1,743 large wind turbines and 30 square miles of solar panels to run a 26 GW electrolysis factory to create GH to send to Singapore (Robbins 2020). Other countries with significant renewable energy potential (such as Namibia, South Africa, and Argentina) are looking at partnerships with corporate investors and donor governments to develop their GH markets.

Source. YaleEnvironment360, Nov. 5, 2020.

Regulatory and market signals to mobilize Chilean domestic demand for GH and support the development of the local GH market are needed. As will be seen in the following subsection, there are several potential domestic GH applications, including in hybrid heavy-haul trucks used in mining operations, in buses, and for methanol production, among others (appendix B outlines these potential applications and their estimated market size. The main driver of local demand for low-carbon technologies is stringent low-carbon goals, mainly within the value chains of large corporations. Multinationals with corporate objectives or locally based companies with voluntary emissions reduction goals are candidates for the introduction of GH in their processes. To become an important actor in the future global market of low-carbon hydrogen and to attract private investment, Chile needs to persevere with market signals that allow economies of scale and the achievement of cost parity. It has already taken steps to create these market signals. In February 2021, Chile reformed its Law 21305 on Energy Efficiency to recognize GH and its energy carrier derivatives as a source of energy (BCN 2021). In addition, Law 20305 was reformed to enable the Ministry of Energy to create and implement regulations to fully integrate GH into the overall energy mix.⁷ On the basis of the above-mentioned reforms, the government is working to update legislation to ensure a consistent and seamless introduction of GH into the energy matrix. In particular, the Ministry of Energy is drafting (a) a norm on blending green hydrogen into natural gas pipelines,⁸ and (b) a regulation covering the infrastructure needed to produce, store, transport, and use GH—which includes compression and refueling stations.⁹ More regulatory development is needed, however (CPI 2021). For instance, as of November 2021, the Supreme Decree 43/2016 MINSAL provides general measures for the storage of GH but does not cover GH’s energy derivatives (BCN 2016). Norms for environmental, health, and safety regulations (EHS) in GH also need to be developed.¹⁰

Prospects for GH production and uses in Chile

This subsection reviews potential GH applications, both for export and for the Chilean market. A model is constructed that estimates the trajectory of production costs for each of the key applications that are identified and compares it to the expected cost trajectory of competing technologies, thus identifying—given the state of knowledge today—when GH applications may become viable. The assumptions underlying these estimates can be found in “appendix A: Model Assumptions, calculations, and results.”

Today there are 36 initiatives in Chile aiming to produce or use GH. Most of these are at a very early stage of development; only one has an identified off-taker and is expected to be operational in 2022. Sponsors are mainly international companies in the energy field. About a third of the projects would produce GH with no clear end-use or off-taker, while another third are projects for applications targeting the replacement of diesel use and power generation projects for off-grid consumption.

The medium- and long-term prospects for competitive production of GH in Chile are encouraging. The competitiveness of current and future projects depends on reducing costs to compete with other feedstocks. Production costs for gray hydrogen in Chile today are in the range of US\$0.80–US\$1.20/kg, depending on the cost of fossil fuel used. The estimated costs of producing GH today are US\$2.30/kg powered by wind in Magallanes and US\$3.50/kg with solar in the north.¹¹ By 2030, GH production costs are expected to fall below US\$2.00/kg both in the north and Magallanes regions, and below US\$1.50/kg by 2050. If solar technology costs continue to drop as expected, GH powered by solar would outperform wind in the long term (2030–50).¹² These cost trajectories are supported by high-capacity factors (that is, the ratio of actual energy output to maximum possible output),¹³ which for solar photovoltaic (PV) plants are around 40 percent in the north of the country, while for wind they reach 60 percent in the southern Magallanes region.¹⁴

While GH production may become competitive relatively soon, the various GH applications vary in terms of their attractiveness and the timeframe for viable adoption. An analysis conducted for this study compares the main potential uses of GH to the respective alternatives (such as battery backup for the grid versus fuel cell backup). The applications are sorted in order of declining market potential (Table 4.1). Depending on the application, either a total cost of ownership (TCO) or levelized costs (LC) methodology is used.¹⁵ Information about the assumptions, calculations, and alternatives can be found in appendix D which includes explanations regarding the state of development of each application considered in table 4.1 as well as its cost make-up, and assumptions regarding the trajectory of costs and technologies, among others.

As table 4.1 illustrates, some GH uses appear to be competitive today, while others may become attractive in the medium and longer term. For instance, GH forklifts outperform the electric benchmark at today's costs, assuming a secure GH supply, although the market is relatively small; ammonia exports—representing a large potential market—are also feasible at today's costs if importing countries implement announced strategies that include willingness to pay a premium for GH.¹⁶ GH blending into the gas grids could reach parity in 2030,¹⁷ while ammonia for use as an explosive in mining blast use and hybrid combustion CAEX trucks used in the mining sector reach competitive costs in the long term (2030–50), based on current knowledge of potential solutions for decarbonization.

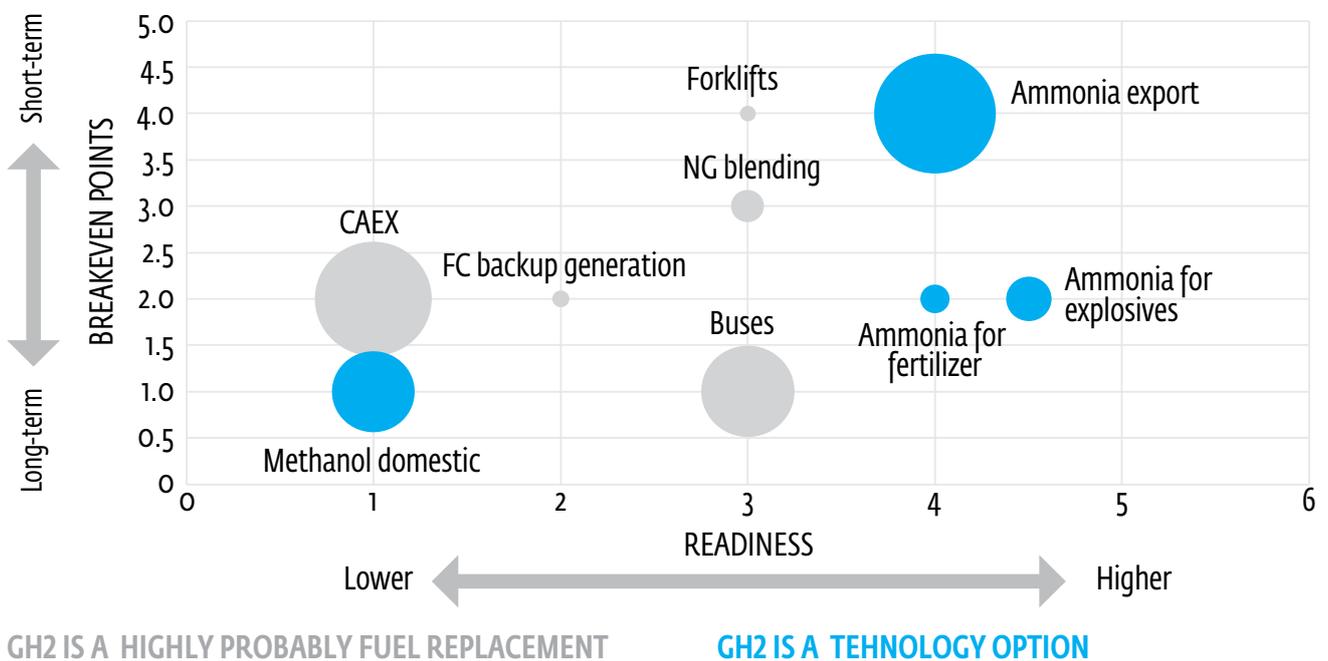
TABLE 4.1 COMPETITIVENESS ANALYSIS OF GH APPLICATIONS

Case study		Method of analysis	Scenario			Energy use
			Today	2030	Long term	
Export	Ammonia export	LC (US\$/kg GH)	6.5	2.8	2.2	Chemical application
	Japan's target GH cost	LC (US\$/kg GH)	10.0	3.0	2.0	Chemical application
CAEX	GH hybrid CAEX (60% GH/40% diesel)	TCO (million US\$)	12.28	9.58	7.47	Drive power
	Diesel CAEX	TCO (million US\$)	7.11	8.32	9.23	Drive power
Buses	GH buses	TCO (million US\$)	6.70	5.05	3.99	Drive power
	Diesel buses	TCO (million US\$)	2.23	2.42	2.55	Drive power
Methanol production	Methanol production	LC (US\$/ton MeOH)	621.0	475.5	324.2	Chemical application
	Average industry price of methanol for the last 5 years	LC (US\$/ton MeOH)	305.2	305.2	305.2	Chemical application
Ammonia production	Ammonia production	LC (US\$/ton NH ₃)	599.4	425.5	257.6	Chemical application
	Average industry price of ammonia for the last 8 years	LC (US\$/ton NH ₃)	363.3	363.3	363.3	Chemical application
Blending in Natural gas grid	LCOH for LNG blending (north of the country, large size) (US\$/kg H ₂)	LC (US\$/kg GH)	2.69	1.83	0.96	Heating/cooling
	Natural gas levelized cost (US\$/kg H ₂)	LC (US\$/kg GH)	1.95	1.95	1.95	Heating/cooling
Forklifts	GH forklifts	TCO (million US\$)	8.18	7.63	7.16	Drive power
	Electric forklifts	TCO (million US\$)	12.94	12.94	12.94	Drive power
Backup generation	Fuel cell backup generation	LC (US\$/kWh)	1,440	1,036	630	Electricity
	Batteries backup storage	LC (US\$/kWh)	642	459	348	Electricity
	Diesel backup generation	LC (US\$/kWh)	386	386	386	Electricity

Source: ImplementaSur, 2021. Note: CAEX = combustion system for mining; GH = green hydrogen; H₂ = hydrogen; kWh = kilowatt-hour; LC = levelized costs; LCOH = levelized cost of energy; LNG = liquefied natural gas; MeOH = methanol; NH₃ = ammonia; TCO = total cost of ownership.

The highest upside in terms of market potential appears to be for green ammonia in international markets, and for heavy-duty trucks in the domestic market. As shown in figure 4.3, international demand for green ammonia is expected to be significant, either for direct application (as a fuel or feedstock) or for use as hydrogen after reconversion, although the latter is not yet commercially possible. Green ammonia could be produced at scale either in the north or in Magallanes, relying on solar or wind, respectively, in proximity to export ports. As for domestic applications, the greatest market potential is in hydrogen for CAEX (heavy-duty) trucks for the mining industry, mainly in the north of the country, although there is still a significant technology gap to bridge (dual diesel/GH internal combustion engines or hybrid fuel cell with batteries are still not fully developed) as well as stiff competition from other potential low-carbon solutions (such as electric trucks using overhead lines) as well as batteries, which are advancing rapidly. Fertilizers are another promising application, and while domestic demand may be limited, regional demand (such as Brazil) is large. GH forklifts, which can outperform their electric benchmark in 24/7 logistic hubs at present costs, while feasible today, are limited by the small scale of the market. GH for fuel cell back-up generation is still uncompetitive with respect to batteries and diesel. A more detailed analysis of each case is presented in appendix B.

FIGURE 4.3 MARKET POTENTIAL, READINESS, AND COMPETITIVENESS FOR SELECTED GREEN HYDROGEN APPLICATIONS

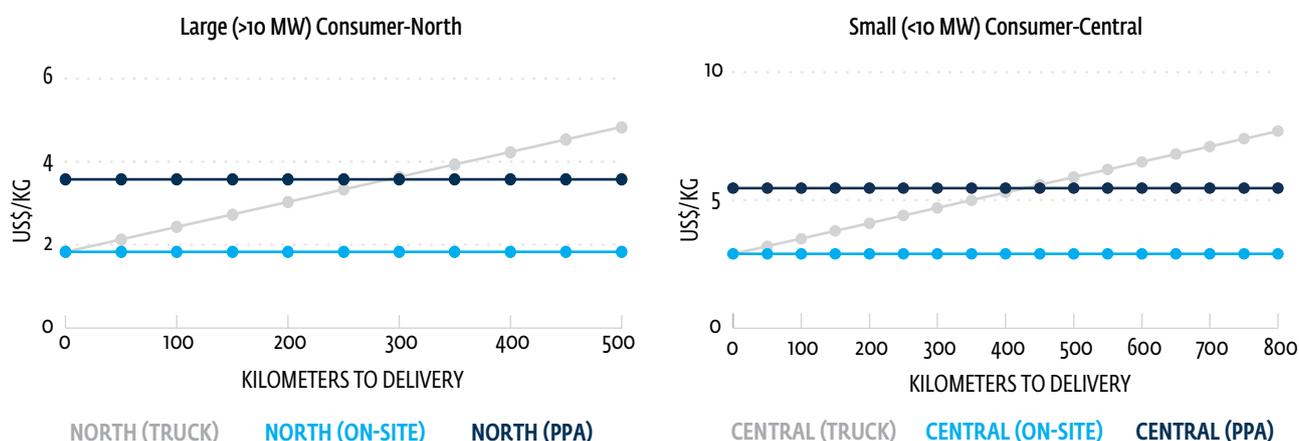


Source: CPSD team.

Note: CAEX = combustion system for mining; FC = Fuel Cell; GH2 = green hydrogen; NG = natural gas.

An important part of the GH equation is the need to ensure its cost-effective transport to demand points. Adapting existing infrastructure (for example, converting the existing natural gas pipeline networks), to transport GH is one possibility. For this, pipeline infrastructure would need to be tested and possibly upgraded to meet safety standards; no reliable cost estimates for this are available yet to judge its value in use. Safely transporting hydrogen through existing infrastructure can be facilitated through its blending with small amounts of natural gas, although a long-term strategy would be needed to avoid locking in use of natural gas and to ensure its replacement (BNEF 2020a).¹⁸ Despite high transmission charges, GH developers are also considering connecting to the grid given the need to keep electrolyzers running, although this implies a cost increase; battery storage is under evaluation but appears not to be competitive yet. Another option is off-grid GH production at locations where renewable energy can be produced most cost-effectively, with compressed GH delivery by truck to the end-user location. Given the structure of electricity grid charges in Chile,¹⁹ this solution may be more attractive than producing GH on premises with electricity from the grid. Dedicated truck GH transportation costs would add US\$0.60/kg per 100 km and, at distances of 300–400 km, is estimated to be more cost-effective than grid-fed electrolyzers (see Figure 4.4 which illustrates the distances at which each option—GH production with grid electricity versus off-grid production—is most cost-effective). Further details on the competitive analysis of GH can be found in (appendix C).

FIGURE 4.4 GH PRODUCTION AT OPTIMAL SITE WITH TRUCK DISTRIBUTION COSTS VERSUS ON-SITE RENEWABLE PPA PRODUCTION



Source: CPSD team.

Note: kg = kilogram; PPA = power purchase agreement; MW = megawatt.

A potential domestic demand niche for GH may be in and around Chile’s mining ports. Some ports, such as Mejillones or Puerto Guacolda II, maintain commercial relations with mining companies throughout the country. These can therefore function as demand hubs, not only for forklifts based on GH, but also for hybrid CAEX trucks (both competitive today provided there is access to a supply of GH). Export applications such as green ammonia could benefit from the same production and storage infrastructure as forklift applications based on GH. A GH valley or hub could be developed around the port of Mejillones (with forklifts and an export terminal for green ammonia). As discussed earlier, assuming that demand is less than 300 kilometers from the location of renewable energy generation (solar PV in this case), it would be most cost-effective to produce GH where the energy is being generated and transport it via dedicated trucks to the location of use. Given Chile’s geography, the area would also be likely to incorporate—within the 300-kilometer (km) radius where truck transport of GH is cost-effective—other GH demand points (such as other mining operations; see figure C.4 in appendix C).

Enhancing linkages between GH and renewable electricity markets

Innovation opportunities to leverage renewable energy to produce GH

There are a number of opportunities to leverage renewable energy to produce GH as well as to find synergies by using GH to increase the flexibility of the existing power grid. This subsection highlights some of these opportunities.

In the near term, oversizing the capacity of solar plants appears to be the most viable and cost-competitive option to expanding the supply of renewable energy for the production of GH. One of the main variables affecting the (levelized) costs of GH production is the usage factor of electrolyzers (see appendix C). Because the cost of the electrolyzer is fixed, the more GH produced, the lower the production cost per unit of output. Both solar and wind technologies are limiting in this respect: solar generation provides high predictability but a low-capacity factor, while wind is less predictable but enjoys a higher capacity factor, especially in the extreme south of Chile (Armijo and Philibert 2019). A potential solution to intermittency is to rely on hydropower when solar or wind are unavailable. Although hydropower represents one-quarter of Chile’s total installed capacity as of April 2021 (CEN 2021), strong civil society opposition suggests that new large hydropower capacity is unlikely to be developed.²⁰ Another technology, concentrated solar power (CSP), has been shown to be particularly suitable for renewable generation at large scale, with a constant generation profile. Chile has already built the first CSP plant in Latin America and has announced several other projects.²¹ The Ministry of Energy announced that by 2050 the installed CSP capacity could reach 10,000 MW. Because of the high electricity intensity need for GH production (Gallardo et al. 2021), CSP could represent an opportunity in the medium to long term, when the technology is more consolidated.

Power transmission infrastructure in Chile is inadequate and has led to curtailment of renewable energy in many substations; the production of GH may be an opportunity to exploit this curtailed energy.²³ Chilean legislation does not support growth of distributed energy resource (DER) systems (PMGD for its acronym in Spanish), a solution that could address this transmission bottleneck by providing small, modular, energy generation and storage technologies where they are needed. Because of an overpopulation of PGMDs, regulation allows for the expansion of primary substation capacity only in response to an increase in demand and represents an imminent

curtailment risk for PMGDs. An interesting business model for GH production could be as insurance for PMGDs that are over-exposed to curtailment; a recent Corfo study has identified 25 substations in the electricity system with high curtailment risk (Corfo 2020). Running an electrolyzer solely with curtailed energy for a few hours per day would not, however, achieve a competitive price; such a model would also need to consider a competitive renewable supply for the remainder of the time (BNEF 2020c).

Green hydrogen also presents an opportunity to increase the reliability of the electricity system by providing flexibility or peaking services, allowing the power system to adjust to demand and supply variability. Many industries use batch processes that require large amounts of energy in short bursts, which could cause reliability problems in the electricity system. Flexibility services could be provided by GH because of its high energy density and rapid delivery rates, securing a 100 percent renewable energy mix (BNEF 2020d). Discussion regarding flexibility services and how to remunerate them is still at an early stage. Today, regulation is a barrier to the deployment of solar PV and storage. Grid parity for this combination is expected in the coming years as battery prices continue to decline.²⁴ The Ministry of Energy is working alongside civil society and the private sector on a flexibility strategy (the MinEnergia Flexibility Strategy) to define the main regulatory changes needed to incorporate flexibility attributes in the market and integrate new infrastructure to secure the reliability of the system with an integrated grid that relies on renewable energy. This strategy is focused on storage and includes opportunities for providers of batteries and other ancillary services to the grid.²⁵

Another regulatory innovation that could be implemented in the short term is an exemption from grid transmission charges. This could contribute to the scaling up of on-site production of GH. A similar transmission exemption was put in place in 2004 for the promotion of distributed generation from renewable energy sources and could be replicated for the early development phase of the hydrogen market. Such an exemption would open the door to supporting various specific technologies.

What would it take to realize the potential of GH in Chile?

To support the development of GH production, the government needs to identify the GH applications it will support and introduce regulation to incentivize investors; financial mechanisms need to be established that reduce the risks for early adopters and bridge the gap between supply and demand. Actions can be focused on the supply side (production of GH), the demand side (usage of GH to provide a product, service, or process), or both. Some recommended initial measures are outlined in this subsection. At this stage, most measures are focused on the demand side, as it is critical to achieve economies of scale to enable project investment.²⁶ The focus is on recommendations to be implemented in the next five years and that target the most pressing needs for market development and the provision of financial support, critical to mobilize private investment. Complementary measures such as strengthening local technological capabilities; enacting EHS regulations; and advocating for GH over blue hydrogen, are being addressed by the Chilean government and international partners. It should be noted that GH is not the goal; rather, it is a tool. An assessment needs to be made as to where, when, and how it can be used, and then it needs to be promoted where it makes sense.

Many of the recommended measures include regulations and incentives to support the establishment of this nascent industry, albeit complemented by a policy and framework to allow the industry grow competitively over time. It will be important to define clear exit strategies—that is, a phasing out of potential subsidies—as regulated and subsidized assets can become stranded assets over time.

The following proposed measures aim to improve the outlook for the development of a GH industry, for both domestic uses and export.

1. **Design and deploy risk-mitigation instruments to attract private investment to shared infrastructure assets.** Electricity transmission infrastructure, electrolyzer capacity, pipelines, storage capacity, and ports are necessary infrastructure investments to enable the supply of GH. These are capital intensive investments that can be seen as “shared infrastructure assets” and that rely on the existence of long-term offtake contracts, preferably in hydrogen valleys where demand can be aggregated. These investments face market risks, including an uncertain demand and very high cost. Risk-mitigation instruments, like blended finance, can improve the risk-return ratio and attract competitive sources of private finance.

2. **Design and implement a contract-for-difference scheme for GH and GH-derived products, matching bankable off-takers with a competitive supply of Chilean products through an auction process.** Price-based mechanisms aim to provide a stable and predictable source of revenue for clean energy investments, to achieve a certain installed capacity. One of the most well-known instruments is feed-in-tariffs.²⁷ Yet another price-based approach called contract-for-difference (CfD) can help reduce the price gap between supply and demand. First, an intermediary would handle double-sided²⁸ auctions to conclude long-term contracts between aggregated buyers and providers. Then, a dedicated fund would cover the difference between the clearing price for providers and the clearing price for buyers. This dedicated fund would use concessional resources to attract private capital, with the expectation of creating revenues as the gap between costs and prices decreases. Once the technology becomes more competitive and the demand for GH starts to catch up, this cost-price gap would be reduced, until the buyers’ clearing price becomes higher than that from providers. This would create an economic surplus that would replenish the dedicated fund so that private capital can be remunerated. Hence, it would be very much like a reimbursable grant that assures the minimum concessionality. This approach would provide investment security and suit primarily export-oriented projects (such as green ammonia and green methanol) to match demand from international customers willing to pay a price premium. Yet, it could also target the demand from domestic industrial consumers of GH and GH-derived products that are close to price-parity (such mining haul trucks and forklifts). The initial cost of the dedicated fund could be split between the markets that would benefit from the economies of scale obtained from this initiative. In addition, a CfD mechanism would install, ensure, and monitor optimal environmental and social criteria for the proposals accepted in the auction process.²⁹ Such a fund could also cover the gap between the clearing price for providers and buyers by selling the carbon credits it accrues from the projects it aggregates; it could also be used for raising money through green bonds.

3. **Implement a domestic GH quota scheme combined with a tradable GH certificate scheme.** Domestic end-users, retailers, or both would produce or buy a certain quota of GH defined by national GH demand targets, similar to renewable portfolio standards (RPS). This approach would help aggregate the demand from early movers, such as hard-to-abate sectors and ports,³⁰ consistent with the sectoral emission reduction targets being developed by the Chilean Long-Term Climate Strategy (ECLP). It would improve conditions for competitive procurement of strategic supplies, setting the scene for the creation of “hydrogen valleys” that can promote new GH users who are in proximity to anchor clients.³¹ Tenders under this scheme would benefit from a well-known demand package. This measure would target, in particular, industrial users who can benefit from the blending of GH into the natural gas network, or from the incorporation of synthetic fuels for specific applications. Some of the potential downsides of this measure that need to be carefully assessed are the pass-through of additional costs to end-users and the lock-in from blending mandates that might delay other decarbonization approaches (like electrification or the deployment of hydrogen dedicated pipelines) (Graafa and Overland 2020).

GH certificates would allow tracking of the environmental contribution of blending GH, so end-users can report on it. A GH certificate scheme would help local producers capture extra revenue or a “green premium” that could boost production and position the Chilean label in international markets. Decarbonization regulations in target markets—such as quotas on consumption, materials, and products, and a carbon tax—are critical to secure revenue streams that can support early development of GH projects in Chile. As is the case with regulatory credits elsewhere, credits for compliance markets are traded at a premium with respect to voluntary credits. If these premiums can be effectively captured by GH project developers in long-term off-take agreements, they could have a material impact and accelerate the nascent project pipeline, particularly in hard-to-abate sectors (such as steel, cement, and heavy-duty transport). While Chile could develop its own certification system (for example, for domestic demand), a better option may be to adopt internationally recognized schemes compatible with those used by target countries (such as CertifHy in Europe).³² Integration of the existing decentralized platforms, each with different approaches and attributes, would be required to avoid double counting and claiming of renewable attributes of GH in order to prepare the ground to adopt schemes compatible with international markets.

- **Procure GHG emission reduction certificates as pilot initiatives leveraging Article 6 of the Paris Agreement.** GHG emission reduction certificates mitigate the economic risk of a project, reducing the viability gap for new projects and thus facilitating the formation of joint ventures with clients. Article 6 of the Paris Agreement is key to broaden the scope of carbon markets.³³ It allows expansion into projects that are more expensive than standard renewable energy investments, like GH projects (since these are additional to the local domestic GHG emission targets set by the NDC). The proposal here is to pilot GHG emission reductions from Chilean GH projects, under any of the market mechanisms from Article 6 of the Paris Agreement, with procurement of certificates by international parties and the assistance of the World Bank’s Climate Warehouse.³⁴ This measure considers launching procurement with funding assistance from donors and leveraging a contract-for-difference scheme applied to GHG offsets. The purpose is to mitigate the risk of the upside (offset), reduce the viability gap for new projects, and define market signals to trigger GH demand. This should reduce the viability gap from new projects and thus facilitate the formation of joint ventures with clients.

- **Promote GH flexibility applications for renewable electricity integration and balancing in microgrids.**³⁵ Promote GH as a long-duration energy storage (>10 hours) and as a balancing asset that can enable the integration of renewables in isolated microgrids (for example, San Pedro de Atacama, Easter Island, and others).³⁶ Several isolated microgrids exist in Chile, most of which are supplied with 100 percent fossil fuels (diesel and natural gas) despite the availability of abundant high-quality renewable energy sources. The distance to the national grid is a limitation, supply is not 24/7 and may be subject to natural events and other contingency interruptions. Because of the poor quality of the existing grids, larger off-takers use their own diesel self-generation—resulting in GHG and local pollutants emissions—or require costly grid upgrades. GH production and storage to regulate load ramp-ups from large consumer and balance demand and supply can be a sustainable solution for these microgrids. Such an approach would include the preparation of a methodology to estimate and monetize the environmental and grid advantages of such GH applications and provide financial assistance to cover investment costs (cost-benefit analysis—including social and environmental costs—providing evidence of cases where the use of GH production and storage outperforms the alternatives.

Table 4.2 provides a matrix of recommendations for developing green hydrogen in Chile.

TABLE 4.2 RECOMMENDATIONS FOR DEVELOPING THE GREEN HYDROGEN INDUSTRY

Strategic objective	Short-medium term actions	Potential partners for Implementation
Supply-side measures		
<p>Design and deploy blended finance mechanisms to attract private investment for infrastructure. The mechanisms should mitigate exogeneous risks and reduce market uncertainty from shared infrastructure assets.</p>	<p>Establish forecasts of the expected infrastructure investments and upgrades required under different GH adoption scenarios, with attention focused on meeting demand niches that are closer to break-even. In addition, encourage partnership and associativity between project developers and suppliers to allow economies of scale and to efficiently allocate project risks: This cooperation should bring down the costs of production, conversion, and transportation.</p> <p>Rapidly deploy remuneration schemes under PPP mechanisms and undertake a roadshow to promote the portfolio among potential private investors. A mechanism is needed to allocate the costs among different users of this type of infrastructure.</p> <p>Establish mechanisms for the continuous review of local technology needs. To keep track of evolving technology in the GH production process, it is key to continuously review local technology needs and organize open-innovation calls to sponsor the establishment of technology providers and academic partnerships, which can transfer and adopt these technological capabilities locally. Also, to mitigate some of the technological risks, it will be necessary to improve the skills required to maintain and operate the new technology.</p> <p>Develop comprehensive EHS regulation. This is a necessary condition to provide certainty for the production, transportation, and distribution of GH. The promotion of research and development and international technology transfer on EHS issues (such as limits for blending into the natural gas pipeline) is important to advance in this area.</p>	<ol style="list-style-type: none"> 1. Government of Chile, Chilean agencies that promote exports and foreign investments, 2. IFI— by providing technical assistance in sizing financial risk, choosing blended finance schemes, and establishing concessional funding.

Strategic objective	Short-medium term actions	Potential partners for Implementation
Demand-side measures		
<p>Provide a stable and predictable source of revenue for GH investments through price-based mechanisms in order to achieve a level of installed capacity.</p>	<p>Design and implement a CfD scheme for GH and GH-derived products through an auction process that matches bankable off-takers with a competitive supply of Chilean GH. An auction process would aim to reduce the price gap between supply and demand. Prospect potential niches of demand, design the CfD scheme, create governance of the CfD intermediary, create the fund, and deliver a roadshow of the first double-sided auction to motivate and recruit customers.</p> <ul style="list-style-type: none"> • Identify early movers for the use of GH and GH-derived products and assess their counterparty risk. Identify and network with potential off-takers abroad willing to pay a premium for GH supply and assess the demand aggregation opportunities of imported Chilean GH. Also, encourage low-carbon procurement by Chilean firms, by leveraging the influence of multinational clients. • Move to a certificate scheme or robust guarantees of origin scheme to create market differentiation and avoid lock-in from blue hydrogen against GH. Advocate for GH as the main option that fulfills a net-zero emission criteria. • Sponsor the development of pilot projects (through concessional financing) to reduce the risk perception from potential domestic off-takers. Also, share lessons learned and leverage experience from successful projects, through the “Green Hydrogen Accelerator” of the Agencia de Sostenibilidad Energética. 	<p>GIZ, government of Germany, Agencia de Sostenibilidad Energética, Invest Chile, other multilateral development banks and sources of concessional funding.</p>
<p>Support the aggregation of demand for GH from early movers, including hard-to-abate sectors and ports.</p>	<p>Implement a domestic GH quota scheme combined with a tradable GH certificate scheme. Domestic end-users, retailers, or both would produce or buy a certain quota of GH defined by national GH demand targets, similar to RPS. This includes setting GH adoption goals, based on economic and environmental goals; analyzing program design options such as size and timing of targets; using GH certificates; establishing flexibility mechanisms; and considering vintage eligibility and assess convenience of tenders.</p> <ol style="list-style-type: none"> 1. Develop legislation supporting a GH quota scheme and analysis for the development of a local market for a GH certificate. The former is under assessment by the Ministry of Energy and the latter is sponsored by the World Bank. 2. Design economic incentives to develop GH valleys (or “hydrogen hubs”) and assess impact in terms of job creation, economic contribution, and innovation. One example of these incentives is tax credits, yet their effect on fiscal revenues must be properly assessed. This input would be complemented by efforts to articulate demand aggregation for industrial clusters. 3. Assess the potential impact of public procurement programs for public infrastructure based on zero-emission materials to boost the GH demand in specific sectors (such as steel or cement). This would contribute to the GH demand goals set by the quota scheme. 	<p>For the development of GH hubs, partner with the EU’s Fuel Cells and Hydrogen Joint Undertaking (initiative under Mission Innovation), and partner with the Hydrogen Territories Platform.</p>

Strategic objective	Short-medium term actions	Potential partners for Implementation
<p>Leverage Article 6 of the Paris Agreement to support expansion into GH projects</p>	<p>Launching procurement of emission reduction certificates with funding assistance from donors and leveraging a CfD scheme applied to GHG offsets. The purpose is to mitigate the risk of the upside (offset), reduce the viability gap for new projects, and define market signals to trigger GH demand.</p> <ol style="list-style-type: none"> 1. Assess the viability of the GH project portfolio. 2. Estimate emission reduction potential, length of the crediting period, and ranges of the expected price points for certificates. 3. Identify potential international donors interested in partnering on this Article 6 pilot. 4. Help Chilean authorities assess the consistency of the pilot with the national NDC and issue a nonobjection statement. 5. Design an emissions baseline. 6. Encourage low-carbon procurement through multinational clients to enhance this measure. 	<p>GIZ (engaged in assessing these types of instruments for GH) and IDB (which has recently piloted a model that monetizes emission reduction as a source of revenue recognized by project financing structures).</p>
<p>Promote GH as a long-duration energy storage (>10 hours) and as a balancing asset that can enable the integration of renewables in isolated microgrids</p>	<p>Elaborate a comprehensive assessment methodology that showcases and monetizes advantages of this GH application identifying the different services and their expected revenues (or avoided costs) together with a broader social and environmental cost/benefit analysis.</p> <ol style="list-style-type: none"> 1. Determine microgrid operation parameters and load profile from target industries. Also help build a suitable business model around this GH application with commercial or industrial consumers that can benefit from the project. 2. Engage stakeholder with the microgrid administrators (such as cooperatives or municipal entities) and the local community. 	<p>Ministry of Energy and research centers</p>

Note: CfD = contract-for-difference; EHS = environment, health, and safety; GH = green hydrogen; GHG = greenhouse gas; GIZ = German international development agency; IDB = Inter-American Development Bank; IFI = International Financial Institution; NDC = Nationally Determined Contribution; PPP = public-private partnership; RPS = renewable portfolio standards.



4.2 ENHANCING RESILIENCE AND COMPETITIVENESS THROUGH CLIMATE-SMART AGRICULTURE

Chile's economy and exports are highly dependent on agriculture and its food industry, but climate change poses growing risks to the sector. The country could reduce the impact of climate change on the agricultural sector through investments in climate-smart agriculture (CSA) technologies, enhancing the sector's productivity, cutting GHG emissions, and building resilience. At the same time, CSA technologies could allow Chile to profit more from new opportunities that might emerge in the southern regions due to increased temperatures. This chapter reviews the impact of climate change on Chile's agricultural sector and provides estimates on projected losses for priority value chains, identifies the progress achieved in the adoption of CSA practices in recent years, and describes barriers to their wider uptake. Although larger producers are already adopting CSA technologies, especially in irrigation, there is room for further increasing private sector investments in partnership with the public sector. Smaller producers confront even greater challenges in the adoption of CSA technologies with greater support needed. By investing in climate-efficient products, Chile's agricultural exporters could also position their products in new higher-value green markets that are expected to grow at a faster pace than traditional low-value market segments.

The agrifood sector is critical to jobs and exports

The agrifood sector is an important contributor to Chile's growth and jobs. Between 1996 and 2020, growth in agriculture far outpaced growth in other sectors, although it has stabilized in recent years. When considering forward and backward linkages, the agrifood industry represents approximately 18 percent of GDP, 25 percent of exports, and 20 percent of internal sales. The food industry and primary agriculture are also an important source of employment, especially in rural areas, employing 23 percent and 9 percent of the national total, respectively. Agricultural employment is particularly important in the regions of Maule and O'Higgins, reaching close to 30 percent of the total.

High-value exports have driven the sector's growth. In 2019, the total value of the food industry's exports was US\$17.6 billion free on board (FOB) or close to 25 percent of GDP with the largest markets being the United States (25 percent), China (18 percent), Japan (10 percent), Brazil (5 percent), and Russian Federation (4 percent), followed by other EU countries. The highest-value exports are fruits (close to 30 percent of the total), especially grapes, cherries, and blueberries; wine (9 percent); pork (3 percent); and salmon and trout (29 percent). Chile accounts for nearly 60 percent of all fruit exports from the southern hemisphere and is the largest global exporter of grapes, plums, apples, blueberries, nectarines, and peaches. Preferential trade agreements (PTAs) to 65 countries or trade blocks have greatly contributed to the industry's growth (Invest Chile 2021). Exports have also benefited from third-party certification initiatives such as the British Retail Consortium, Global Good Agricultural Practice (GAP), Global GAP Risk Assessment on Social Practices (GRASP), Rainforest Alliance, and Tesco and Walmart providers to test compliance with good agricultural practices (World Bank 2020a). In addition, Chile has built its own fresh fruit certification, named ChileGAP, a program recognized by Global GAP, China GAP, and the United States.

The food production system is segmented into three groups—small family producers, medium-sized farmers, and large industrial producers—with different productivity levels and commercial orientation. Large industrial producers, focused on high-value products and exports, mainly fruits, have been the main drivers of the sector's growth in recent decades. They represent about a third of the total number of farms. Medium-sized farmers include some commercial producers as well as family producers that use external labor. Their presence is particularly strong in the dairy sector, which involves long-term purchase contracts with processing plants, higher levels of technology adoption, and a clear commercial focus (Fernández Barros and Pérez 2019). While most of the production is for the internal market, total exports of dairy products (especially condensed milk and butter) reached US\$120 million in FOB in 2020 with the United States, Peru, and Mexico as primary markets. Dairy production is mainly concentrated in the southern regions of Los Lagos and Los Ríos.

Small-scale (family) agriculture makes a valuable contribution to the domestic market of flowers and horticultural products such as tomatoes, corn, onion, beans, lettuce, and carrots. Using a limit of 12 hectares of basic irrigation, the 2007 Agricultural Census estimates that there are about 296,351 family farms with the typical family farm having less than 5 hectares. Over 50 percent of the land dedicated to the production of horticultural products corresponds to subsistence farms and small production, with serious capacity gaps in product quality management, a scarcity of new varieties, and a shortage of horticultural specialists.

Deteriorating conditions for agriculture due to climate change

Climate variability and extreme weather events are already increasing in Chile posing an important risk to its agriculture. Climatic forces seriously impact the frequency and intensity of extreme hydrometeorological phenomena such as the “mega-drought” that lasted from 2010 to 2015. Chile is among the 30 countries in the world with the highest water stress and the only Latin American one that will undergo extremely high-water stress by 2040. Water stress will result from the combined effects of rising temperatures in critical regions and changes in precipitation patterns (WRI 2015). Both groundwater and surface water supplies will likely decrease, with Valparaíso and Metropolitan as key affected regions (Table 4.3). Agriculture in Chile uses a staggering 88 percent of the available fresh water, but limited availability is already pressing the sector to use it more efficiently (Escenarios Hídricos 2018). For agribusiness to thrive, water management challenges must be addressed by both the public sector (through policy and capacity and governance building) and the private sector (through incentives for more sustainable water use) (Box 4.2).

Winds, solar radiation, and forest fires will also increase along with the occurrence of extreme weather events, and new pests will be unleashed in crops. Damage by more frequent winds and higher solar radiation will be more severe in the plateau area (altiplano). The probability of fires will also rise because of lower rainfall (González et al. 2011) and strong oscillations between cold winters and dry summers (Urrutia-Jalabert et al. 2018). In addition, changes in weather patterns will unleash new fungal diseases. The presence of pests is an extremely sensitive matter that can cause very large losses if exports are denied access to markets.

TABLE 4.3 WATER DEMAND AND AVAILABILITY FOR AGRICULTURE (SELECTED REGIONS), 2016

Region	Leftover water (km ³)	Irrigation demand (km ³)	Irrigation availability(km ³)	Deficit of surplus (km ³)
Atacama	0.05	0.12	0.05	-0.06
Coquimbo	0.57	0.53	0.43	-0.10
Valparaíso	0.60	0.65	0.45	-0.19
Metropolitana	2.14	1.03	0.91	-0.12
O´Higgins	4.61	1.58	1.84	0.26
Maule	15.25	2.24	3.65	1.40
Biobío	26.81	1.25	4.84	3.59

Source: Santibañez 2016.

BOX 4.2 KEY WATER MANAGEMENT CHALLENGES IN THE AGRICULTURAL SECTOR

- 1 Weak governance of water management: The regulatory and institutional framework for the institutional water resource management of basins could be strengthened. Weak coordination among national and local institutions restricts the management of water resources by sections. Transparency of the water market at the basin level and supervision of users, including of illegal withdrawals, could be increased. Limited, fragmented, and contradictory information on water resources contained in the public registry generates mistrust between actors.
- 2 Rising demand but falling supply: Growth in agricultural production, together with an excessive granting of water use rights to private users, is causing an increase in demand. At the same time, rising temperatures are causing lower rainfall and snow precipitation and a retreat of glaciers.
- 3
- 4 Overexploitation of aquifers: Estimates suggest that 110 basins in Chile are overexploited with demand surpassing their natural renewal, especially in the region of Valparaíso. Better water management and control are needed to allow the use of groundwater in a sustainable manner, including the complementary management of surface and groundwater.
- 5 Natural disasters: The frequency of extreme hydroclimatic events is rising, and population settlements are located in areas prone to floods.
- 6 Water pollution: The use of chemical products in agribusiness and the lack of sewage treatment in rural areas are contributing to water pollution. Saline infiltration is rising as aquifer levels drop.

Source: Loyola 2020.

Fruit and horticulture production have already been negatively affected by climate change during the past decade, but opportunities for new fruit poles are opening in the south. Less cold winters have decreased fruit yields.³⁷ A study by the Chilean Academy of Agronomic Sciences (2020) projects significant reductions in cold periods during the winter in different areas of the north, central, and south of Chile. This will require adaptation measures, including the search for new crops in the north that can survive in the new conditions. Conversely, a rise in temperature can reduce the risk of frost during the spring, which could increase the yields of fruit varieties. In addition, the widening of minimum and maximum temperatures has provoked a surge in new pests that cause damage to horticulture and high-value fruits.³⁸ For example, the *pseudomonas syringae* pathovar *actinidiae* found very favorable conditions in the Maule Region, and following the frosts of September 2013, the pathogen caused wounds in the kiwi and spread to the rest of the country (Redagricola 2019).

Severe droughts, floods, and higher temperatures are also contributing to decreased milk and meat production. The lack of rainfall in the southern zone during the summer months (December 2020 to March 2021) caused losses in some crops and lack of forage for the animals, resulting in lower cow production. Changes in temperature are also affecting production. In the regions of Los Ríos and Los Lagos, with a strong presence of dairy producers, the frost of 2007 decreased the availability of meadows for feeding animals, requiring diet supplements. This situation endangered the commercial viability of dairy farms without irrigation since feed supplements substantially increase operating costs.

To date, few studies have provided estimates of the impact of climate change on agriculture and most of them have just focused on specific regions or basins. For example, Fernández et al. (2019) estimate that, just considering the general effects of climate change and a 30 percent drop in water availability by 2040, the total cultivated land in semi-arid areas like the Maule region could fall by 17 to 30 percent, depending on improvements in irrigation efficiency. Estimates from Meza (2017) suggest that costs in the Maipo Basin could be as high as US\$101.2 million per year without better irrigation. The Chilean Climate Risk Atlas (ARCLIM), sponsored by the Ministry of Environment in collaboration with domestic and international partners, demonstrates the potential impact of climate change on the yield of 13 priority value chains (Pica-Téllez et al. 2020).

New estimates on the cost of climate change for 10 priority agricultural and three priority livestock value chains were conducted for this study in partnership with researchers working on the ARCLIM.³⁹ The value chains were the same as in those in the earlier ARCLIM study and were selected because of their relevance to Chile's agricultural and livestock sectors and the availability of data and models to simulate the impact of climate change (Tables 4.4 and 4.5).⁴⁰ The estimates will require further adjustments in the future. In particular, it will be very important to evaluate the impact of climate change on water resources, which will require joint hydrological and agricultural models that explicitly recognize the geographical, hydrographic, and climatic features of each of the basins as well as potential improvements in water use.

The simulations suggest that most of the regions can be expected to experience significant losses across a wide range of agricultural products, but the impact on livestock could be marginally positive.⁴¹ Without new climate adaptation measures, total annual losses on the 10 priority agricultural value chains are estimated at close to Ch\$0.330 billion on average for the period 2030–50, while total annual gains in the 3 livestock chains would be Ch\$0.011 billion on average (Table 4.4 and 4.5). Small variations in the productivity of high-value crops can have a significant economic impact. Apples, walnuts, cherries, and corn are expected to experience the largest losses, with most losses regionally widespread. The areas most affected correspond to the agricultural land located from the Bío region to the north, which contains the largest high-value fruit and vegetable production. Apples, one of the most important fruit trees with production concentrated between the Metropolitan and Maule regions, could suffer from the expected change in temperatures during the winter and summer periods. Regarding cherry production, the central zone of Chile will be negatively affected, while the southern zone could experience a slight increase in yield due to lower frost intensity. Walnut production is also highly susceptible to climatic conditions and frosts, while the expected changes in summer temperatures will likely reduce corn yields by 15 to 30 percent. Notwithstanding those forecasts, technological progress and climate change could open new fruit poles from the Nuble Region to the south. FedeFruta estimates an increase of 7,300 hectares of fruit trees (including high-value crops such as cherry, blueberry, walnuts, and hazelnuts) after 2012 from the Biobío to the south.⁴²

TABLE 4.4 ESTIMATED ANNUAL LOSSES DUE TO CLIMATE CHANGE IN 10 PRIORITY AGRICULTURAL VALUE CHAINS PER YEAR, 2030–50

Crop	National Average Income (Ha/Ch\$)	National Average Impact (Ha/Ch\$)	National Average Relative Impact (% of income)	Estimated National Aggregated Loss (Ch\$, million)
Wheat	876,720	(77,362)	(9)	-2,738.7
Wheat (secano)	625,659	(27,565)	(4)	-8,065.3
Corn	1,334,606	(580,162)	(43)	-47,009.8
Potato	4,686,726	(402,961)	(9)	-7,098.2
Potato (secano)	3,252,793	(117,137)	(4)	-1,065.8
Beans	3,691,010	(350,100)	(9)	-3,521.6
Cherries	11,624,640	(1,516,166)	(14)	-50,444.6
Apples	18,129,171	(5,465,059)	(31)	-146,757.4
Almonds	7,763,810.48	(223,995.11)	(2.9)	-3,401.6
Walnut	5,826,524	(963,077)	(17)	-60,044.4
Total		-		-330,147.5

Source: Meza 2021.

TABLE 4.5 ESTIMATED ANNUAL IMPACT OF CLIMATE CHANGE ON THE MAIN LIVESTOCK VALUE CHAINS PER YEAR, 2030–50

Crop	National Average Income (Ha/Ch\$)	National Average Impact (Ha/Ch\$)	National Average Relative Impact (% of income)	Estimated National Aggregated Loss (Ch\$, million)
Beef cows	850,390	7,996	1.06	1,564.6
Dairy cows	2,520,473	43,815	1.96	8,571
Sheep	556,038	9,617	1.94	1,870
Total				11,006.6

Source: Meza 2021.

By contrast, the total estimated effects on three priority livestock value chains will generally be neutral or marginally positive, especially for dairy cows. Livestock production is mainly located in the southern zone of Chile, which is characterized by a temperate climate with abundant rainfall. Temperature increases will induce plant growth which, together with small reductions in precipitation, will allow grassland to have normal growth and increase livestock production (table 4.5).⁴³ These climate change scenarios, however, could underestimate the occurrence of severe summer droughts or extreme weather events, which could affect the growth of grasslands as previously noted.

Initial adoption of climate-smart agriculture practices

CSA technologies are critical to help mitigate the effects of climate change on agriculture and to reduce its GHG emissions. These technologies encompass adaptation and mitigation production practices that not only help improve yields but do so in a sustainable way that helps manage future productivity, with special care of the soil and water resources. A meta-analysis of crop simulation under several climate scenarios found that adoption of CSA technologies could increase crop yields by an average of 7 to 15 percent compared with nonadoption (World Bank 2018).⁴⁴ CSA practices comprise a wide range of complementary strategies that embody different degrees of technological sophistication and upfront investments, including

- **nutrients** (such as organic matter, biodigesters and types of fertilizers);
- **water** (such as the expansion of more efficient and technified irrigation systems and new accumulation infrastructure);
- **energy efficiency** and a shift to renewable energy;
- **plant genetic improvement** to increase resistance to droughts and diseases or increase yields;
- **agronomic management strategies** to improve selection of sowing dates, graft, variety relationships, pruning, and fertilization levels;
- **precision agriculture or agritech**, in which inputs are optimized to make sustainable intensification more feasible, to allow savings, and to reduce the environmental footprint; and
- **climate information tools** to enhance policy making and private investment.⁴⁵

Numerous studies have already identified important measures that the Chilean agricultural sector could adopt to mitigate GHG emissions and cut production costs. In particular, the MAPS Chile Project identified CSA practices related to (a) organic agriculture, (b) biodigesters, (c) carbon sequestration in agricultural soil by applying organic matter, (d) plant genetic improvements, (e) use of fertilizers with nitrogen cycle inhibitors, and (f) use of renewable energy in irrigation that could result in annual reductions of more than 4 carbon dioxide equivalent (CO₂eq in million metric tons; MMt), based on 2014 estimates (Table 4.6).⁴⁶ The last item (use of renewable energy in irrigation) would produce the largest savings. Other studies have also noted that the adoption of smart energy technologies in agriculture could lead to substantial reductions in GHG emissions. Estimates from 2016 indicate that fossil fuels were 68 percent of the total energy consumption in the agricultural and food sector, and that the sector could reduce energy consumption by 16 percent with basic energy efficiency measures (AChEE 2016). Moreover, the substitution of fossil fuels with renewable energy could produce additional savings of 33 percent (equivalent to 18,594 GWh). In sum, the use of smart energy in the agrifood chain could lead to savings of 23,935 GWh.

TABLE 4.6 ESTIMATED IMPACT OF CSA ADOPTION IN CHILE

Technology	Description	Estimated impact
Organic agriculture	The application of organic matter to the soil in order to increase CO ₂ capture.	The promotion of organic agriculture could lead to accumulated reductions of 0.98 CO ₂ eq (MMt) by 2030, with an annual average reduction of 0.07 CO ₂ eq (MMt).
Implementation of biodigesters	The implementation of biodigesters at the property, to transform CH ₄ emissions generated in wells or lagoons from accumulated organic waste (slurry and/or manure).	The implementation of biodigesters could lead to accumulated reductions of 0.94 CO ₂ eq (MMt) by 2030, with average annual reductions of 0.06 CO ₂ eq (MMt).
Plant genetic improvement	The integration of genetically improved forage plants with lower methanogenic power into beef livestock systems. These species contain high levels of condensed tannins, which have the ability to reduce CH ₄ production through a direct toxic effect on methanogenic organisms in the rumen.	Plant genetic improvement could lead to accumulated reductions of 0.55 CO ₂ eq (MMt) by 2030, with average annual reductions of 0.04 CO ₂ eq (MMt).
Carbon sequestration in agricultural soil by using organic matter	The incorporation into the soil of materials with a high content of stabilized carbon in quantities higher than the mineralization levels registered by the said soil (deliberate accumulation). This enhances the stable organic carbon content in the soil, which in turn increases the carbon sequestration in agricultural soils above the base values considered in equilibrium.	Carbon sequestration in agricultural soils by application of organic matter could lead to accumulated reductions of 1.39 CO ₂ eq (MMt) by 2030, with average annual reductions of 0.09 CO ₂ eq (MMt).
Use of fertilizers with nitrogen cycle inhibitors	The application of urease inhibitors (IU) and/ or nitrification inhibitors (IN) in combination with nitrogenous sources to crops/meadows, to slowdown the denitrification and volatilization process of ammonia in the soil, in order to reduce the direct and indirect N-N ₂ O emissions on the base values considered in equilibrium (capture = emission).	Use of fertilizers with nitrogen cycle inhibitors could lead to accumulated reductions of 0.91 CO ₂ eq (MMt) by 2030, with average annual reductions of 0.06 CO ₂ eq (MMt).
Use of renewable energies in irrigated agriculture	The introduction of pumping systems for irrigation that use renewable energy sources (solar or other types). This would be a reduction for non-issuance.	The use of renewable energies in irrigated agriculture could result in accumulated reductions of 1.67 CO ₂ eq (MMt) by 2030, with average annual reductions of 0.11 CO ₂ eq (MMt).

Source: CPSD team elaboration based on MAPS Chile estimations of 2014.

Note: CH₄ = methane; CO₂ = carbon dioxide; CO₂eq = carbon dioxide equivalent; IN = nitrification inhibitors; IU = urease inhibitors; N-N₂O = ammonia; MMt = million metric ton

Chile's government is already fostering the use of CSA practices in the agricultural sector in partnership with the private sector. According to DIPRES (2021), in 2019, the Ministry of Agriculture (MINAGRI) and its associated agencies had the highest percentage (48 percent) of budget expenditures on initiatives related to climate mitigation (Ch\$39,298 million) and adaptation of the six ministries under analysis.⁴⁷ In particular, the Foundation for Agricultural Innovation, or Fundación de Innovación Agrícola (FIA), has played an important role in promoting CSA innovation, primarily among small farmers. During the 2015–20 period, nearly 72 percent of FIA's investments in CSA technologies focused on the horticultural sector, dominated by small producers, with an emphasis on management technologies (nearly 40 percent of the total) followed by pest control, marketing, and irrigation. In the fruit sector, primarily driven by large exporters, nearly half of investments have been on irrigation and biotechnology. More recently, the MINAGRI released the “Agri-Food Sustainability Strategy 2020–2030,” the first of its kind, providing key strategic guidelines for advancing CSA practices and aligning the sector to Chile's climate NDCs. The strategy defines three cross-cutting pillars (skills and innovation, networks, and economic capital) that will support interventions on three dimensions (environmental, social, and economic) and will be implemented through biannual action plans.

Following severe droughts during the past decade, the introduction of better water management technologies in agriculture has become a priority for the public sector as well as for larger scale producers (Fedefruta 2019). New irrigation technologies such as “drip” can increase water use efficiency by as much as 90 percent (Table 4.7). Multiple public instruments are already available to foster the adoption of improved irrigation technologies. In 2019, INDAP, the institute for the technological development of small farmers, identified irrigation as the priority among its sustainability programs, transferring almost US\$21 million for irrigation projects, and the National Irrigation Commission (CNR), tendered 37 projects for more than Ch\$ 67 billion. Corfo also provides partial credit guarantees for micro-, small- and medium-sized companies that invest in irrigation systems and provides subsidies for studies on irrigation (Revistaei 2019).⁴⁸ No other technology has received such a large public investment in agriculture.

TABLE 4.7 WATER USE EFFICIENCY OF DIFFERENT IRRIGATION SYSTEMS

System		Efficiency percentage
Gravitational	Laid	30
	Groove	45
	Cups	65
Pressurized	Aspersión	75
	Microaspersión	85
	Drip	90

Source: Manejo de Riego y Relaciones Hídricas, Facultad de Agronomía, PUC, in Echeñique 2018.

At the same time, large-scale producers are also making important investments on irrigation efficiency, according to a 2019 survey conducted by the National Society of Agriculture, or Sociedad Nacional Agrícola (SNA). In the dairy sector, the Consorcio Lechero estimates that technified irrigation could be the best way to enhance productivity by increasing dry matter in the pasture by 50 percent on average. Total investments in mobile sprinklers, however, are still limited in the dairy sector (Agrocolun 2019).

In addition to more efficient irrigation systems, the expansion of the hydrological infrastructure will be critical to meet the needs of the agricultural sector and to store glacier water during summertime. This effort will require substantial investments and greater knowledge of the potential environmental and social impacts. First, desalination of seawater has been adopted in mining, but it is not yet clear in which geographical areas and for what types of crops these significant investments could be profitable. The environmental impacts of these technologies also need to be analyzed because they can cause residual water problems in the surrounding aquifers. Second, water recycling could be increased. At present, 22 percent of the water used in the sewage treatment plants is not returned to natural channels but sent directly to the sea. This water, representing a flow of 6.62 cubic meters per second, could be treated and reused. Fourth, water resources could be transferred to deficit basins. These macro-projects entail numerous risks and tradeoffs, thus requiring a careful analysis of technical requirements as well as social and environmental aspects. Currently, two basin transfer projects are being promoted by the private sector to bring water for irrigation from basins in the south-central zone to the northern regions.

Public and private sector investments in genetic innovation to increase yields and resilience are also growing, especially in the fruit sector. Most noteworthy is the research conducted by the fruit consortiums, involving universities, the Chilean Agricultural Research Institute (INIA) and the private sector, on table grapes, stone fruit, and berries, which demonstrate that the country has the potential to take a leap into genetic innovation, especially in the viticulture and fruit sectors (Echeñique 2018b). Between 1991 and 2016, the Ministry of Education, the Ministry of Economy, and the MINAGRI granted US\$15 million for 32 projects related to the genetic modification of economically important crops and forest species (Sánchez and León 2016). Chile is ready to develop new national varieties in those species in which it has a critical mass of production and significant market, especially fruits. This will require the renewed existence of germplasm banks, whose collections will be the basis for genetic improvement. Genetic research can also be promoted in search of sustainability of basic annual crops such as cereals, oilseeds, and industrial crops; native and exotic forestry species; and dairy, beef cattle, and sheep, among other products. New and genetically improved varieties can be widely disseminated with the active role of nurseries and producer associations. The demand for new varieties has been in high demand in recent times, with the replanting of orchards in the central zone and the advancement of new plantations in the southern, coastal, and foothills territories.

The Chilean fruit sector has accumulated experience in precision agriculture, having achieved higher yields and important savings on water and agro-chemicals. The technologies used by precision agriculture measure the factors that affect the variability of production and product quality at any given time in order to adjust and optimize the use of inputs.⁴⁹ In addition, these technologies allow the quantification of inputs used for ecological certification (such as water, carbon, energy, and nitrogen) with great precision. INIA and FIA have partnered with fruit producers to actively promote the use of these technologies (Echeñique 2018b).

The wider adoption of CSA technologies can open up new opportunities for Chilean exports in light of the growing global demand for traceable and climate-efficient products. The fast-growing performance of the sustainable and organic sectors indicates that green commodities are becoming an attractive niche market. Sales of organic food and drinks reached nearly US\$120 billion in 2019, with the United States, the EU, and China as the largest markets, and could grow to US\$175 billion in the next few years. (Willer et al 2021) By contrast, the growth expectations of conventional markets are low. Changes in food markets are coming from the demand side in both high- and middle-income countries (especially China) and also from regulatory changes such as the General Food Law in the EU, which limits the amount and type of waste obtained throughout the production chain, along with new carbon taxes that especially demand deforestation-free products. Chile's organic exports have been steadily rising from US\$202.5 million in 2014 to US\$287.3 million in 2018 and could expand significantly more (ODEPA, 2020). Exports of fruits and vegetables, however, could be relegated to low-value market segments if better CSA practices are not embraced more widely.

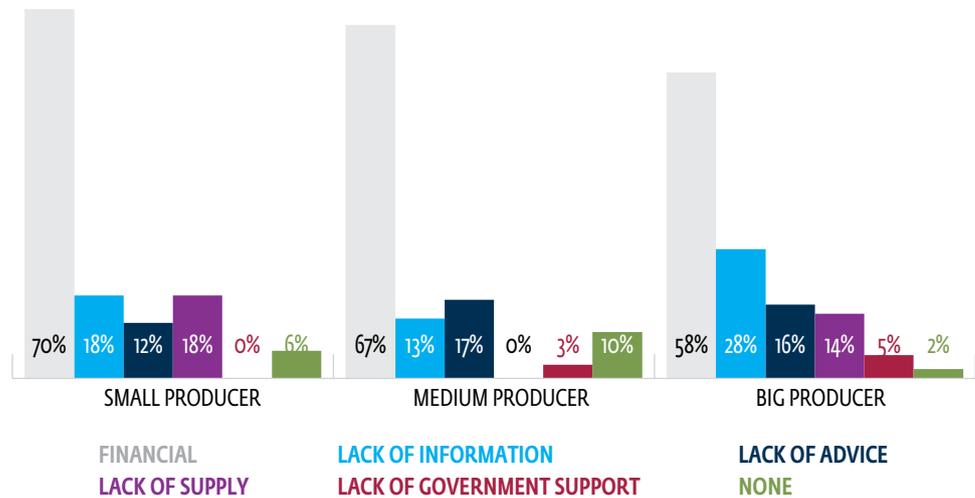
Despite public investments, the uptake of CSA technologies remains quite limited among small producers. Data from the Institute for Agricultural and Livestock Development (INDAP) indicate that only 37 percent of small farmers performed mechanized work and 6 percent used a computer in their business in 2016. The adoption of measures for improved natural resources conservation and management is particularly low among beneficiaries of INDAP's programs. On average, 11 percent of INDAP users apply methods to optimize water quality, 5 percent have GAP or Good Practices on Livestock Certification (BPG) certification, 15 percent have technical irrigation, 50 percent use recovery methods for soils, and 8 percent apply RISES (solid industrial waste; *residuos industriales solidos*) and RILES (liquid industrial waste; *residuos industriales líquidos*) management measures.

Challenges to scaling up CSA in Chile

While some progress has been made, multiple obstacles are holding back the wider and faster uptake of CSA technologies. Prior studies and stakeholder consultations point to limited access to finance and information on technologies available as key barriers to scaling up CSA adoption, especially among smaller producers. High upfront costs deter investments in renewable energy. More intense efforts are also needed on innovation and R&D as well as better coordination among agencies supporting CSA innovation and technology transfer. The available physical infrastructure falls short of what is needed to cope with the strong variability of precipitation in Chile. Agri-environmental information can also be strengthened to support policy making and investments by the private sector. Higher penetration of digital technologies in rural areas together with capacity building, as discussed in section 4.3, would also support the broader adoption of precision agriculture and other CSA practices.

Limited access to finance

Access to finance is one of the main barriers to adoption of CSA technologies—with small producers facing higher constraints. A 2015 market study by PMG Business Improvement in the Coquimbo and Los Lagos regions indicates that the main barrier to accessing new technologies for increasing productivity, water efficiency, and adaptation to climate change is project financing (64 percent), followed by the lack of information (21 percent) and of advice (15 percent). Financing is an even greater barrier for small producers, with 70 percent of them considering it the most important constraint versus 58 percent of large producers (Figure 4.5).

FIGURE 4.5 CONSTRAINTS IDENTIFIED BY SMALL, MEDIUM, AND LARGE PRODUCERS (%)

Source: PMG Chile 2015.

Several factors have typically made the financing of agriculture challenging, but the features of CSA projects make their financing even more complex. First, the sector is perceived as risky because of exposure to high price volatility and climate variability. Second, agricultural financing requires highly specialized knowledge (such as technical knowledge of sowing and harvest dates and types of products and yields). Third, production is highly dispersed across the country, further raising transaction costs (Clarke and Associates 2009). Small farmers tend to be more dispersed and to have limited financing knowledge, thus posing another obstacle. In addition to the traditional agricultural financing challenges, adopting CSA practices often demands a substantial upfront investment to support the necessary transformational changes (Sadler et al. 2016). This entails a significant increase in the amount of capital as well as longer maturities (five to seven years) and more flexible conditions (such as repayment schedules adjusted to cash flows) so that producers can make the necessary investments to sustain or raise current yields while increasing their resilience and cutting emissions. Moreover, both producers and financial institutions typically have inadequate knowledge of how CSA investments will enhance production, how these improvements can be reflected in productions plans, and how to conduct the loan appraisal process accordingly. Addressing these challenges requires new solutions. Innovative financing initiatives, often coupled with technology extension services, are emerging globally along supply chains that could be tested in Chile (Box 4.3).

BOX 4.3 SWITZERLAND: PILOTING A GOAL-ORIENTED FARMER PAYMENT SYSTEM FOR CLIMATE-SMART MILK PRODUCTION

Cattle (raised for both beef and milk, as well as for inedible outputs like manure and draft power) are the species responsible for producing the most emissions globally, mainly in the form of methane from enteric fermentation. The same is seen in Switzerland, with cattle contributing 3.3 million of the 6.0 million tons carbon dioxide equivalent that the agricultural sector emits annually. The dairy industry—the largest cattle group in Switzerland—plays a crucial role in reducing the country’s overall greenhouse gas (GHG) emissions. Both the government of Switzerland and Nestlé, the world’s largest food and beverage producer and a major milk buyer in Switzerland, have pledged to reduce their net GHG emissions by one-third and zero net, respectively, by 2050. Switzerland became Nestlé’s pilot country for GHG reduction in dairy production. Thus comes the creation of a multistakeholder climate-smart dairy farming project that is based on a participatory bottom-up approach that tackles this challenge.

Implementing climate-smart practices can have a high fixed cost in the short run due to large investments in new technologies and ways of working. Not only have Swiss farmers faced economic challenges, but also over the years, climate change has threatened the sustainability of the agricultural ecosystem in the country. Given the difficult economic situation of many Swiss dairy farmers, financial incentives were crucial to motivate farmers to implement the GHG reduction measures. Nestlé provided the funding to dairy farmers in two forms: a participation payment and a goal-oriented premium payment related to GHG reductions. Farmers were able to set individual measures based on their baseline GHG emissions per kilogram of milk and were compensated according to the kilograms of milk produced using the climate-smart livestock practices. Extensive technical assistance was provided to facilitate the adoption of the new working practices. The project was successful and demonstrated the possibilities of scaling up.

Source: FAO 2021.

Among other obstacles, high costs and financing challenges are slowing down investments in renewable energy infrastructure. Chilean farmers are highly sensitive to energy prices because of their high energy usage across the value chain, including to extract and distribute water, to heat animals or greenhouses, and to maintain or process fruits. In areas not connected to the national grid, farmers use highly polluting diesel generators, with a higher cost and environmental impact (El Mercurio 2021). A higher use of renewable energy in the sector would substantially lower its environmental footprint and reduce electricity costs along the value chain. The National Irrigation Commission has completed 906 irrigation projects powered with photovoltaic energy, of which 80 percent correspond to small agriculture, but high costs constitute a big adoption barrier (El Mercurio 2021). Innovative modalities such as the energy service company (ESCO) approach have been applied in several EU countries to finance renewable energy in the agricultural sector and could be tested in Chile (Box 4.4).

BOX 4.4 ESCO APPROACH TO FINANCE RENEWABLE ENERGY IN THE AGRICULTURAL SECTOR

An energy service company (ESCO) offers energy services, typically on a turn-key-basis, and may include energy-efficiency or renewable energy projects, or both. When adopting an ESCO approach, the farmer no longer has to make a large investment upfront and can obtain a price lower than the price paid to the grid.

The three main characteristics of an ESCO are the following:

- ESCOs guarantee energy savings, the provision of the same level of energy service, or both, at a lower cost. The performance guarantee can (a) revolve around the actual flow of energy savings from a project, (b) stipulate that the energy savings will be

sufficient to repay monthly debt service costs, or (c) stipulate that the same level of energy service will be provided for less money.

- The remuneration of ESCOs is directly tied to the energy savings achieved.
- ESCOs can finance, or assist in arranging financing, for the operation of an energy system.

ESCOs differ from traditional consultants or equipment suppliers by financing or arranging financing for the operation, and their remuneration is directly tied to the energy savings achieved.

Source: European Union, Joint Research Centre, European Energy Efficiency Platform.

Inadequate development of the R&D system and effectiveness of technology extension systems

Chile's adaptation to climate change will require a more intense process of technological innovation along with a stronger push on technology diffusion. Innovation is needed to facilitate the adoption of technologies that help optimize the use of production inputs such as water, energy, and fertilizers. Genetic innovations will be another important tool to adapt to climate change both to mitigate the impact on existing crops and to allow the development of new opportunities such as the advancement of horticulture, viticulture, and fruit growing in the southern part of Chile (Echeñique 2018b).

Innovation will also be critical to reducing the release of methane from livestock and limiting GHG emissions from the sector under the new long-term Climate Change Strategy approved by the government in November 2021. Many OECD countries are actively conducting research on this space. New Zealand, for example, has separated methane targets from other GHGs reduction targets, because the release of methane from livestock accounts for one-third of all the country's GHGs, and is actively funding public-private research initiatives to find new feed supplements (such as red seaweed) for livestock to drastically cut methane emissions (Ainge Roy 2019).

However, Chile's overall efforts in innovation are low compared to its peers and so are its innovation investments in agriculture. According to the OECD, 40 percent of food processing companies in Chile are active in innovation compared to 70 percent in Belgium and around 60 percent in France and Italy (OECD 2018f). Building on successful public-private R&D partnerships, with strong ties to the higher education sector, is key to increasing the participation of the private sector in agricultural innovations and to scaling up the adoption of CSA technologies in the country.

Moreover, at least five public institutions are contributing to innovation and technology transfer in the sector, with more coordination needed to achieve greater impact. INIA conducts R&D on agriculture in collaboration with universities and the private sector and also provides technology extension services. Its research covers, among other things, (a) genetic improvements for multiple crops; (b) adaptation of species and varieties of fruit trees to the new agricultural frontier in the southern regions; (c) pest control in changing climatic conditions; (d) control of GHG emissions, especially by livestock; (e) prevention of deforestation; (f) irrigation technologies; and (g) generation of new applications for decision-making by producers.⁵⁰ Corfo administers the R&D tax credit, including for agriculture and the food sector, but the number of projects with R&D tax credits in these sectors seems very low.⁵¹ CNR finances CSA solutions related to irrigation, while FIA finances innovation projects related to climate change and sustainable agriculture and promotes knowledge networks in these areas. INDAP also supports innovation in small agriculture by providing financing and technology extension services for smaller farmers and by establishing alliances with universities and research centers. In addition, large and medium-sized producers of specific agro-ecological zones are forming technological transfer groups (GTTs) to exchange knowledge on technology adoption. In 2020, 65 GTTs were operating with INIA's collaboration and another 80 with SNA support. These different initiatives provide valuable technology transfer on CSA technologies but could be better integrated to achieve greater impact.

The existing infrastructure is inadequate to cope with the strong variability of precipitation in Chile. With current water demands, reservoirs at best have a capacity to mitigate the drought of a couple of consecutive years, which is clearly insufficient during prolonged droughts (Santibañez 2018). The built capacity of reservoirs is still relatively small. In 2008, all the reservoirs between regions I and VII stored 5.3 cubic kilometer (km³), or 40 percent of the annual water consumption by irrigated agriculture, which reached about 14 km³. These figures place the country in a situation of vulnerability in the face of prolonged drought periods and rapidly melting glaciers. To resolve this situation, the country's reservoir capacity has to grow by approximately 50 percent to significantly reduce the impacts of droughts. Using the tools established in Law 18.450, on minor irrigation works, CNR is expected to keep investing in civil works, technification, accumulation, and irrigation management, with a special emphasis on the "Small Farming and Indigenous Population Program," in which Ch\$5,255,000,000 or 8.3 percent of the total budget for minor works was invested in 2020.

Insufficient availability of agrienvironmental information is affecting policy making. According to the latest Environmental Performance Review report of Chile carried out by the OECD (2016), Chile presents gaps in agrienvironmental and climate information, the conservation status of species, soil contamination, the value of biological biodiversity and ecosystems, and the cost that supposes their loss. The lack of adequate information impairs policy making in the agricultural sector. To adequately respond to the sector's challenges, a robust information system is required so that public and private investments (such as on irrigation and forestry) are based on a clear understanding of the areas that are most vulnerable today and their projected evolution in the next 20 or 30 years, and of the plant varieties that will adapt best to future conditions.

Recommendations

Transforming Chile's agriculture into a climate-smart sector is critical to align the sector to the country's NDC targets, to maintain its competitiveness, and to boost the resilience of family agriculture. The recently released the "Agrifood Sustainability Strategy

2020–2030,” which fills important vacuums by identifying key strategic priorities and enhancing governance and coordination mechanisms. However, it could greatly benefit from a detailed roadmap that translates the priorities into concrete targets that can be monitored over time and that identifies resources needed to achieve those targets. The biannual action plans will be useful working tools but too short to monitor progress on the achievement of higher-level objectives and to provide continuity to policies and programs over time. Governance mechanisms could be further strengthened by including the Ministry of SKTI within the new interministerial committee responsible for coordinating policies and programs on agrifood sustainability. Innovation is a key cross-cutting pillar of the strategy, and R&D investments in CSA by both the public and the private sector need to substantially increase along with more effective technology transfer mechanisms. The “Roadmap towards Climate Neutrality” produced by the Department of Agriculture, Food and the Marine, Republic of Ireland, in collaboration with public and private agents, combines strategic priorities with more concrete actions and targets and could be illustrative as Chile moves forward with the implementation of the agrifood sustainability strategy.

Opportunities abound for expanding innovative financing instruments for CSA. The agrifood sustainability strategy identifies the need to enhance financing mechanisms for CSA, but the financing of agriculture—in particular, CSA—is complex. A review of the full set of financial instruments available for CSA and opportunities for encouraging new innovative financing mechanisms is much needed. New solutions along supply chains could combine financing instruments with technical extension services—the two biggest challenges faced by small farmers. The experience of Nestlé with livestock could be adapted to other value chains (Box 2.3). Banco del Estado could intensify efforts to finance CSA. For example, FIRA, a second-tier development bank in Mexico focused on agriculture, has provided extensive technical assistance to rural financial institutions to assist with the development of new CSA portfolios. Credit guarantees for irrigation programs by Corfo could be expanded to other CSA areas that might require high upfront investments. Efforts underway to grow the coverage and type of insurance instruments (including new pilots on parametric insurance) need to ensure that these are complemented with CSA measures to foster sustainability and prevent market distortions, especially when insurance programs are subsidized. Finally, the issuance of green bonds by large agribusinesses such as CMPC and Hortifrut could be further encouraged.

Investment in renewable energy technologies could be further promoted. Because farmers are highly exposed to energy prices, the adoption of renewable energy sources is key to lower both the costs of agricultural production and GHG emissions. New public-private partnerships (PPPs) or private partnerships could be sponsored to foster the transition to renewable energy, building on successful experiences in Chile (such as the program on use of renewable energy in irrigation⁵² led by CNR and the Ministry of Energy) as well as global experiences such as ESCOs (Box 4.4).

Greater water use efficiency and irrigation is needed, along with substantial investments in physical infrastructure. Water governance systems can be improved through comprehensive watershed management and a clarification of roles, including MINAGRI’s. In addition to adequate planning of irrigation systems and an expansion of technified irrigation, investments in physical infrastructure such as water accumulation

reservoirs and desalination systems will be needed in the medium to long term to manage the lower rainfall and variability projected for the coming years. The capacity of reservoirs needs to grow by 50 percent to avoid the costly impact of prolonged droughts. Finally, the expansion of affordable internet in rural areas together with capacity building will be critical to facilitate the adoption of CSA practices and precision agriculture (see section 4.3).

Table 4.8 lists recommendations to support climate-smart agriculture in Chile

TABLE 4.8 RECOMMENDATIONS FOR SUPPORTING CSA SOLUTIONS

Priority reforms	Short term (< 2 years)	Medium-long term (> 2 years)	Responsible for implementation
Implementing the “Agrifood Sustainability Strategy” and achieving greater coordination on R&D and innovation initiatives	Develop a detailed roadmap to support the implementation of the “Agrifood Sustainability Strategy 2020–2030” and expand the Interministerial Committee on Agrifood Sustainability to include the Ministry of STKI.		Interministerial Committee on Agro-sustainability
Expanding financing instruments for CSA	Conduct a review of available CSA financing instruments and identify opportunities for expanding access to existing instruments and promoting new financing ones.		Ministry of Agriculture Ministry of Finance
Increasing R&D on CSA	Identify strategic R&D priorities and programs to support them, including initiatives that will stimulate greater private financing.		Interministerial Committee on Agro-sustainability
Improving water resource governance	Establish a legal framework that defines the responsibilities and competencies of the actors involved in water management, including the roles of MINAGRI and its agencies in relation to other public agencies.		MINAMB SEGPRES MINAGRI

Priority reforms	Short term (< 2 years)	Medium-long term (> 2 years)	Responsible for implementation
Needed development of robust sources on environmental information related to agriculture for policy making	Based on international (such as EU FaST, World Bank's Ag Observatory and Climate Change Knowledge Portal) and local (ARCLIM) experiences, promote a consolidation of available data sources on environmental and climatic information for policy makers and the general public.		MINAGRI MINAMB
Facilitating the dissemination and adoption of existing CSA technologies, especially by small and medium-sized farmers		Raise awareness among farmers, especially smaller farmers, of the benefits of innovating and adopting CSA approaches. Promote collaborative knowledge networks similar to GTTs for small producers, by enhancing coordination among INDAP, FIA, and INIA.	MINAGRI INDAP INIA FIA SNA—Codesser
Improving water governance systems through comprehensive watershed management		Strengthen governance systems to improve the capacity to capture and use water efficiently. An integral management of hydrographic basins needs to be the main criterion to define the location of investments in infrastructure.	MINAGRI MOP
Promoting the use of renewable energy in agriculture		Explore public-private partnerships, or private partnerships (such as ESCO) to facilitate farmers' access to renewable energy markets.	MINAGRI MinEnergia MINAMB

Priority reforms	Short term (< 2 years)	Medium-long term (> 2 years)	Responsible for implementation
<p>Expanding the availability of freshwater through public investment in infrastructure</p>		<p>Invest in water accumulation systems, favoring medium and minor reservoirs, considering the scarcity of public resources and the environmental and social impact of major works.</p> <p>Increase the coverage of technified irrigation systems.</p> <p>Develop mixed seawater desalination systems, especially for the most arid regions, reducing the pressure on surface and underground freshwater channels and combining these investments with irrigation projects.</p> <p>Improve water use efficiency, both at the property and off the property, by adequately planning irrigation systems, seeking their automation, and jointly safeguarding the efficient use of energy.</p>	<p>MINAGRI</p> <p>CNR</p> <p>Corfo—ASCC</p> <p>Small and large-scale producers</p>

Note: ARCLIM = Climate Change Risk Atlas; ASCC = Sustainability and Climate Change Agency; CNR – National Irrigation Commission; Codesser = Corporación de Desarrollo Social del Sector Rural; Corfo = Chile Economic Development Agency; CSA = climate-smart agriculture; ESCO = Energy Service Company; FIA = Foundation for Agricultural Innovation; GTT = technology transfer group; INDAP = Institute for Agricultural and Livestock Development; INIA = Chilean Agricultural Research Institute; MINAGRI = Ministry of Agriculture; MINAMB = Ministry of the Environment; MinEnergía = Ministry of Energy; MOP = Ministry of Public Works; R&D = research and development; SEGPRES = Ministry General Secretariat of the Presidency; SNA = National Society of Agriculture; STKI = science, technology, innovation and knowledge.



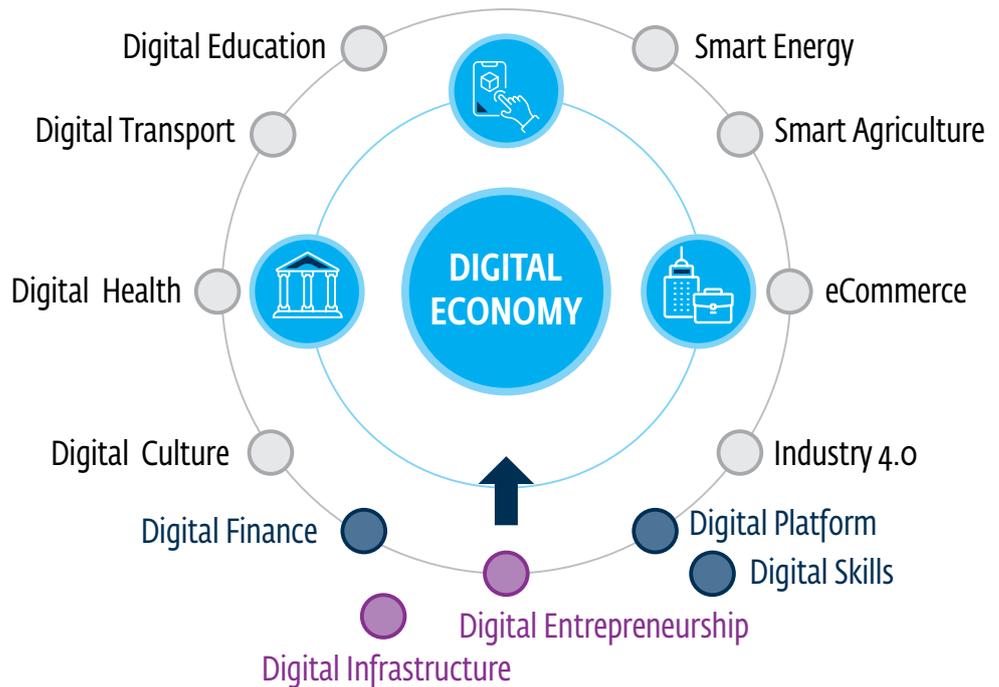
4.3 ENHANCING PRODUCTIVITY AND ENTREPRENEURSHIP THROUGH THE DIGITAL ECONOMY

A recent boost to the digital economy

Chile is well-positioned to profit from a vibrant digital economy—if some constraints, especially on skills, infrastructure, and entrepreneurship, are addressed. Technological change can open a window of opportunity to transform Chile's economy and overcome structural weaknesses such as low firm productivity, disparities in service delivery, and high territorial concentration of economic opportunities. Indeed, greater adoption of digital technologies can boost firm productivity by enabling innovation, facilitating market access, and reducing the costs of a range of business processes. Chile is at the forefront on technology innovation in some respects, being the launchpad for several globally recognized technology companies, but digital innovation and entrepreneurship could be broader based. Increasing the uptake and exploring opportunities and synergies in, for instance, mining, solar, electro-mobility, and smart agriculture could be a game changer for Chile, but some constraints have to be overcome especially on skills, entrepreneurship, and infrastructure.

The development of the digital economy has been given a significant boost by the COVID-19 pandemic, but usage could be further strengthened. Government, citizens, and the private sector are all part of the digital economy (Figure 4.6). Chile ranks 34th out of 193 countries in the United Nations’ 2020 E-Government Development Index, below Uruguay and Argentina in Latin America and the Caribbean, as well as most OECD countries. Chile’s overall rank is held back primarily by its relatively lower scoring on telecommunication infrastructure.⁵³ The number of subscriptions to mobile broadband services is high, surpassing levels in other Latin America and the Caribbean countries but remaining below the OECD average. Some 82 percent of the population are internet users, many through mobile services. Among internet users, 61 percent purchased through digital channels in the first quarter of 2021, increasing from 49 percent a year earlier.⁵⁴ Still, an important segment of the population does not have access to high quality and affordable internet, especially in rural areas and urban peripheries. About 35 percent of households do not subscribe to fixed broadband, and 2 percent of Chileans do not have any type of connectivity⁵⁵. Data prices also remain high.⁵⁶

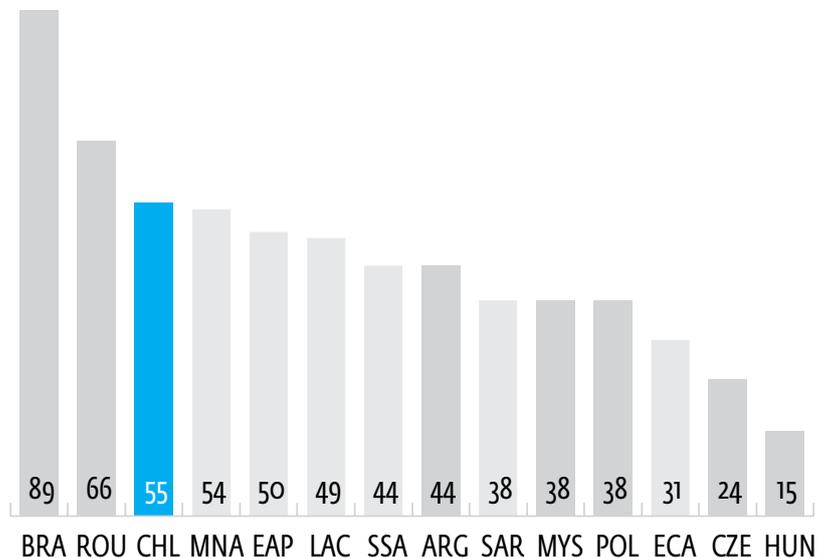
FIGURE 4.6 THE DIGITAL ECONOMY



Source: World Bank Group 2019.

While digitalization has also accelerated among firms during the past year, the adoption of more sophisticated uses of technology would have an even more transformational impact on firms. The Chile Business Pulse Survey indicates that, before March 2020, 72 percent of formal businesses in Chile already used internet or other digital platforms.⁵⁷ Among firms that did not use any online platforms before the pandemic, 48 percent have adopted them since the outbreak. Meanwhile, 78 percent of the firms previously using online platforms report having increased their usage since then. Conditioning on sample characteristics and the timing of the surveys, there is a 55 percent estimated probability that a firm in Chile would have either started or increased usage of digital technologies, a rate higher than in other countries covered by the BPS (Figure 4.7). In addition, 37 percent of sales are made online, one of the highest figures among more than 60 countries covered by the BPS; a large percentage of firms and workers are also teleworking.⁵⁸ The adoption of more sophisticated uses of technology, however, could increase substantially, especially among SMEs. While Chilean firms use social networks, clouds, mobile devices, and digital marketing quite widely, the use of digital management tools or more advanced technologies that leverage big data or artificial intelligence is far more limited (Figure 4.8). In addition, digital adoption amid the pandemic was more concentrated among large (66 percent) and medium (62 percent) firms than small firms (54 percent) that had more limited skills and capabilities. The government is seeking to accelerate digitalization among SMEs through the PYME Digital program.

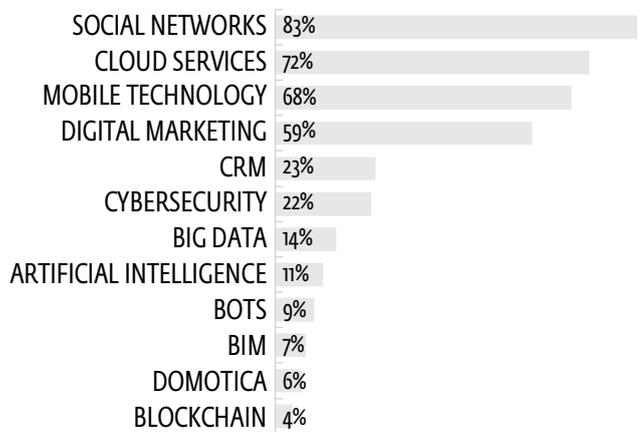
FIGURE 4.7 PROBABILITY OF INCREASING USE OF DIGITAL TECHNOLOGY (% , 4Q20-3Q21)



Source: World Bank based on data from the Business Pulse Surveys collected during 4Q20–3Q21.

Note: Figure includes the following countries for each region considered. EAP: Cambodia, Indonesia, Malaysia, Mongolia, the Philippines and Vietnam. ECA: Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Georgia, Greece, Hungary, Italy, Kosovo, Kyrgyz Republic, Latvia, Lithuania, Moldova, Poland, Portugal, Romania, Slovak Republic, Slovenia, Tajikistan, Turkey, and Uzbekistan. LAC: Argentina, Brazil, El Salvador, Guatemala, Honduras, Nicaragua, and Paraguay. MNA: Jordan, Morocco, and Tunisia. SAR: Bangladesh, India, Nepal, Pakistan, and Sri Lanka. SSA: Benin, Burkina Faso, Ghana, Kenya, Liberia, Madagascar, Malawi, Senegal, Sierra Leone, South Africa, Tanzania, Togo, and Zambia. Individual countries are BRA = Brazil; ROU = Romania; CHL = Chile; ARG = Argentina; MYS = Malaysia; POL = Poland; CZE = Czech Republic; HUN = Hungary.

FIGURE 4.8 ARE THESE DIGITAL TOOLS CURRENTLY USED AT YOUR FIRM? (% OF FIRMS, 4Q20-3Q21)



Source: World Bank based on data from the Business Pulse Surveys collected during 4Q20–3Q21.

Note: BIM = Building information Modeling; CRM=customer relationship management.

The number of digital platforms has also increased significantly in recent months. Digital platforms have particularly grown in transport (Uber, Didi, Beat, Cabify) and delivery (Rappi, Pedidos Ya, UberEats, Cornershop), with more than 300,000 workers providing services through them (Chamber of Members and Deputies 2020). A few platforms—including Cornershop—were originated by Chilean entrepreneurs. A bill submitted to Congress (Chamber of Members and Deputies 2019) will create a better regulatory framework for the functioning of these digital services, and its approval could be positive for the industry’s development (see the labor subsection, 3.6). In addition, a bill in Congress (Chamber of Members and Deputies 2017) on the processing and protection of personal data will be critical to the growth of digital platforms and other parts of the digital economy. As noted in the financial section, digital finance has also seen important growth recently. Chile has 179 national financial technology (fintech) start-ups, an increase of 60 percent during the past two years; another 35 operate locally but with foreign headquarters. They are primarily focused on electronic payments, reducing the cost of financial services, and fostering lending tools, with a special emphasis on underbanked enterprises and households. The regulatory framework for this sector could be enhanced. An “Open Finance” regulatory framework such as the one included in the Fintech bill sent to Congress in September 2021 and referred to in the Competition subsection (section 3.3) would contribute to the sector’s growth. Advancing on adequate regulation could thus generate incentives and legal certainty that would benefit the development of the industry and its consumers. (UC 2021).

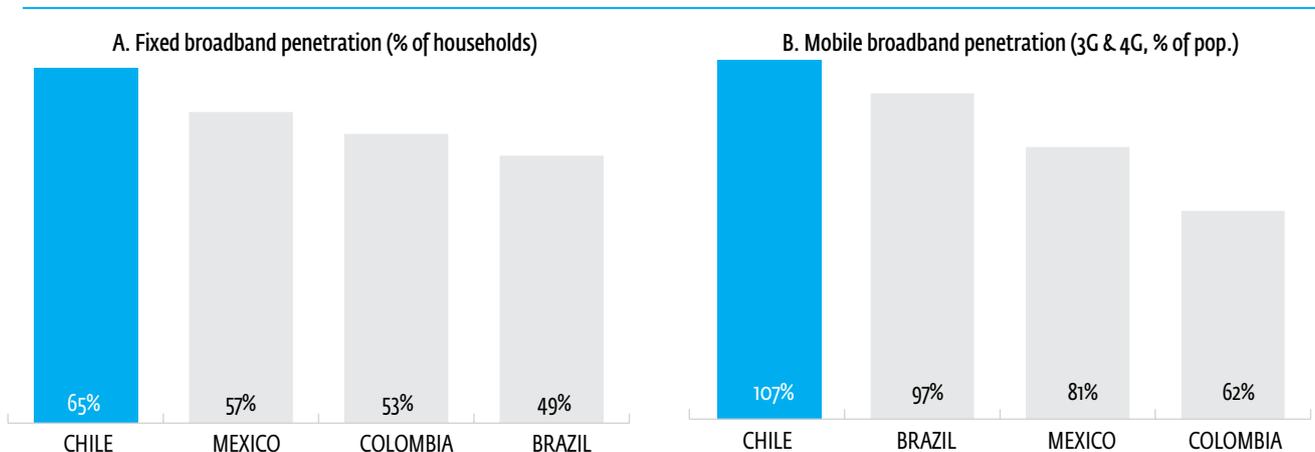
Despite encouraging developments, the digital entrepreneurship ecosystem could be more vibrant. Digital entrepreneurship serves as a critical foundation that enables traditional businesses in value chains to adopt digital technologies and new digital business models, and that helps the government deliver services more efficiently. They generate positive spillover effects for the rest of the economy. Digital enterprises and start-ups, however, have difficulties scaling up and growing, among other reasons because of funding constraints. Lack of technical skills is also a significant barrier to digital entrepreneurship.

Enhancing digital skills, the digital entrepreneurship ecosystem, and digital infrastructure will be critical to building stronger foundations for the digital economy. The remainder of this chapter focuses on the state of digital infrastructure and digital entrepreneurship in Chile, complementing the earlier analysis on digital skills on the Education and Skills subsection, 3.5.

Narrowing the divide while leapfrogging to new technologies

Chile has built a solid telecommunication infrastructure with high penetration rates and good-quality services, but peri-urban and especially rural areas still have low fixed broadband access. Chile has a very dynamic and competitive telecom environment with various players along the value chain. Penetration rates are high, especially for mobile broadband (Figure 4.9), and in 2012 long-term evolution (LTE) spectrum was launched with positive impacts on fourth-generation (4G) penetration throughout the country. Fifth-generation (5G) spectrum, which could be a game changer for the digital economy because of speed and latency, was awarded in March 2021 to different operators, making Chile the first country in Latin America and the Caribbean to do so. However, infrastructure gaps in fixed broadband access remain in peri-urban and rural areas, while affordability issues limit access by lower-income households even within cities. Infrastructure sharing has increased since the 2012 Tower Act but remains low, which hampers the expansion of connectivity to unserved populations.

FIGURE 4.9 COMPARISON OF MOBILE BROADBAND AND FIXED BROADBAND PENETRATION IN SELECT LATIN AMERICA AND THE CARIBBEAN COUNTRIES, 2020



Source: World Bank, World Development Indicator databank.

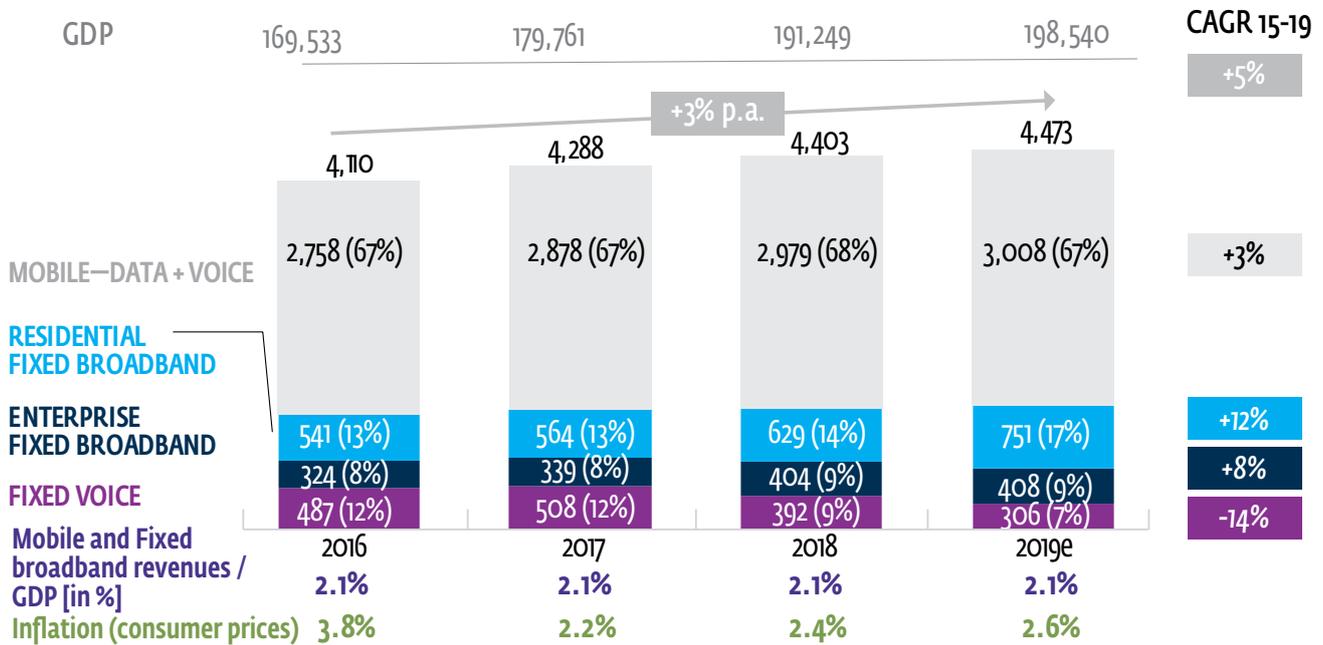
Institutional and regulatory framework

The Chilean government has supported broadband network deployment to reduce the digital divide. Since the early 1980s, public sector policies have enabled the development of digital infrastructure throughout the country and have fostered digital inclusion. This support started with the approval of the General Telecom Law in 1982, which opened the sector to private sector actors. One shortcoming is that the regulatory governance of the telecom sector is not technically independent, because SUBTEL is a centralized organism of the Ministry of Transport and Telecommunications, a political body. To support network deployment, the government launched in 2013 the Digital Broadband Development Plan, “Imagina Chile Digital Agenda 2013–2020.” In 2015, the Fibra Optica Austral (FOA) project (to roll out 4,000 km of fiber optic infrastructure in the Patagonia Region) and the Fibra Optica Nacional (FON) project (to build 10,000 km of fiber optic network throughout the country) were launched to develop national connectivity. In May 2021, the government and Telcos announced a partnership to reduce the digital divide, with the government committing US\$230 million in additional subsidies to the FON and FOA projects. Besides efforts to expand infrastructure, government policies on digital inclusion have focused on reducing the skills gap through various training programs, delivering computers to students from vulnerable sectors (such as through the MINEDUC ICT Scholarship) and improving internet access in schools (such as through Connectivity of Education 2030).

Despite these efforts, challenges remain in terms of regulation to foster effective competition and network deployment. There is no clear universal access obligation for operators to increase telecom coverage in rural and low-income urban areas. Regulation regarding the spectrum assignment process, which uses a comparative selection model, could also be enhanced. In the fixed market, unbundled bitstream access is mandatory and since 2009 has been regulated by SUBTEL, which sets operators’ tariffs. However, local loop unbundling has not been fully achieved because of missing regulations on the last mile and lack of long-distance infrastructure access. Additionally, in the fixed market, incentives and regulations to foster active or passive infrastructure sharing between telecom operators are not adequate. Finally, information on national and international connectivity infrastructure deployment are not shared by SUBTEL, resulting in high search costs for interested agents and potentially preventing investment in new infrastructure.

Market dynamics and infrastructure maturity

Chile’s telecommunication market keeps growing, led by fixed broadband, while the mobile segment is more established. The telecommunications market in Chile is performing well, growing by 3 percent per year since 2016, driven by fixed broadband acceleration and to a lesser extent mobile market growth (Figure 4.10). The Chilean mobile market is one of Latin America’s most mature, after a decade of rapid growth; services revenues are largely stable with most growth happening on mobile data. Fixed broadband is increasing rapidly, however, while fixed voice is decreasing in line with international trends.

FIGURE 4.10 TELECOMMUNICATION MARKET IN CHILE (CLP BN; 2015-19)

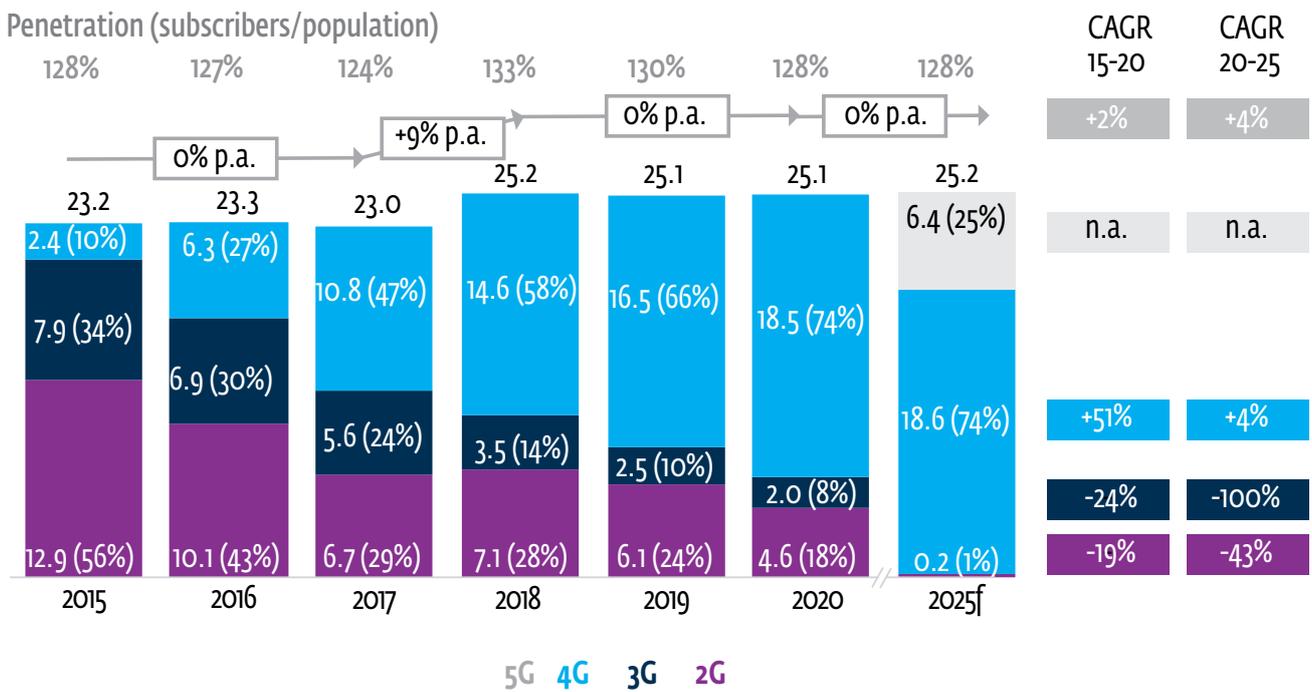
Source: SUBTEL, Buddecomm, Fitch, Telefónica, World Bank, Roland Berger data.

Note: Estimation mainly based on Entel communication on global market data. CAGR = compound annual growth rate; GDP = gross domestic product.

The mobile market is characterized by good connectivity and growing competition. In Chile, capabilities in terms of national and international connectivity are satisfactory, with ample infrastructure (four active subsea cables and three ongoing projects,⁵⁹ and four main national networks). Chile registered the largest growth in mobile broadband penetration among OECD countries in the past decade. Competition in the mobile market is growing, with four leading mobile network operators (MNOs) and a stable market blended average revenue per user (ARPU) since 2016. The group performance and 4G introduction were good drivers to maintain the ARPU level. Entel and Movistar remain the market leaders; Claro is in third position followed by WOM. The fourth player has outperformed market growth by rapidly increasing its subscriber base at 51 percent per year; its market share jumped from 3 percent in 2015 to 21 percent in 2020 through national roaming agreements. Incumbent MNOs are facing strong competition from this new provider and is pursuing an offensive pricing strategy. Recent regulatory changes (Agostini and Wellington 2020) have also increased competition in the sector, although operators still retain considerable market power as stated in the Competition subsection of the CPSD (3.3).

The deployment of 5G will be a game changer for the mobile market in Chile as it unleashes a whole new series of applications areas such as mining, logistics, and telemedicine. Although 4G is currently the dominant mobile technology in Chile (figure 4.11), 5G deployment is advancing rapidly and will shape the market in coming years because of its much faster data speed and lower latency. Chile has been a frontrunner in the adoption of new cellular generations of technology in the region. A recent study (Arezki et al. 2021) shows that countries with a good regulatory framework anticipate the adoption of a new generation of cellular technology, producing a positive impact on the local stock market and the economy. In early 2021, Chile auctioned and assigned 5G, the first in Latin America, preparing it to achieve the benefits from its early adoption (Box 4.5).

FIGURE 4.11 NUMBER OF MOBILE SUBSCRIPTIONS BY TECHNOLOGY IN CHILE, 2015–25 FORECAST BY MILLION SUBSCRIBERS



Sources: Fitch and Roland Berger.

Note: CAGR = compound annual growth rate; G = generation; p.a. = per annum.

BOX 4.5 EXAMPLES OF POTENTIAL 5G APPLICATIONS IN CHILE

The applications of fifth-generation (5G) technology vary widely. From watching a high-definition video while cruising the city on a bus to performing a surgery remotely, this new generation of mobile connectivity offers huge potential in terms of applications.

Two main features characterize the new technology: speed and latency. First, the amount of data that can be downloaded per second is substantially higher than in previous mobile generations (speed). At the same time, the delay between a given instruction and a data transfer is below 10 milliseconds (latency). These two elements open a new range of applications that are likely to affect our daily lives over the next decades.

An example is the implementation of 5G in Chilean ports to improve logistic management and increase operation efficiency. The improvement will allow a higher volume of goods to be disposed in a shorter amount of time.

Another potential application of 5G in Chile is in the mining industry. Faster data speed and lower latency will allow firms to automatize processes, improve overall productivity, and create a safer environment for workers. For instance, workers will be able to manage the riskiest operations from a secure location. Similarly, miners will be able to wear helmets that collect and transmit data about the air quality to detect the presence of toxic gases.

Chile is also planning to cover all the local hospitals with 5G signals, unleashing a whole new offering of e-health applications. For example, doctors and patients will have access to a wide range of telemedicine services because increased capacity and low latency allow the exchange of bigger volumes of data and permit monitoring in real time.

Source: CPSD team elaboration based on interviews.

Building wireless links to connect mobile towers and fostering infrastructure sharing will be crucial to the successful deployment of 5G in Chile. World Bank research estimates that building wireless links to connect mobile towers is the most cost-efficient strategy to reach universal mobile coverage.⁶⁰ To connect mobile phone towers back into the internet, network operators need to build a “backhaul” connection using fiber optic cable or a set of wireless links. This step is one of the main costs of connecting rural and remote areas, which is much of the focus of Chile’s universal broadband policies. The use of these technologies has a large impact on the required investment. For example, fiber optic links are highly desirable because of their large capacity, but they often require much higher upfront investments in areas of low existing demand, relative to using a wireless connection. Fiber also takes much longer to deploy than a wireless link does. The cost of building a mobile network also depends on the regulations in place. Infrastructure sharing can play an important role and can occur in various places throughout a mobile network. Active infrastructure sharing strategies (such as sharing the electronic infrastructure of the network, including radio access networks such as antennas and transceivers) guarantee more substantial cost savings of deployment compared to passive strategies (including sharing nonelectronic infrastructure such as physical sites and power systems at a cell site). More comprehensive sharing strategies, however, run the risk of reducing infrastructure-based competition between network operators, which is beneficial for consumers and has historically led to stronger investment outcomes. Hence, policy makers need to carefully balance the pros and cons of each option. An alternative is to try to balance out these benefits by retaining market-based infrastructure competition in viable urban and suburban areas, while reducing the deployment costs in unviable rural and remote areas. Policy makers will also need to understand the environmental implications of 5G deployment across the country and make infrastructure choices accordingly (Box 4.6).

BOX 4.6 REDUCING THE ENVIRONMENTAL IMPACT OF 5G DEPLOYMENT IN CHILE

The debate on the impact of digital technologies on climate change is growing, with important implications for the promotion of universal broadband policies. Assets operated to provide broadband require electricity to function, and the production of this energy releases carbon and other atmospheric emissions (Farquharson et al. 2018). Using 5G with fiber optic links is the most energy-efficient infrastructure option for the per user capacity targets tested (5, 10, and 20 megabits per second), producing the smallest environmental footprint. The World Bank estimated the demand for electricity required for operation of cellular broadband infrastructure over the next decade (2020–30). As expected, higher data consumption is linked to increased carbon dioxide (CO₂) emissions as more energy-consuming assets are needed to deliver greater system capacity.

Current estimates place the proportion of cellular sites using off-grid power at 2 percent for Chile (GSMA 2021). This is the proportion of sites that use diesel-powered generators to operate, raising questions regarding the environmental sustainability of such sites.

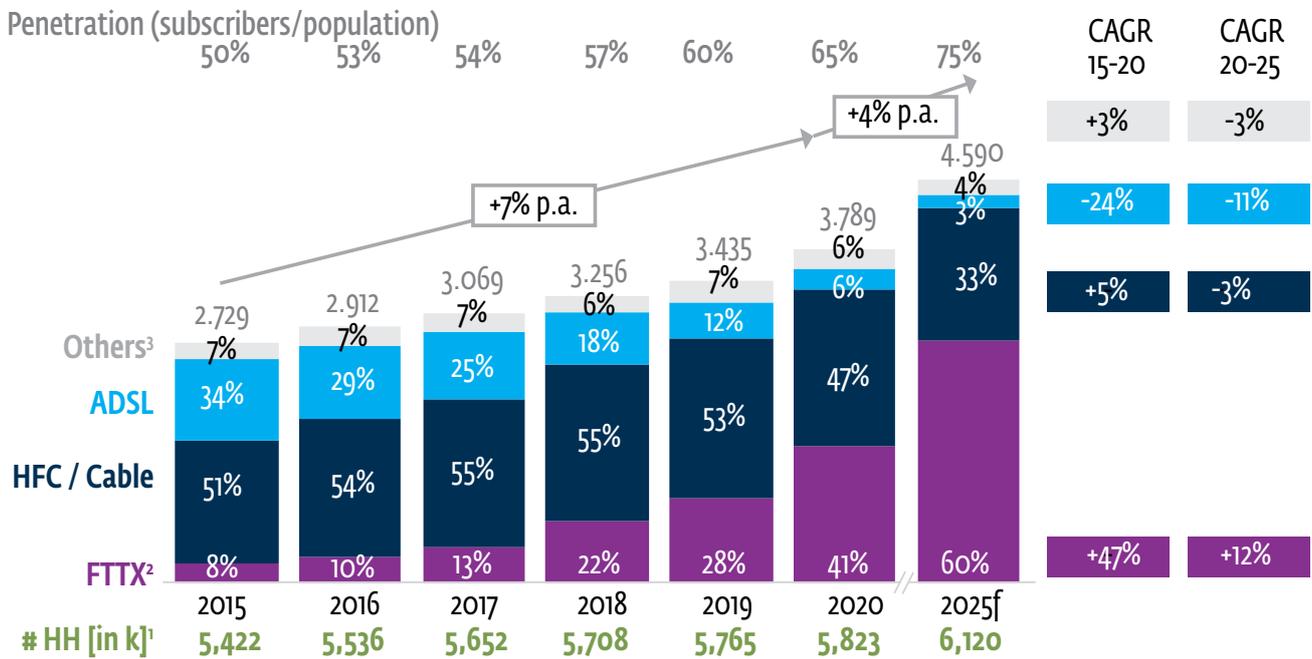
Shifting existing cellular sites from using diesel generators to using renewable sources, such as photovoltaic or wind battery systems, can result in significant sustainability benefits. This can also be an application of green hydrogen, which is assessed in this CPSD. The World Bank estimates that implementing renewable energy power for existing off-grid cellular sites over the next decade would lead to CO₂ emission savings of up to 19 percent compared to emissions associated with cellular sites using diesel generators, assuming 5G universal coverage with a wireless backhaul link.

Chile is also planning to cover all the local hospitals with 5G signals, unleashing a whole new offering of e-health applications. For example, doctors and patients will have access to a wide range of telemedicine services because increased capacity and low latency allow the exchange of bigger volumes of data and permit monitoring in real time.

Source: CPSD staff elaboration.

The acceleration of optical fiber (fiber to the x; FTTx) deployment has created the enabling conditions for rapid growth of fixed broadband in upcoming years. Fixed broadband increased its market value over the past five years, driven by both the residential (65 percent of total market with a yearly growth rate of 12 percent) and corporate (35 percent of total market with a yearly growth rate of 8 percent) segments. The market is very dynamic, driven by subscription and ARPU increases within a fragmented competitive context. Cable technology dominates the market, but FTTx deployment and subscriptions have seen rapid growth in recent years (Figure 4.12).⁶¹ Chile ranks sixth among OECD countries in terms of FTTx broadband connection growth (37.6 percent year-on-year as of June 2020) after Israel, the United Kingdom, Ireland, France, and Italy. The six main fixed broadband operators (Movistar, GTD, Entel, Mundo Pacifico, Claro, and VTR) in Chile are accelerating FTTx deployment in the main urban areas, increasing the number of homes connected.

FIGURE 4.12 NUMBER OF FIXED BROADBAND SUBSCRIPTIONS BY TECHNOLOGY, 2015–25 FORECAST BY MILLION SUBSCRIBERS



Source: SUBTEL, Buddecomm, Fitch, and Roland Berger data.

Note: ADSL = asymmetric digital subscriber line; CAGR = compound annual growth rate; HFC = hybrid fiber coaxial; FTTH = fiber to the home; FTTC = fiber to the curb; FTTB = fiber to the building; FTTX = fiber to the x; p.a. = per annum.

(1) Household number estimates are based on 2017 census data and assume 1% CAGR from 2017 onward versus 2.1% 2002–17 historical CAGR.

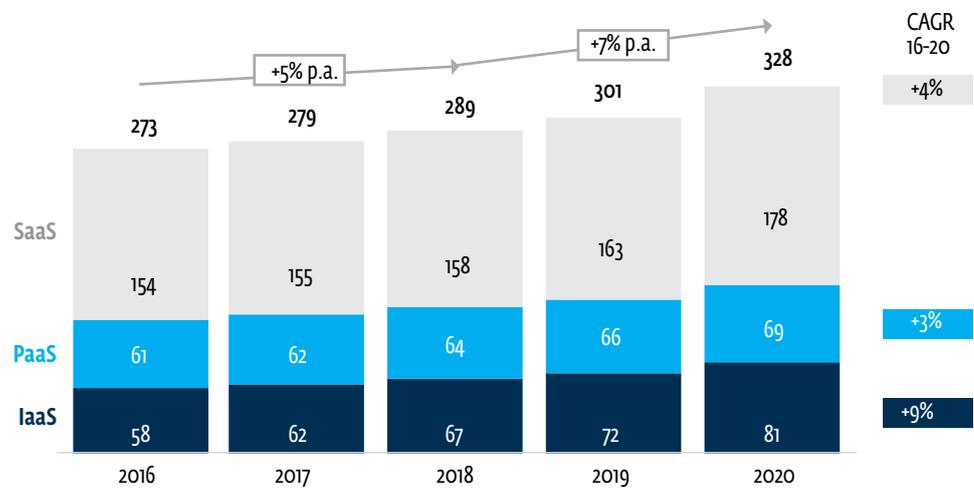
(2) FTTX includes FTTC and FTTH/FTTB.

(3) Others include Wimax, wireline, and wireless.

Nationwide, fixed broadband penetration is moderate but increasing, and there are still access gaps due to affordability issues. A fixed reliable connection is important because the speed it provides allows users to perform videocalls, stream videos, or do other activities involved in telework, distance learning, or telemedicine. Almost half of fixed broadband connections are in the Santiago metropolitan region, which represents 40 percent of the country’s population, and penetration in other regions varies from 40 to 80 percent. The government is supporting long-distance fiber optic projects, including in rural and low-income areas. It has been successful in developing FTTx in the south, including in the Magallanes, Aysen, Los Rios, and Los Lagos regions, through the FOA project, although there are still unserved populations in rural and peri-urban areas. More than 90 percent of rural localities are still not connected to fixed internet. Infrastructure sharing has increased since the 2012 Tower Act, but it remains low. In addition, Chile still lags the most developed economies in terms of access to fixed broadband and affordability, as the cost of data is above international recommendations, as previously noted.

Advances on regulation, infrastructure maturity, and digitalization will enable cloud market development. Cloud computing can be transformational to firms by allowing them to scale up technical resources and to gain flexibility in a cost-effective manner and increase their productivity. Chile’s competitive cloud market reached approximately US\$328 million in 2020, increasing at a strong 7 percent annually since 2018 (Figure 4.13). Growth has been driven by rising demand for cloud services from enterprises and the local technology industry; on the supply side, the local presence of hyperscalers (Google, AWS) as well as regional players and the main telecom players has contributed to the industry’s expansion. Strengthening regulation will be key for cloud market growth, especially the approval of a bill proposal submitted to Congress in 2017 on the processing and protection of personal data (Chamber of Members and Deputies 2017). In addition, robust international connectivity, well performing national backbones, and the strong development of last-mile fiber-optic networks are also critical for cloud market development. Finally, the digitalization level will be another influential factor. The rate of adoption of smartphones in Chile is 67 percent, in line with the Latin America and the Caribbean average, and there is strong development of online services, such as recent rapid growth in fintech start-ups and digital platforms, as noted previously.

FIGURE 4.13 PUBLIC CLOUD MARKET BY SERVICE TYPE (US\$ MILLION, 2016-20)

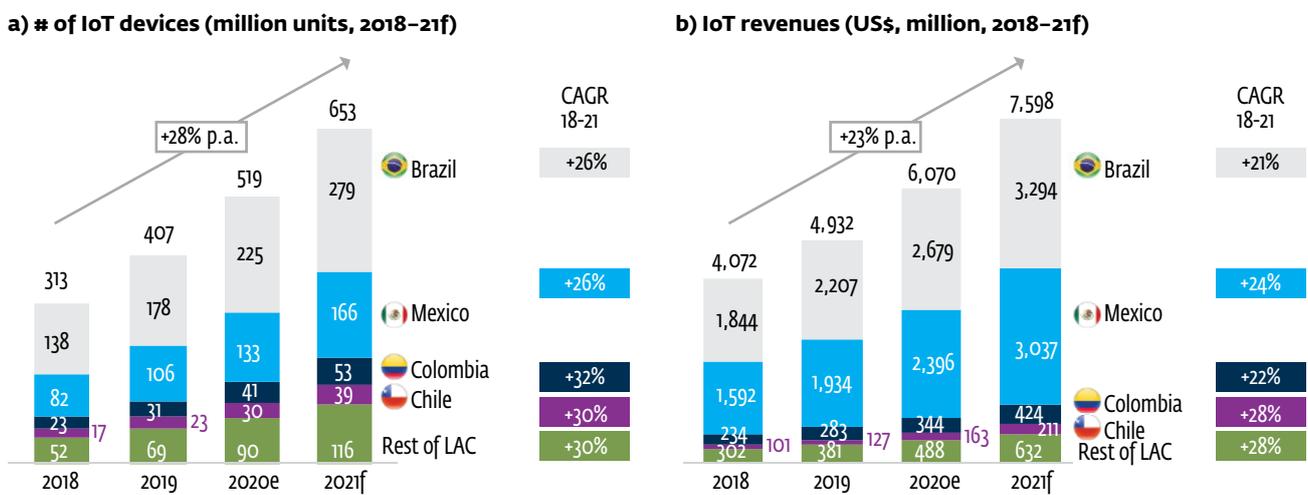


Source: Gartner, Eurostat, Roland Berger.

Note: CAGR = compound annual growth rate; IaaS = cloud-based services; p.a. = per annum; PaaS = hardware and software tools available over the internet; SaaS = software available through a third party over the internet.

The internet of things (IoT) market remains modest in Chile compared with other Latin America and the Caribbean countries (below US\$200 million) but has been growing at a very fast pace in recent years. Annual growth of almost 30 percent has been enabled by increased IoT offerings from telecommunication actors and other IoT players as well as some local initiatives such as the Araucania Smart City (Figure 4.14). Chile is poised to be among the countries with the fastest IoT spending growth in Latin America and the Caribbean, along with Mexico and Colombia.

FIGURE 4.14 IOT NUMBER OF DEVICES AND REVENUES EVOLUTION IN LATIN AMERICA AND THE CARIBBEAN, 2018–21 FORECAST



Source: IDC, Frost & Sullivan, Roland Berger data.

Note: The rest of Latin America (LAC) consists of Argentina, Bolivia, Paraguay, Peru, Uruguay, and all countries in Central America and the Caribbean. Chile's number of IoT devices and revenue are estimated in comparison to other countries in Latin America and the Caribbean and based on gross domestic product. Panel b. shows business-to-business revenues only. CAGR = compound annual growth rate; e = estimated; f = forecast; IoT = internet of things; LAC = Latin America and the Caribbean; p.a. = per annum.

Building a more dynamic digital entrepreneurship ecosystem

Digital entrepreneurship has gained more momentum in Chile, but several aspects of the ecosystem still need to be enhanced to unlock its full potential. The COVID-19 pandemic has pushed companies to change their business models, adapt, and adopt digitalization, thus fostering greater digital innovation and entrepreneurship. A few flagship success cases such as Cornershop, Not Co, and Betterfly have recently disrupted consumption and production patterns and have attracted attention and international capital (Box 4.7). However, most digital ventures in Chile do not grow. Low digital entrepreneurship has also led to the low export performance of digital services. Chile could benefit from far greater digital entrepreneurship if several constraints are addressed.

The government has fostered entrepreneurship through Corfo, primarily through direct and indirect funding, but with mixed results. State action has focused on the development of new ventures, as well as on institutions that provide support to these new ventures such as angel networks, business incubators, and accelerators. The participation of the business sector in entrepreneurial dynamics was relatively low during the 2010s and venture financing depended substantially on government funding. While government programs have fostered entrepreneurship more broadly, the digital sector has been the main beneficiary by far. Over the past 10 years, the state has financed more than 3,000 start-ups through six programs: Seed Capital, Seed Expansion, the Subsidio Semilla de Asignación Flexible (SSAF) Challenge, SSAF innovation, the S Factory, and Start UP Chile, which is the largest. These programs provide nonrefundable funds (on average US\$49,000) as seed capital for business development. The information technology (IT) sector has been the main recipient. Between 2010 and 2019, the most important sectors financed by Start-Up Chile were information and communication technology (ICT; 27 percent of projects), commerce (13 percent), marketing (10 percent), education (9 percent), financial and business services (6 percent), and transport and infrastructure (6 percent). Importantly, many of the projects supported outside the ICT sector are also digital undertakings.

Corfo has also strongly promoted programs to support venture capital (VC) development. In 2020, Corfo's Investment and Financing Management Department approved US\$932 million, mainly as credit lines to investment funds; and Corfo itself registered investments in 412 companies. The legal framework prevents Corfo from undertaking equity participation in VC funds, which has constrained the type of instruments that it can use. In addition, Corfo's Innovative Entrepreneurship area has promoted the creation of angel investor networks and flexible seed capital funds, which have been assigned to business incubators and accelerators for allocation to new ventures with high growth potential.⁶² While entrepreneurship programs were seeking to fill important gaps, effectiveness appears to have been mixed, partly because of bureaucratic and administrative constraints. Some of the instruments used might not have been fit for purpose as discussed further in the following discussion.

BOX 4.7 SUCCESSFUL CASES OF DIGITAL ENTREPRENEURSHIP IN CHILE

Cornershop, the first Chilean unicorn

Cornershop, owned by Uber, is an online grocery shopping app that enables people to shop online at different stores. Shoppers choose the products and have them delivered at the address and time requested. The application was developed and launched in Chile and Mexico in 2015 by Chilean entrepreneurs. In 2019, Uber invested US\$380 million in it to support its growth in Mexico, Brazil, and the United States. In June 2021, Uber acquired the remaining 47 percent of shares for US\$1.4 billion to assume 100 percent control of the company. Cornershop's enterprise valuation reached US\$3 billion in 2021, becoming the first Chilean unicorn. (Global Private Capital Association, 2021) The vision of Cornershop's founding team was critical.

Not Co, the second Chilean unicorn: Food based on artificial intelligence

The Not Company (Not Co) is a food technology start-up founded in 2015 that produces plant-based alternatives to animal-based food by using artificial intelligence. After several funding rounds, NotCo has

raised almost US\$400 million, reaching a valuation of US\$1.5 billion in July 2021, positioning the company as the second Chilean unicorn. The company has attracted influential international investors such as Jeff Bezos.

Betterfly: Transforming the insurance industry

Betterfly is an insurtech company founded in 2018 whose model is based on charging companies a small membership fee and providing benefits through an app that include telemedicine, mental health support, fitness, meditation, nutrition, finance, and wellness education for employees. In June 2021, Betterfly raised US\$60 million in funding, reaching an enterprise valuation of US\$300 million, which made the firm the most highly valued insurtech company in Latin America. The investors were DST Global partners, QED investors, Valor Capital, Endeavor Catalyst, and Softbank. In September 2021, it acquired five companies to expand in Latin America. The company currently has operations in Chile, Argentina, Brazil, and Ecuador. In 2022, it plans to offer services in Colombia, Mexico and Peru in addition to setting up its main offices in the United States.

Source: CPSD elaboration based on desk research and interviews

Enablers of and constraints to digital entrepreneurship

Multiple factors can influence the development of Chile’s entrepreneurial ecosystem. The Isenberg model on entrepreneurship ecosystems highlights the importance of policy (regulatory), finance, support (especially telecommunications infrastructure), human capital, entrepreneurial culture, and access to markets (Figure 4.15).⁶³ On these domains, Chile performs relatively better on the policy environment and telecommunications. The overall business environment and quality of institutions are critical to facilitating the development of digital entrepreneurship. Chile benefits from a robust policy environment, including strong institutions, rule of law, and a good overall business environment. The digital infrastructure is relatively developed, although gaps remain, especially on data pricing and coverage of rural areas and urban peripheries, as noted earlier.

FIGURE 4.15 ISENBERG ENTREPRENEURSHIP ECOSYSTEM MODEL



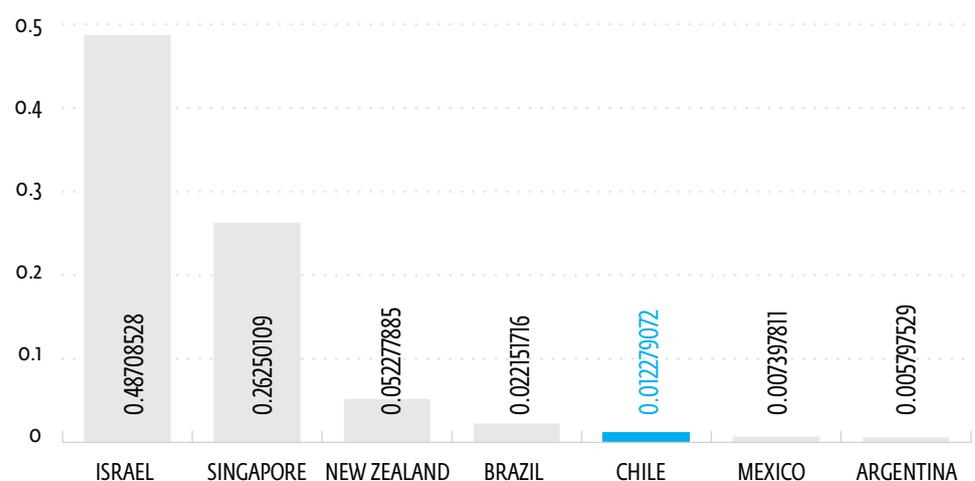
Source: CPSD team elaboration based on Isenberg, Daniel. The entrepreneurship ecosystem strategy as a new paradigm for economic policy: principles for cultivating entrepreneurship, Babson Entrepreneurship Ecosystem Project, Babson College, Babson Park: MA. 2011. Note: The six aspects in the figure are colored green, yellow and orange depending on whether they are assessed to be enablers, have some gaps, or are barriers to digital entrepreneurship, respectively. The assessment is based on reports such as Global Entrepreneurship Monitor (GEM 2020), Global Innovation Index, World Economic Forum’s Global Competitiveness Index, Snapshot of Chilean Entrepreneurship (ASECH 2019), and extensive interviews with stakeholders.

Start-ups, however, have difficulties scaling up and growing, mainly because of inadequate financing and gaps in technical skills, the overall entrepreneurial culture, and a small domestic market. Few local ventures scale up. Scale-ups are only 1 percent of total companies in Chile, and the country has one of the highest rates of firm exits among economies assessed by the Global Entrepreneurship Monitor (GEM).⁶⁴ This lack of success reflects low levels of venture capital beyond the early stage as well as gaps in the workforce where entrepreneurial talent does not sufficiently translate into successful business growth. Other factors that contribute to low innovation-led business growth include a small domestic market size (which would require many ventures to consider external as well as local markets from the start) and insufficient contestability in some sectors (such as mining, fishing, forestry, and pharmacies). In addition, limited linkages between universities, firms, international buyers, and investors make thriving in the ecosystem more challenging.

Funding beyond the early-stage phase is needed to enable digital start-ups to grow.

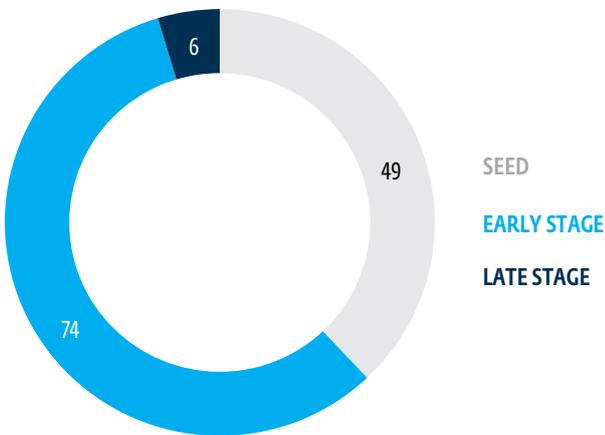
Financial support is the top constraint to entrepreneurship, according to the GEM survey (GEM 2020). While growing, venture capital is still scarce and quite dependent on public support (Figure 4.16). Corfo has contributed to about 70 percent of invested VC funding in the country since 1998. The availability of financing is far more limited at the scaling-up and internationalization phases. Only 5 percent of VC deals between 2016 and 2020 involved late-stage funding, with the majority concentrated on early-stage investments (Figure 4.17 and Figure 4.18). Only a few start-ups in the country have achieved unicorn status to date (Box 4.7). Most likely, few institutional limited partners are active in this market and few start-ups have demonstrated enough scale and prospects to enter into later-stage VC. Although the Central Bank of Chile increased the upper thresholds for investment in alternative assets by pension funds, VC funding by institutional investors remains limited, and the propensity of some pension funds to request a seat on the investment committee may deter private investors.

FIGURE 4.16 VENTURE CAPITAL DEALS PER BILLION PURCHASING POWER PARITY GDP, 2020



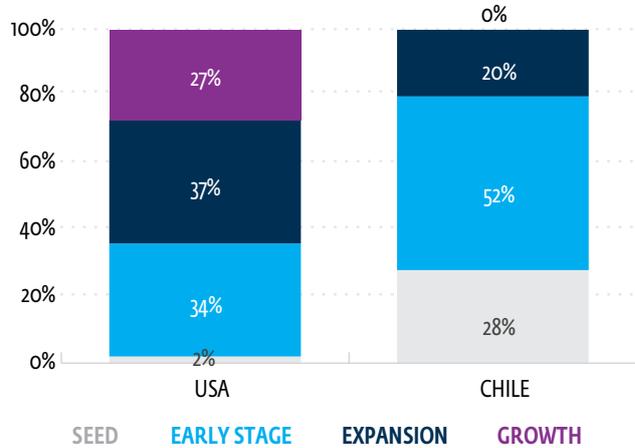
Source: Global Innovation Index 2021. Refers to the value of Venture Capital deals received by companies located in each country.

FIGURE 4.17 NUMBER OF VC DEALS IN CHILE BY STAGES, 2016–20



Source: Global Private Capital Association (Emerging Markets Private Equity Association).

FIGURE 4.18 FUNDS BY INVESTMENT STAGE IN CHILE AND THE UNITED STATES, %

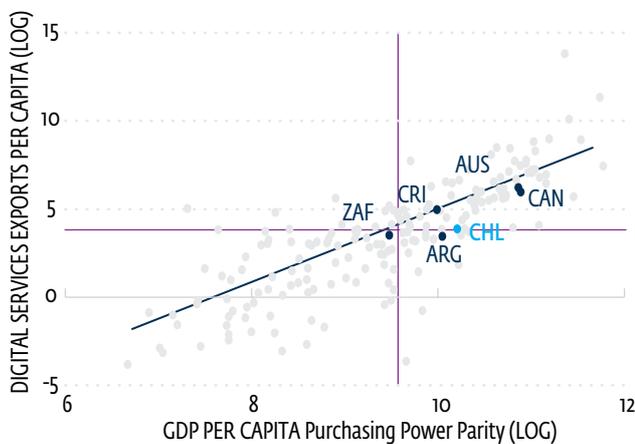


Source: Corfo.

The characteristics of VC funds in Chile prevent more financing deals, while state instruments are not the most suitable to the unique needs of the VC sector. Local stakeholders indicate that private funds tend to invest in lower-risk businesses and mainly within networks of personal or business connections. Fund managers are more focused on the use of traditional risk reduction tools such as diversification and strategic control of the invested companies, an approach that does not promote accelerated growth of projects with high potential (CNID 2018). Meanwhile, support from investment funds with state subsidies is generally inadequate for international scale, besides being slow and bureaucratic. State subsidies are granted through project competitions based more on technical rather than commercial evaluations and require the fulfillment of pre-established stages, reducing the flexibility of ventures and innovation. Public programs also impose multiple restrictions on the use of funds—for example, only 30 percent can be used in human resources or business development talent.⁶⁵ All of this slows the business development and innovation of ventures. At the same time, projects that win competitions receive limited “smart money” support, with gaps in the provision of assistance and networking. Over the past few years, VC volumes in the region have risen substantially because of a surge in late-stage VC in Brazil and Mexico. This active regional VC investor base could enter Chile should the ecosystem generate enough buzz and demonstration of commercial returns.

Besides financing, Chile’s relatively small domestic market can limit the growth of specialized and niche digital ventures. Although several start-ups have emerged in the ecosystem, their ability to reach sufficient scale in a country with a relatively small market is challenging. Start-ups have to scale up early on to become commercially sustainable. Commercial expansion is limited by the size of the domestic market, the reluctance of big traditional producers to adopt new technologies, and the challenges of international expansion. Even assuming the technology can be scaled up relatively easily, scaling up requires the financing of sales and marketing costs to acquire new customers, networks with local partners, and the expansion of human resources (to hire staff, for example). For early-stage companies of limited size, these challenges can be expected to be even greater. Furthermore, during the inception phase, products or services may not be conceived with the broader idea of a regional scale-up in mind, and the product or service might need to be adjusted later for the regional market, which could take time. The export performance of digital services is lower than what could be expected judging from Chile’s level of development (Figure 4.19), and the usage of domestic digital services value-added into Chile’s downstream economy remains small compared with peers (Figure 4.20).⁶⁶ This analysis suggests that there is a large unfilled export potential around digital entrepreneurship.

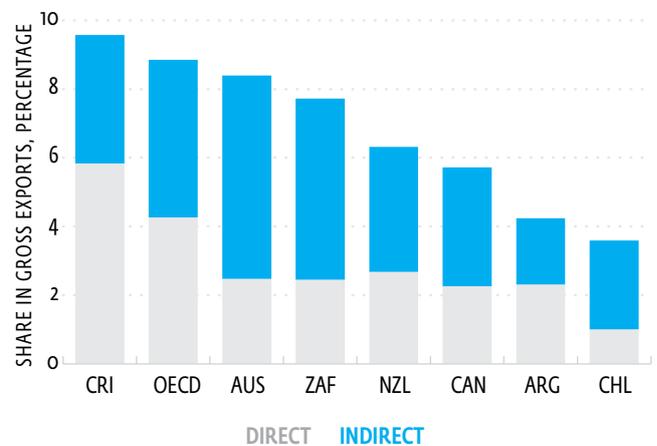
FIGURE 4.19 DIGITAL SERVICES TRADE EXPORTS, 2019



Source: CPSD team’s calculations; WTO-OECD BaTiS and World Bank’s World Development Indicators.

Note: Countries: ARG = Argentina; AUS = Australia; CAN = Canada; CHL = Chile; CRI = Costa Rica; NZL = New Zealand; ZAF = South Africa.

FIGURE 4.20 DOMESTIC DIGITAL SERVICES VALUE-ADDED IN GROSS EXPORTS (DIRECT AND INDIRECT)



Source: CPSD team’s calculations, OECD.

Note: OECD = Organisation for Economic Co-operation and Development. Countries: ARG = Argentina; AUS = Australia; CAN = Canada; CHL = Chile; CRI = Costa Rica; NZL = New Zealand; ZAF = South Africa

Networking between firms and the rest of the digital entrepreneurship ecosystem is limited (Figure 4.21). Access to incubators and accelerators, especially those funded by Corfo, is relatively easy, thus enabling knowledge flows and spillovers among entrepreneurs and providing spaces for innovation. A network of more than 300 entrepreneurship-focused institutions throughout the country provides coworking spaces and some degree of business acceleration. However, for the entrepreneurship ecosystem to move to the next stage, greater connectivity between the private sector, the public sector, and other stakeholders will be necessary, including access to corporates, research institutions, universities, and the media. Chile trails OECD countries in different aspects of collaboration, although it still performs better than the Latin America and Caribbean average. Collaboration with international ecosystems that host more innovative capacity, successful entrepreneurs, and VC funding is generally limited. Insufficient networking opportunities become a barrier to many firms that need support to access international markets to export their products.

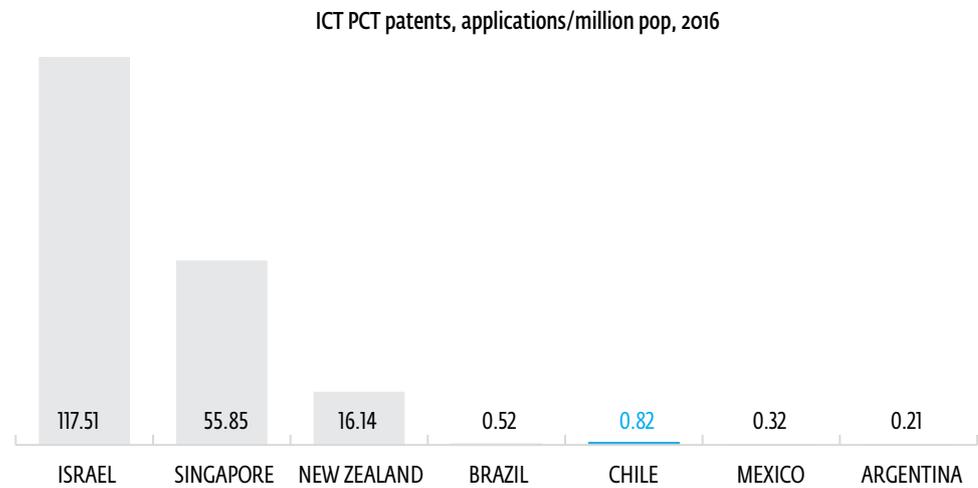
FIGURE 4.21 CHILE'S RANKING ON DIFFERENT ASPECTS OF COLLABORATION COMPARED TO LAC AND THE OECD, 2019



Source: World Economic Forum (WEF) Global Competitiveness Index, 2019.

Note: LAC = Latin America and the Caribbean; OECD = Organisation for Economic Co-operation and Development.

Expanding digital entrepreneurship requires cutting-edge skills that Chile is still developing. The digital skills gap emerges in the top five constraints to entrepreneurship identified by surveys such as the GEM. While domestic talent generally possesses good entrepreneurial and basic digital skills, they are not sufficiently “cutting-edge” to enable the country to expand to more technologically advanced verticals (such as artificial intelligence or deep tech).⁶⁷ Indeed, the number of ICT patents filed by Chile under the Patent Cooperation Treaty remains quite low (Figure 4.22). A growing number of Chileans pursue graduate degrees, but few do so in STEM areas: 7.3 percent of graduates are in natural sciences, mathematics and statistics, information and communication technologies, and engineering compared to an average of 22.6 percent in the rest of OECD countries. The skills gap section of this CPSD gives a comprehensive analysis of the higher education and training landscape in Chile.

FIGURE 4.22 ICT PATENTS FILED UNDER THE PATENT COOPERATION TREATY, 2016

Source: WEF 2016.

Certain characteristics of the local entrepreneurial culture could also be hindering dynamism in the ecosystem. While entrepreneurial culture is strong in Chile according to some global indicators (including GEM),⁶⁸ other global indexes point to low scores on critical thinking in teaching and on companies embracing disruptive ideas (WEF 2019), and to a relatively conservative and risk-averse society,⁶⁹ issues that could be hindering aspirations to grow large and become global. This could change in coming years as younger generations, who have been more exposed to a globalized world, take the lead in businesses.

Recommendations

Chile is well positioned to take advantage of the technologies of the next decade and promote digital inclusion for all Chileans. Together policy makers, private actors, and civil society can improve the digital ecosystem, giving the entire population access to meaningful connectivity. To achieve this ambitious goal, some key actions are necessary, while minimizing climate impact where possible. Measures could focus on lowering tariffs through the expansion of mobile data towers to encourage the development of digital infrastructure, coverage, and the entry of new operators. Setting up an independent regulator for the telecom sector will help strengthen regulatory capacities and increase the sector's efficiency. In addition, the approval in Congress and enforcement of the bill proposal to strengthen the protection and processing of personal data will be critical to the growth of the digital economy.

To increase fixed broadband access in underserved areas, network development needs a stronger regulatory framework that fosters broader mutualization. Several options can be considered. One alternative is issuing specific licenses to allow nontelecom players to own and operate infrastructure. Another is to support a mandatory open access policy for all telecommunication actors to active and passive infrastructure—for example, a requirement for infrastructure owners to allow others to access their infrastructure without discrimination, including how open access shall be provided. Finally, it could also be helpful to build civil work regulations with mandatory obligations across industries to adhere to specific construction guidelines and facilitate infrastructure sharing (such as fiber ducting specifications in residential developments and an obligation to provide open access to ducts upon development completion).

The Chilean digital entrepreneurship ecosystem can transition from a system that is dependent on government funding and is locally focused to a more regional and globally oriented ecosystem. The government can encourage private investments in Chilean venture capital from high-net-worth individuals (HNWI), local institutional investors, and the growing regional VC funds. Successful examples include the city of London, where the government introduced tax rebates for HNWIs who invested in incubators and accelerators. The creation of VC funds focused on strategic sectors would be important, such as the positive experience of the Fenix Fund in Chile that concentrates on mining. In July 2021, a fund of funds initiative was presented to the Ministry of Economy by the Chilean Association of Entrepreneurs (ASECH) with the support of other institutions such as Endeavor. Advancing on a fund-of-funds initiative as other countries have successfully done could be a good strategy to increase risk financing, replacing some of the current credit lines to investment funds. Benefiting from national and international corporations with local subsidiaries, corporate venturing and open innovation could be promoted further. The government could ignite more buzz around its ecosystem, deepening relations with the local and international media, and be more proactive in the attraction of regional and international funds to the country, especially after the consolidation of Chile's first unicorns and the increased VC momentum in Brazil and Mexico. The Association of Family Businesses (AEF), which has been recently promoting impact investments among its members, could be another important player in promoting venture financing.⁷⁰

Fostering regional or global expansion early in the life of start-ups will be important to overcome Chile's small market size as other countries have done (such as Estonia, Israel, and Singapore). Chile can leverage the region's relative homogeneity in terms of language and culture to scale up. For example, Israeli digital enterprises focused on global scale-up early on—facilitated by mentorship provided by funds managed by well-known entrepreneurs—and on engagement with foreign VCs. These funds often incubate the business within the country, with a small development team, to prove the product and then scale up by building sales and marketing abroad. VC funds may establish a dedicated “CFO [chief financial officer]-in-Residence program” to help their portfolio companies set up for regional or global expansion early on. Chile could also develop partnerships with international hubs, such as Brazil and Israel, and approach regional VC funds. Such partnerships were developed in Hungary with the INPUT program and in India with Silicon Valley.

To foster the benefits of networking, Chile could introduce innovation vouchers for corporate R&D or research collaborations and create research anchors embedded in domestic clusters. Innovation vouchers enable a firm to contract research from selected local or international research institutes and develop new linkages, encouraging future innovation. The government could create research anchors to support key strategic clusters. For example, the municipality of St. Louis, (in the US state of Missouri) deployed a strategy to develop an agro-tech cluster by establishing research institutes (such as in plant sciences), incubators, and accelerators in collaboration with the private sector and universities. As evidenced by countries and cities that successfully used cluster strategies to develop their digital niches (such as Estonia and Ireland), investing in the innovative capacity of individuals, firms, and research bodies is critical to ensure that the Chilean ecosystem does not stagnate and remains vibrant and competitive.

Closing the skills gap could help expand digital entrepreneurship and the digital economy more broadly. Digital skills and STEM fields need to be taught early in public and private schools, because early exposure favors the pursuit of graduate STEM careers. Universities could further increase efforts to provide relevant training by updating curricula over time. Public and private partnerships could also contribute to securing new educational, research, and workforce training opportunities for faculty and students, expanding their current network and promoting the usefulness of these careers. This process takes time but is important to improve the relevance and inclusiveness of the educational system.

Table 4.9 offers a matrix of recommendations to encourage private sector development in digital infrastructure and entrepreneurship.

TABLE 4.9 RECOMMENDATIONS TO SUPPORT DIGITAL INFRASTRUCTURE AND ENTREPRENEURSHIP

Strategic objective	Short-medium term	Potential partners for Implementation
Demand-side measures		
Fostering higher mobile access network mutualization and reinforcing high-speed broadband access for the population	Develop a favorable regulatory environment: <ul style="list-style-type: none"> • Improve the spectrum assignment process. • Approve and enforce the bill proposal on data protection. • Enforce the bill to declare telecom services a public interest to guarantee telecom’s universality and affordability. • Enforce regulations on unbundling of the local loop. • Set up an independent regulator for the telecom sector to strengthen its regulatory capacities. 	SUBTEL Congress Private sector

Strategic objective	Short-medium term	Potential partners for Implementation
<p>Developing fixed broadband access network in rural areas and underserved areas through regulatory measures that foster broader mutualization</p>	<p>Several options could be considered:</p> <ul style="list-style-type: none"> • Issue specific licenses allowing nontelecom players to own and operate infrastructure. • Support mandatory open access for all telecom actors to active and passive infrastructure (such as a requirement for infrastructure owners to allow others to access their infrastructure without discrimination, including outlining how open access shall be provided). • Build civil work regulations with mandatory obligations across industries to adhere to specific building and construction guidelines and facilitate infrastructure sharing. <p>The government could also improve regulation to</p> <ul style="list-style-type: none"> • Establish a universal access obligation for operators to increase telecom coverage in rural and low-income urban areas. • Regulate last-mile and long-distance infrastructure access. 	<p>SUBTEL Congress Private sector</p>
<p>Accelerating emerging local and regional cloud actors</p>	<ul style="list-style-type: none"> • Accelerate the development of regional cloud actors. • Approve and enforce the bill proposal on data protection. 	<p>SUBTEL Congress Private sector</p>
<p>Contributing to the development of IoT connectivity</p>	<ul style="list-style-type: none"> • Accelerate ongoing initiatives (such as the Araucania project). • Foster the acceleration of IoT adoption by supporting such actors (including Sigfox) and similar initiatives. 	<p>Corfo GORE Universities SUBTEL Private sector</p>
<p>Transitioning the Chilean digital entrepreneurship ecosystem from a system that is dependent on government funding and is locally focused to a more regional and globally oriented ecosystem that is private sector driven</p>	<p>Encourage private investments in Chilean venture capital from HNWIs, local institutional investors, and the growing regional VC funds.</p> <ul style="list-style-type: none"> • Consider including incentives such as tax rebates for HNWIs investing in incubators and accelerators. • Create VC funds focused on strategic sectors (such as the Fenix Fund on mining). • Establish a fund of funds initiative. • Develop corporate venturing and open innovation. • Streamline support from investment funds with state subsidies. • Focus on financing later stages of firms' start-up cycle. • Ignite buzz around the ecosystem to attract regional and foreign investment funds. • Approach regional VC funds active in Brazil and Mexico through showcase events by accelerators to enhance funds' interest in Chilean start-ups. • Develop training programs on start-up investment for funders and investors. 	<p>Ministry of Economy, Development and Tourism ASECH Private institutions (Endeavor) National and international corporations Corfo Chilean Venture Capital Association AEF</p>

Strategic objective	Short-medium term	Potential partners for Implementation
Promoting regional expansion early in the life of start-ups	<ul style="list-style-type: none"> • Leverage the Latin America and Caribbean region's relative homogeneity in terms of language and culture. • Develop partnerships with international hubs and approach regional VC funds. • Establish international exchange programs for entrepreneurs with a focus on enabling regional or global scale-up for Chilean ventures. 	Corfo MSTIK VC funds Private sector ANID
Stimulating corporate R&D and networking and collaborations with the rest of the ecosystem	<ul style="list-style-type: none"> • Introduce innovation vouchers for R&D. • Foster research hubs in key domestic clusters (such as in agro-tech) by establishing research institutes, incubators, and accelerators in collaboration with the private sector and universities. 	Corfo ANID Universities Private sector

Notes

1. Hydrogen can also be produced by using fossil fuels, and where the resulting emissions are captured and sequestered, this is referred to as blue hydrogen.
2. The French firm, Alstom, for example, is running hydrogen-powered locomotives (Economist 2021).
3. Some studies that highlight Chile's competitiveness as a GH producer include The Future of Hydrogen, in which the International Energy Agency (IEA 2019) calls Chile a hidden champion and estimated that the country can deliver 160 million tons per year of GH with a capacity to produce GH at US\$2/kgH₂ by 2030; "First Latin America & Caribbean Hydrogen Economy Index" by Hincio positions Chile at the top of its hydrogen index for the Latin America and Caribbean region and notes that the country has the largest number of projects under development. This 2021 index considers GH public policies, ecosystem structure, projects operating and under development, mobility adoption, and international cooperation agreements.
4. Resolución externa N° 171 lists production and transmission facilities under construction. The nonconventional renewable energy segment—which includes biomass, geothermal, and small hydro in addition to solar and wind—is the fastest-growing segment in the Chilean electricity system (it does not include hydroelectric with dams and run-of-river over 20 MW of installed capacity. In terms of installed capacity, the nonconventional segment is the second-largest category behind thermal generation (coal, natural gas, and diesel). In addition to the 9.12 GW already installed, there are 5.2 GW in construction, 23.8 GW approved by the Environmental Assessment System, and 18.9 GW in evaluation Coordinador Eléctrico Nacional, "Informe Mensual del Coordinador Eléctrico Nacional," 2021. [Online]. Available: <https://www.coordinador.cl/reportes-y-estadisticas/>
5. That is, through hydrogen blended into natural gas pipelines.
6. Although water availability is important for GH production and water is scarce northern Chile (where solar energy is abundant), this issue is not a binding constraint because of the possibility of using desalinated water. The impact of desalination costs on overall hydrogen production costs is minimal.
7. BCN 2021—see article 4, sections c, d, and e.
8. On September 2021, the Ministry of Energy started to work on this regulation based on the ISO norm/TS 20100 relative to gaseous hydrogen.

9. On September 2021, the Ministry of Energy started to work on this regulation based on the international norm NFPA 2.
10. For more information on the need to develop norms on GH₂, please refer to the study Centro de Energía UC 2020.
11. Levelized costs, at utility scale and at today's costs.
12. More information on the assumptions and calculations for the LCOE (Levelized cost of energy) and LCOH (levelized cost of Hydrogen) can be found in Appendix H.
13. The capacity factor is the ratio of actual energy output over a given period of time to the maximum possible electrical energy output over that period. Capacity factors vary considerably by fuel type (and by plant) and are a measure of reliability. According to the US Energy Information Administration, in 2019, US capacity factors ranged from an average of 93.5 percent for nuclear power to 24.5 percent for solar.
14. An estimated levelized cost of energy (LCOE) of US\$18/MWh from wind at 61 percent capacity factor was reported by the Selknam project developers, interviewed as part of this report, as a result of simulations for 5 MW turbines in the Magallanes region.
15. The TCO corresponds to the present costs of acquisition, operation, maintenance, and renewal of the equipment over a period of 20 years, while the LC is a measure of the average net present cost of each application over its lifetime, per unit of output.
16. In 2018 the Japanese Ministry of Economy, Trade and Industry (METI) developed a “Basic Hydrogen Strategy” whose key aspects include expanding international GH supply chains and setting cost targets for carbon-free energy. These correspond to US\$10/kg H₂ by 2020, US\$3/kg H₂ by 2030, and US\$2/kg H₂ by 2050. These cost targets assume that by 2030 the commercial scale supply chain of hydrogen would be established, and 300,000 tons of hydrogen would be imported by Japan annually. Import targets increase to 5–10 million tons of GH by 2050.
17. Assuming green premia or carbon prices are not considered.
18. Chile will need to address its lack of infrastructure to transport and store hydrogen, taking care to avoid stranded or costly investments (Armijo and Philibert 2020). For example, while blending mandates may reduce emissions from heating uses in the industrial and residential sectors, they could also, however, block or delay other decarbonization approaches, such as electrification or the deployment of dedicated hydrogen pipelines (Graafland and Overland 2020). For long-term mitigation efforts it is important to avoid lock-in effects in terms of continuing natural gas use because of the small amount of GH in the pipeline. As example, Britain's hydrogen network plan states that “(...) gas networks will, with regulatory approval, carry out to enable 100% hydrogen to be transported in different sectors, (...)”. (ENA 2020).
19. Law 20,936 (2016) introduced a new transmission toll scheme based on the voltage levels and paid mainly by end users as a stamp charge per unit of grid energy consumed and is in the range of 12-20 USD/MWh. For clients connected at the distribution level, grid charges can reach 50 USD/MWh.
20. This is due to weak water administration and to water shortages in the central part of the country due to a decade of drought. A recent study suggests that by 2035 a deficit in electricity generation due to water resource shortages is possible (Revistaei 2021). There does exist some space for existing hydropower in hydrogen production if it can provide electricity at a cost of, for example, US\$20/MWh, which in general would be possible only during limited low-demand hours (between 11 p.m. and 6 a.m.).
21. The first CSP project in the Latin America and the Caribbean region, Cerro Dominador, is located in the Antofagasta Region, with a total capacity of 210 MW. See Gubinelli, Guido. April 13, 2021. “Avanza Cerro Dominador y la Discusión sobre la Concentración Solar de Potencia. https://www.energiaestrategica.com/avanza-cerro-dominador-y-la-discusion-sobre-la-concentracion-solar-de-potencia-en-chile/?utm_source=email_marketing&utm_admin=136890&utm_medium=email&utm_campaign=Advierten_.”
22. Curtailment is the deliberate reduction in output below what would have been produced, in order to balance energy supply and demand, or due to transmission constraints.
23. Generation projects with an installed capacity of less than 9 MW. See Energía Estratégico 2021.
24. A new regulation was issued in early 2020 that recognizes capacity for energy storage coupled with a utility and pays it accordingly. But this regulation does not recognize capacity for an isolated electricity storage project.
25. The government and AES recently announced that AES would be increasing its storage capacity in Chile by 188MW to a total of 363 MW by 2023. The government targets having 2 GW of storage by 2030.
26. Currently, efforts from the public sector are focused in developing a supply side, so there is an opportunity to help demand, considering also that this is the side exposed to technology risks.
27. Feed-in-tariffs involve an obligation to purchase the electricity produced by renewable energy producers, at a fixed tariff. It should be noted that the approach experienced significant difficulties, and many developers went bankrupt as prices decreased.
28. A double-sided auction is a two-sided auction that aims to obtain the most competitive price from the supply side and simultaneously obtain the highest availability to pay from the demand side.
29. The CfD scheme for GH will be soon deployed in the context of the German national hydrogen strategy. This is implemented through the H2Global initiative, which aims to bring the supply and demand together with a double auction mechanism. The auctions are handled by an intermediary (HINT.CO) to conclude long-term purchase contracts on the supply side and short-term resale contracts on

the demand side. The intermediary compensates for the difference between the offer and the demand price using a funding mechanism. For more information see <https://h2-global.de/>.

30. Ports should be considered as a cornerstone for GH ecosystems since they are related to several close-to-market applications, as forklifts and export, and additionally there could be some synergies with infrastructure utilization (as chemical storage and transport) and mining applications due to the commercial relationships (as for example Mejillones port).
31. The World Bank is providing technical assistance to support the establishment of quotas for green fuels and has carried out an initial assessment of what green hydrogen certification could look like.
32. The World Bank has carried out an assessment of various international certification schemes and has come to similar conclusions.
33. Article 6 of the Paris Agreement recognizes that parties may choose to cooperate voluntarily in implementing their nationally determined contributions (NDCs) to allow for higher ambition and to promote sustainable development and environmental integrity. Article 6 cooperative approaches offer an important opportunity to attract international finance for climate mitigation projects, augmenting and complementing traditional forms of climate finance. Key considerations in designing Article 6 projects include meeting the requirements elaborated in the Paris Agreement and subsequent (still-to-be-decided) rules and guidelines.
34. The World Bank's Climate Warehouse allows the tracking of GHG emission reduction for projects under Article 6 of the Paris Agreement. For more information, see <https://www.worldbank.org/en/programs/climate-warehouse/reports-resources>.
35. The World Bank is already supporting the government with an ongoing study assessing the feasibility for GH2 in noninterconnected systems.
36. A similar initiative has been developed in California. See <https://www.sdge.com/sites/default/files/documents/CleanEnergy.pdf> and <https://microgridknowledge.com/borrego-springs-microgrid-renewable/>.
37. For further information, please see <https://arclim.mma.gob.cl/>.
38. Rising temperatures modify the ecosystem of arthropods (insects, arachnids and other invertebrates), including their diversity and abundance, their geographic distribution, and their interactions with herbivores.
39. The Ministry of Environment and domestic and international partners created the Chilean Climate Risk Atlas (ARCLIM) <https://arclim.mma.gob.cl/>. The ARCLIM system hosts information on about 50 separate climate indexes, and it projects climate impacts until 2070 using historical data dating back to 1970. Information is shown down to 5 kilometers of resolution and is mapped by territorial units, including communes, watersheds, and cities. The value chains include some of the most important export fruits (cherries and apples) and export nuts (walnuts and almonds); the most important grains (wheat and rainfed wheat, and corn); the most important root vegetables (potatoes and rainfed potatoes); a very important legume (beans), and some of the most important livestock products (dairy cows, meat cows, and sheep).
40. The estimates considered GHG emission scenarios associated with RCP8.5 and used projections of global circulation models toward the year 2050. Subsequently, simulation models of crops were used to calculate changes in crop yield and livestock capacity in the grasslands of southern Chile. The change in the net production margin was estimated by using prices and production costs available in ODEPA reports.
41. Estimates are conservative because they do not account for water supply restrictions.
42. The simulations assume that there is no change in the current pattern of production.
43. The CropSyst model was used to generate the annual biomass of grasslands that can grow under different scenarios, with the results used to calculate the impact on animal growth.
44. The study covers Africa, Asia, and Latin America.
45. According to the Food and Agriculture Organization of the United Nations (FAO), sustainable intensification of agriculture (SIA) means building productive agriculture systems that conserve and enhance natural resources. These systems can use the ecosystem approach, a strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use in an equitable way (FAO 2016).
46. MAPS (Mitigation Action Plans & Scenarios)
47. The study encompassed the Ministries of Agriculture, Public Works, Social Development, Economy, Energy and Environment.
48. The "Active Irrigation Program" has two modalities: (a) the Intrapredial Modality subsidizes up to 70 percent of the total cost of studies related to irrigation and drainage, and water distribution within a property, with a ceiling of US\$4,200; and the (b) Extrapredial Modality subsidizes up to 70 percent of the total cost of studies related to irrigation and drainage and water distribution of an organization of water users, involving multiple properties, with a ceiling of US\$12,700.
49. These include (a) satellite remote sensing and drones; (b) geographic information systems; (c) monitoring and sampling systems through high-precision sensors located in soils, foliage, trunks, and roots; (d) infrared bands; (e) crop thermo maps; (f) specialized software for database management; and (g) automated communication to intervention instruments (fertigation equipment, for example).
50. Genetic improvements also cover the development of varieties of annual crops, fruit trees, vegetables, and forage, with higher levels of adaptation to climate change (tolerance to drought and resistance to pests and relevant diseases). INIA also engages in data gathering and sharing through its agro-meteorological stations (nearly 150 throughout the country) for climate risk management.

51. During 2012–16, just 5 percent of fruit companies benefited from R&D tax credits with an amount of Ch\$6,734 million or 4 percent of the total R&D tax credits certified (ASOEX 2018). During 2019, 61 R&D projects for Ch\$37,140 million received tax credit certifications, with just 1.3 percent of the total corresponding to three companies in agriculture, livestock, forestry, and fisheries.
52. CNR, “Energías Renovables en Riego,” <https://www.cnr.gob.cl/temas-transversales/energias-renovables-en-riego/>.
53. The e-government index comprises several subindexes: e-participation, online service, human capital, and telecommunications infrastructure.
54. Cámara Nacional Comercio Servicios y Turismo data.
55. Subsecretaría de Telecomunicaciones, Estudios y Estadísticas sectoriales <https://www.subtel.gob.cl/estudios-y-estadisticas/telefonía/>
56. Data prices are 2.9 percent of gross national income per capita, above the affordability threshold target of 2 percent recommended by the International Telecommunication Union and the United Nations Broadband Committee.
57. The BPS survey was conducted in Chile between June 11 and July 21, 2021, and includes 800 observations from firms in manufacturing, retail, and other services sectors. Similar surveys have been conducted in more than 60 countries across the globe.
58. For large, medium, and small firms, 61, 50, and 16 percent of them, respectively, are allowing telework and 17, 23, and 14 percent of their workers, respectively, are teleworking.
59. South Pacific Cable System and Mistral cable in the last phase of construction and the Humboldt transoceanic cable project that plans to connect Chile to Latin America and the Caribbean and Asia.
60. Network data were provided by SUBTEL.
61. Fiber technology (based on fiber optic cables) provides a faster connection than cable (based on copper wires).
62. The amount of the Flexible Seed Capital funds for each business incubator is approximately US\$828,000. This money can be allocated by the business incubator to its incubated ventures as seed capital.
63. The Isenberg Entrepreneurial Ecosystem Model was developed by Daniel Isenberg at Babson College in 2011.
64. Firms that have rapid growth potential, growing at least by 20 percent per year in employees for three consecutive years, starting from 10 employees.
65. In the case of the Seed Capital (Capital Semilla) program, subsidies need to be used for market research, which is not always critical for some ventures. In the case of innovation programs, ventures are restricted to suppliers registered with Corfo and do not have the freedom to select other institutions or private companies. Any amendment to the original project that received the funds must be previously approved by Corfo, delaying business development.
66. Digital services sectors include financial services, computer services, information services, telecom, and publishing services.
67. In the WEF’s Global Competitiveness Index, Chile score 4.3 (within a range of 1–7 with 7 being the best) for the variable digital skills among the workforce, higher than the Latin America and Caribbean average score of 3.6 but below the OECD average score of 4.8. Finland is the highest at 5.8.
68. According to GEM, 74 percent of respondents in Chile agree that most people consider starting a business a desirable career choice, compared to 70 percent and 56 percent for Latin America and the Caribbean and the OECD, respectively.
69. Hofstede Insights, <https://www.hofstede-insights.com/product/compare-countries/>.
70. AEF groups together 82 of the main business families in the country that concentrate economic activity in different productive sectors.

APPENDIX A:

GREEN HYDROGEN: MODEL ASSUMPTIONS AND CALCULATIONS

Costs assumptions for the Levelized Cost of Electricity (LCOE):

TABLE A.1 WIND AND SOLAR CAPEX, OPEX

Crop	Today	2030	Log term
Wind			
CAPEX US\$/kW	1,266	1,180	1,104
OPEX (% CAPEX)	2%	2%	2%
Solar			
CAPEX US\$/kW	871	657	536
OPEX (% CAPEX)	1.7%	1.7%	1.7%

Source: ImplementaSur, 2021

LCOE full results:

TABLE A.2 CAPACITY FACTORS AND LEVELIZED COST OF ELECTRICITY (LCOE) IN SELECTED REGIONS

Concept	North	Central	South	Magallanes
Solar capacity factor	38.1%	2.8%	23.9%	17.4%
LCOE solar "Today" (US\$/MWh)	26.86	35.44	42.85	58.75
LCOE solar "2030" (US\$/MWh)	20.27	26.74	32.33	44.33
LCOE solar "Long Term" (US\$/MWh)	16.52	21.79	26.34	36.12
Wind capacity factor	37.2%	37.9%	34.2%	51.8%
LCOE wind "Today" (US\$/MWh)	41.10	40.40	44.73	29.52
LCOE wind "2030" (US\$/MWh)	38.31	37.65	41.69	27.51
LCOE wind "Long Term" (US\$/MWh)	35.83	35.22	38.99	25.73

Source: ImplementaSur, 2021, using capacity factor data from Coordinador Eléctrico Nacional and Armijo and Philibert 2019. Cost data from IEA 2019

Costs assumptions for the storage and transport models:**TABLE A.3 CAPITAL AND OPERATIONAL COSTS OF STORAGE**

	CAPEX (US\$/kg GH)			OPEX (% of CAPEX)
	Today	2030	Long term	
NH₃¹	9.5	9.5	9.5	4%
LH₂²	90	90	90	4%
Low pressure CH₂³	783	433	278	3%
High pressure CH₂⁴	3,913	2,598	1,855	3%

Source: ImplementaSur, 2021

Methylene (CH₂) at high and low pressure is mostly used in applications that require hydrogen storage at a higher density. Some examples are tank systems for recharging hydrogen-based vehicles, such as forklifts, buses, and CAEX mining trucks. Likewise, it can be used in systems for the production of hydrogen energy vectors, such as ammonia and methanol, as a buffer in the production, making it more flexible. The costs for both low and high pressure compressed hydrogen consider compression costs. Liquid hydrogen (LH₂) storage CAPEX does not vary between the three scenarios. For this vector, boil-off losses of 0.1 percent of the stored capacity per day—associated with small variations in storage temperature—are considered.

With a CAPEX of US\$9.5 per kilogram of hydrogen, ammonia has the lowest storage cost of the four vectors mentioned. This is because ammonia (NH₃) does not incur major compression costs, and the volumetric hydrogen density of NH₃ is greater than LH₂, using less space for the same amount of energy. As a result, this vector is very useful for the storage of hydrogen in ports of export, where the stability of its transport conditions (25°C, 20 bar) and density allow for relatively simple transport compared to LH₂. Like LH₂, this vector has the same storage capital across the three temporal scenarios considered.

The hydrogen transportation model considers the use of dedicated trucks. Hydrogen truck transportation can be used cost effectively in the GH value chain. According to the International Energy Agency (IEA), transportation by truck is cheaper than pipeline when transporting less than 500 tons of hydrogen per day. Considering the above, there are multiple applications in which transportation by dedicated trucks is preferred, such as transport from small and medium-sized hydrogen production plants to ports of export. It should be noted that in a narrow country like Chile, in which the maximum width is 360 kilometers, domestic transport may not play a significant role in costs in an export scenario.

1. Gallardo et al. 2021.
2. Gallardo et al. 2021.
3. Own elaboration, using NREL 2014 and Armijo and Philibert 2019.
4. Own elaboration, using NREL 2014 and Armijo and Philibert 2019.

The cost of dedicated truck transport is dependent on the amount of hydrogen transported and the kilometers transported, considering 0.125 US\$/kg GH for every 100 kilometers traveled in the case of LH2 and NH3, and 0.6 US\$/kg GH for every 100 kilometers traveled in the case of CH2 (both at low and high pressure) (Gallardo et al. 2021). Therefore, the model is sensitive to the mass densities of the selected vector. Cost assumptions and efficiency for electrolyzers are:

TABLE A.4 COST ASSUMPTIONS AND EFFICIENCY FOR ELECTROLYZERS

Electrolyzer	Today	2030	Log term
CAPEX US\$/kW	872	700	269
OPEX (% CAPEX)	2.2%	1.5%	1.5%
Efficiency (%)	64%	69%	74%
Stack lifetime (oper. hours)	95,000	95,000	100,000
Stack repl. Cost (%CAPEX)	40%	40%	40%

Source: IEA, 2019

Levelized Cost of Heat (LCOH) and LCOE formulas and calculations are the following:

Using a hybrid production model from best available wind and solar in each region, the best combination of resources was obtained considering off-grid generation and optimal oversizing capacity of renewable to achieve lowest levelized production costs for GH (LCOH).

$$LCOH = \frac{CAPEX_{Ez} [CRF(1 + \frac{\%Stack\ Cost_r}{(1+WACC)^{Nr}}) + \%OPEX_{Ez}]}{CF_{Ez} \cdot 8760} \frac{LHV}{\eta} + LCOE(1 + \%curtailment) \frac{LHV}{\eta} + C_{H20} Q_{H20} - P_{O2} Q_{O2}$$

Where,

CF_{Ez} is the optimal electrolyzer capacity factor for each region's available VRE sources (optimal is solar in the north, central and south regions and wind in Magallanes).

CRF is the capital recovery factor for a 7 percent discount rate and lifetime of plant (30 years).

$\%Stack\ Cost_r$ is the stack replacement cost, as a percentage of CAPEX (40 percent), at time Nr (calculated as the quotient: stack lifetime hours / yearly full load operating hours).

LHV equals to the low heating value of hydrogen which is 33.381 kWh/kg and n is the electrolyzer's efficiency

$$LCOE = \frac{CAPEX_{VRE}(CRF + \%OPEX_{VRE})}{CF_{VRE} \cdot 8760}$$

is the levelized cost of electricity for the VRE plant

$C_{H_2O} Q_{H_2O}$ is the cost of supply of water at a 17 lt / kg GH rate and water cost depending on each region (5 US\$/m³ in the north and 1.5 US\$/m³ in the rest of the country).

$P_{O_2} Q_{O_2}$ is the revenue from oxygen sales at a 7.8 kg O₂ / kg GH production rate and oxygen price of 0.03 US\$/kg O₂ for all regions.

Curtailement is a result of the on-site production sizing resulting from optimized hybrid variable renewable energy (VRE) plant oversized relative to the electrolyzer capacity. Hybrid production is obtained for the central and south regions, whereas solar is the dominant technology in the north and wind in Magallanes. Results obtained from optimized sizing model for all regions at investments costs in the “2030” scenario are presented below:

TABLE A.5 OPTIMAL SIZING OF VRE FOR SELECTED REGIONS FOR HYBRID ON-SITE GH PRODUCTION

Concept	North	Central	South	Magallanes
Electrolyzer capacity (MW)	1.00	1.00	1.00	1.00
Optimal solar capacity (MW)	1.07	0.94	1.06	0.00
Optimal wind capacity (MW)	0.00	0.70	0.65	1.18
Hybrid electrolyzer capacity factor (%)	39.7%	50.6%	44.5%	61.1%
On-site curtailment (%)	2.23%	5.66%	6.65%	0.10%
Hybrid LCOE “2030” (US\$/MWh)	20.27	32.21	36.77	27.51
Hybrid LCOH – “2030” (US\$/kg)	1.83	2.23	2.58	1.79

Source: ImplementaSur, 2021, using hourly generation data for selected VRE plants in the north, central and south regions and results from Armijo and Philibert 2019 for Magallanes. Cost data from IEA 2019

APPENDIX B:

MAIN APPLICATIONS SUPPORTING THE DEVELOPMENT OF A GH MARKET

This appendix is devoted to summarizing the applications that hydrogen could satisfy in different industries throughout the country. Main sectors of application are ordered according to the size of their potential hydrogen market, with those with the highest demand first. The transport sector stands out in terms of its potential, first with trucks in mining operations, with a market potential of 600,000 tons of GH a year. It is followed by the bus transport sector, with 380,000 tons of GH and domestic methanol production with 300,000 tons of GH as potential demand. The sizes of these sectors are presented in table B.1.

TABLE B.1 HYDROGEN MARKET POTENTIAL OF DIFFERENT INDUSTRY SECTORS

No.	Sector of application	Market potential (ton GH/year)
1	Trucks (mining operations)	600,000
2	Buses	380,000
3	Methanol	300,000
4	Ammonia	127,000 ⁵
5	Gas blending	50,000
6	Fertilizers	37,000
7	Forklifts	13,000
8	Backup generation	12,000

Source: ImplementaSur, 2021

5. This market potential includes the use of ammonia in explosives and fertilizers.

Transport uses

Hydrogen, as an energy carrier, is highly flexible and versatile. It can be used in fuel cells to produce electricity; it can be used directly in a combustion process to produce movement at the internal combustion engine (ICE), releasing water as a by-product. Hydrogen is a suitable fuel to use and decarbonize the transport sector, as it can be applied to light and heavy-duty vehicles. While the technology to use hydrogen in transportation is proven, there is a lack of development to reach economies of scale and the needed infrastructure to run a hydrogen-based transportation system, as is the case for fossil fuels. Here it is important to mention that hydrogen solutions will compete directly with battery transport solutions, which is the main low carbon solution for several transportation sectors (such as lightweight vehicles, or public transportation). On the other hand, GH should be a suitable solution for heavy-duty applications.

Trucks

Prototype truck models are available at least since 2016, with lorries performing far better than diesel equivalent trucks (longer operational range, higher torque). Again, the logistics of providing hydrogen across routes is an important barrier for the full development of this option.

In Chile, the main economic activity is mining, and emissions from mining trucks fueled with diesel are responsible for 5,000 GgCO₂eq (gigagrams of CO₂ equivalents, i.e. greenhouse gas emissions). The industry is mainly concentrated in the Atacama Desert, a zone with the most intense solar radiation worldwide. Thanks to the decrease in the price of photovoltaic energy, projections are being made in order to reach a competitive price for GH to substitute fuel in haul trucks for mining. Corfo has developed a technological program “Development of Dual Diesel Hydrogen Combustion Systems in vehicles and equipment for mining operations”, seeking to create a technological consortium to adapt and develop technological solutions for the transformation of the conventional diesel-based operation of vehicles or equipment in mining operations, but experts agree that this kind of technology should be delivered by the Original Equipment Manufacturer (OEM). Trucks and machinery in mining operations have a market potential of 600,000 tons of GH in Chile. Hydrogen applications in mining haul trucks will compete with batteries or catenaries applications, which are being studied and deployed in other countries.

Buses

Currently the costs of the hydrogen technology are still far higher than the equivalent for diesel buses and there is space to reduce them. Several projects have demonstrated the viability of urban buses based on hydrogen, such as CHIC (Clean Hydrogen in European Cities), with more than 26 buses in four countries and 9 charging stations. In Berlin, 54 hybrid buses (hydrogen-diesel) ran between 2010 and 2016 with promising results, including a range of operation sufficient for this type of service, higher efficiency, and short refueling times. The costs of those buses are still higher than their equivalent based on diesel, and this is the main barrier for a massive introduction of hydrogen-based mobility. Other barriers are related to spare parts availability, capacity building, and high maintenance costs.

This sector has an estimated market potential of 300,000 tons of GH.

In Chile, EVs are rapidly being adopted as more than 400 electric buses currently run on the Santiago streets under the RED public transport systems. The Ministry of Transport and Telecommunications is working on the acquisition of more electric buses. The challenge is the upfront cost for electric buses, as they must be bought by the fleet.

Forklifts

The use of this type of vehicle has been quite widespread, especially for retail operations with more than 5,000 units in the U.S. The advantage is the confinement of the units whose operation is satisfied with in situ hydrogen supply. The charging time is reduced, the energy and power are continuous for the operation (in contrast with batteries where the energy supply diminishes when the batteries are in low charge), the operation is reliable even with low temperatures, and the devoted infrastructure for hydrogen production and storage is smaller than its equivalent with batteries. Similar initiatives are being developed in European countries such as France and Germany. Using hydrogen fuel cells for forklifts was one of the first applications of hydrogen as a fuel in distribution and logistics centers. This has been implemented by companies like Walmart, Amazon, Carrefour, and BMW. These kinds of projects can be replicated in Chile and assures profitability, as they have already been implemented.

Methanol

Methanol is a versatile compound in the chemical industry, used to produce formaldehyde, acetic acid, and can be used as fuel, as it can be used to replace petrol in light and heavy-duty vehicles. Methanol production is based on hydrogen and carbon monoxide, stemming mainly from natural gas. The main barrier for this application is that carbon capture and storage (CCS) systems are required, which today are in an early development stage.

In Chile, two gas production plant use steam reforming of methane with an 85 percent thermal efficiency. In another project an integrated commercial e-methanol plant is being developed, consisting of the installation of a pilot plant to produce GH through an electrolyzer functioning with wind power. The project intends to produce 350 tons of methanol and 130,000 liters of GH per year.

Ammonia

Ammonia is the most-produced synthetic chemical in the world. Hydrogen is used through the Haber-Bosh process, responsible for 90 percent of ammonia produced globally. Ammonia can be used as an energy carrier, as a fertilizer, and for the production of explosives. In 2014, ammonia production reached 176 million tons with China, Russia, India, and the U.S. representing 54.7 percent of global production. Production of ammonia with GH could reduce CO₂ emissions up to 420 million tons/year, in the best-case scenario. Nonetheless, production prices for NH₃ are still significantly lower with grey hydrogen.

In Chile there are several pilot projects in progress for ammonia production. Ammonia production has the benefits of being a target product for several industries, such as fertilizers, explosives, chemicals, and energy.

Gas blending

There are several challenges to consider in using current gas networks for gas blending with hydrogen. The materials used in gas distribution networks limit mixtures to approximately 20 or 30 percent depending on the pressure of the pipes and the quality of the steel. For mixtures with low concentrations in volume (10-15 percent), the solution does not present major risks and appears viable. Another important point to consider is the end use of this gas mixture. For example, vehicles that run on natural gas and gas turbines are designed for a fuel gas that contains less than 2-3 percent hydrogen by volume. In occupying existing gas networks, the difficulty of possible cracks and leaks is presented, due to the absence of information on the networks, particularly those of distribution, and due to the pressure used.

Higher pressure increases the probability of failure. To transport hydrogen, it is required to use softer steels and therefore high-pressure gas networks are not suitable for its transport. To incorporate pressure reduction stations, it should be considered that the hydrogen is heated during its expansion and for this reason, the use of intermediate cooling stations may be employed.

Fertilizers

As mentioned above, ammonia (NH₃) is widely used as a component of fertilizers in agriculture, as the world's most manufactured synthetic chemical. The global CO₂ emissions associated with the manufacture of nitrogen fertilizers are estimated at 420 million tons of carbon dioxide per year (MtCO₂ / year). These emissions could be eliminated by producing ammonia with hydrogen from renewables and subsequently sending it to fertilizer factories and other industries.

Chile is an importer of fertilizers, at a volume of approximately one million tons per year, of which the main one is urea, and the rest divided into various ammonia-based fertilizers. This corresponds to an aggregate demand of approximately 37,000 annual tons of hydrogen, which could potentially be satisfied with local production.

It's important to highlight that the production of green fertilizers faces the same barriers as methanol applications, that needs the incorporation of CCS systems for the production of urea and other fertilizers.

Glass

Hydrogen is used in the production of high-quality glass. The glass manufacturing process includes a bath of tin where hydrogen and nitrogen are mixed producing a flawless glass and protecting the furnace. In Chile, hydrogen is used in the manufacture of special glasses for surface polishing of glassware and edge scorching after the forming process, to remove marks created by molds for different glass products such as tableware products, perfume bottles and crystal items, which gives them a smooth and shiny appearance. In Chile two such hydrogen production plants, one of which focuses on hydrogen feed for the glass plant in Lirquén. Hydrogen production takes place through an electrolysis plant capable of producing high purity hydrogen (99.999 percent).

Cement

Hydrogen could be used in furnaces replacing fossil fuels, thus avoiding CO₂ emissions. A fuel mix that includes hydrogen improves the combustion process allowing the use of other alternative fuels and reduces emissions by 10 percent. The project operates with a devoted hydrogen plant (in situ) producing 10 m₃ of hydrogen each hour, without need of storage (direct injection in the furnace). The use of hydrogen is part of the overall strategy to reduce CO₂ emissions in the cement production process, accounting for 5 percent of the total expected reductions.

Steel

Nowadays hydrogen is mainly used to produce highly pure molybdenum and tungsten. The use of hydrogen has been proposed to produce steel, which is an essential material used for construction, infrastructure, machinery, and household goods. Currently, steel production represents a considerable share of the carbon footprint as it is responsible for between 7 percent and 9 percent of all direct fossil fuel emissions, and each ton produced results in an average of 1.83 tons of CO₂, according to the World Steel Association. From the different technologies being investigated to reduce CO₂ emissions in steel production, GH is gaining ground as a viable alternative for the energy transition in this sector, as an auxiliary reducing agent (e.g. direct injection of hydrogen into the blast furnace tuyeres or in the production of direct reduced iron).

Refineries

Hydrogen is used in refineries to decrease the sulfur content of the crude oil and fuels. Since the environment regulations demand cleaner fuels with less sulfur content, the demand for hydrogen has risen. The process, known as hydrocracking, breaks the heavy molecules into lighter components such as gasoline and diesel. Other components useful for the refineries are obtained through this process, such as lubricant oils and feedstock for other petrochemical uses. In Chile, the largest use of hydrogen appears in refineries for the hydrotreating, hydrocracking and desulfurization of fuels. Two companies in Chile have a hydrogen production plant for refineries.

Agroindustry

The agricultural sector is important in the Chilean economy, accounting for 1.2 percent of the GDP and 7.7 percent of employment⁶. Chile is a net importer of fertilizers, with 1.1 million ton/year, mainly urea (52 percent) and phosphates (26 percent). Urea is produced from ammonia that is generated with a combination of hydrogen and nitrogen. There is a potential to substitute imported urea with locally produced ammonia, stemming from GH. As the CO₂ emissions related to ammonia production with grey hydrogen are not accounted for in Chile, the reduction in emissions resulting from local ammonia production with GH could be used in carbon markets.

6. See: <https://www.ine.cl/estadisticas/sociales/mercado-laboral/ocupacion-y-desocupacion>

Gas blending

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Back-up generation

Stationary applications are those in which fuel cells are operated in a specific location for primary power. In this way, hydrogen can be used as backup energy for telecommunications facilities. One of the advantages of fuel cell-based systems is that they are silent and have low emissions, so they can be installed in various places both indoors and outdoors. These systems take up little space and provide energy directly to the customer without loss of efficiency due to transmission in large electrical networks. The main challenge is to maintain the balance between electricity generation and consumption. Electrical systems require technologies capable of changing their generation quickly, connecting/disconnecting rapidly, staying on standby to face new changes, increasing their electricity consumption quickly, and with the possibility that the process is interrupted and storing energy during a significant period for it to be subsequently delivered to the network. For these reasons, it is required to include a fuel cell and an inverter to operate as storage for the electrical grid. In Chile, for power generation systems, hydrogen is used as a coolant in thermoelectric turbines. Dry hydrogen is used to cool electrical generators due to its high thermal conductivity and low viscosity.

Export

The hydrogen market worldwide is estimated as high as US\$ 300bn by 2030. Chile, according to its National Green Hydrogen Strategy, expects to become a hydrogen exporter before the end of the current decade with a global market share of almost 1 percent, exporting US\$ 2.5bn by 2030 and US\$ 24bn by 2050, with a production's cost of 1.5 US\$/kg of GH (MinEnergia 2020a).

Other applications

Tar sands

Bitumen, a mix of organic liquids, is obtained from tar sands. Then, it is distilled using different petrochemical techniques such as hydrocracking where hydrogen is needed to complete the process. With additional hydrogen, the crude oil obtained is further refined in more valuable products such as diesel or petrol. Hydrogen is a key feedstock to the production of liquid fuels from tar sands.

Coal liquefaction

The Bergius process is used to produce synthetic fuels (liquid hydrocarbons) using hydrogen with bituminous coal of high volatility, at high temperatures and pressures. The reaction produces heavy and mid weight oils, gasoline and some gases.

Light vehicles

Electric vehicles based on fuel-cell technology (FCEV) run with power between 80 and 120 kW with an efficiency from “tank to wheel” of 45 to 60 percent. OEM began their first model two decades ago and now FCEV are available in some specific locations (California, Japan). Nowadays, almost all the big car manufacturers have FCEV prototype models.

Charging stations for FCEV

One of the main barriers to developing hydrogen-based mobility is the implementation of the needed infrastructure to fuel the vehicles. The investments required to install the whole logistic chain to provide hydrogen at the end point are quite expensive and face the risk of not matching the demand (enough cars to justify the infrastructure). Service stations are available in the U.S., Japan, South Korea, and some western European countries. Plans to install new stations are in place in Germany, Japan, and the U.S. (mainly California).

Trains and tramways

The main advantage of trains run by hydrogen is that they avoid the infrastructure of electrification for a whole route (cables, posts, catenaries, etc.), reducing the investment costs. Current models in Europe can run for 100 km routes with speeds up to 140 km/hr. China is leading the manufacture and use of urban, hydrogen-based, tramways, with models that run up to 70 km/hr transporting 285 passengers each.

APPENDIX C:

COMPETITIVENESS OF GH PRODUCTION

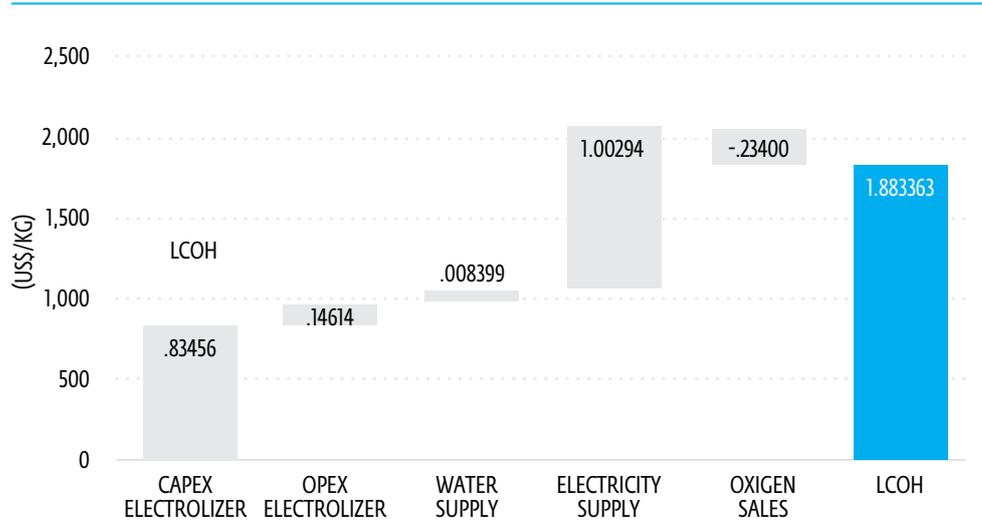
Despite the hydro potential in the central and southern regions, large hydro dam or even run of river (RoR) projects face strong environmental and community opposition, with developments taking ten or more years and not always obtaining the required social licensing to be completed.

Existing single-axis tracking solar can achieve annual capacity factors of 40 percent or more in the best performing photovoltaic plants in the far north and annual wind capacity factors in Magallanes are reported to be in the 50 percent-60 percent range. See Appendix H: Model assumptions, calculations, and results for more.

Using a seven percent discount rate for capital and a lifetime of 25 years for VRE plants, available generation data from operating plants in the northern, central, and southern regions obtained from the Coordinador Eléctrico Nacional, and reference capacity factor for Magallanes from Armijo and Philibert (IEA, 2019), LCOE for each region is presented in Appendix H: Model assumptions, calculations and results.

Even considering high water costs of 5 US\$/m³ (assumed only when production takes place in the northern zone), the impact on operating costs is relatively low compared with total OPEX.

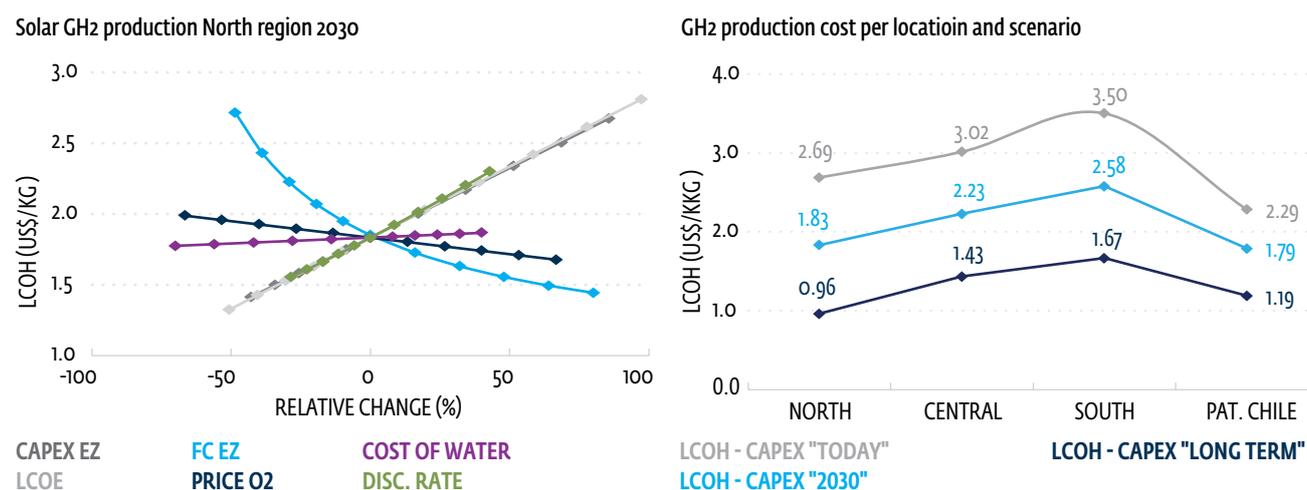
FIGURE C.1 LCOH BREAKDOWN NORTH, YEAR 2030, SOLAR ON-SITE



Source: ImplementaSur, 2021

Sensitivity analysis shows that most relevant components of production costs for GH are electrolyzer capacity factor (CF Ez), discount rate, cost of electricity, electrolyzer's investment cost (CAPEX Ez), the price at which surplus oxygen could be sold, and finally the cost of water.

FIGURE C.2 GH PRODUCTION SCENARIOS



Source: ImplementaSur, 2021

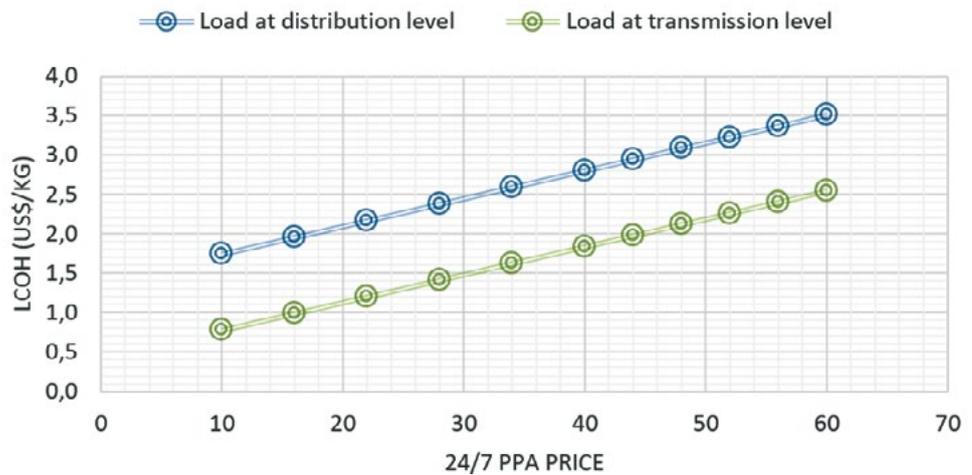
At today's costs of technology, GH sourced by wind energy in Magallanes has the lowest levelized production cost but this is expected to change with solar in the North being the most competitive in the long term as shown in appendix A, table A.2: Capacity factors and levelized cost of electricity (LCOE) in selected regions. In the central and southern regions, hybrid production of hydrogen using combined wind and solar would be less competitive than dedicated solar or wind production in the northern and Magallanes regions.

Expected prices for GH and main variables to create a competitive product

In Chile, transmission no longer follows generation projects like it used to do for conventional power projects that took 5-10 years of development. With generation projects taking less than 3 years to be developed (e.g., wind and solar) large transmission projects are lagging behind. Increasing opposition to develop long overhead lines are impacting costs and project completion dates. As an example, even though the interconnection of both independent power systems SING and SIC happened in November 2017, it was not until June 2019 that the relevant 500 kV line between Cardones and Polpaico allowed proper integration of both subsystems, 1.5 years later than planned and almost 7 years after the ministerial decree. Among the recent transmission projects announced is the Kimal – Lo Aguirre transmission line construction. With high voltage direct current (HVDC) technology, it is receiving bidding offers for its construction, but experts have already mentioned that it is

probable that this project will suffer a delay in its commissioning date. The project will be the first in Chile in the direct bipolar current. It will have a capacity of 2,000 MW per pole, a voltage level of at least 600 kV, and an approximate extension of 1,500 kilometers. According to the industry, this line would not be operational before 2030.

FIGURE C.3 ON-GRID GH PRODUCTION COST 2030 AND EZ CAPACITY FACTOR OF 95 PERCENT



Source: ImplementaSur, 2021

Considering distances between potential GH application and production, it is probable that GH distribution will be performed mainly by trucks, since distances are identified to be closer to 300 km. In the next figure a radius of 300 km from the Mejillones port is presented, indicating the mining operation sites within this area.

FIGURE C.4 300 KM AREA FROM MEJILLONES PORT



Source: ImplementaSur, 2021

APPENDIX D:

GREEN HYDROGEN: USE-CASES AND ASSUMPTIONS

CASES BASED ON TOTAL COST OF OWNERSHIP (TCO)

Hydrogen fuel cell forklifts

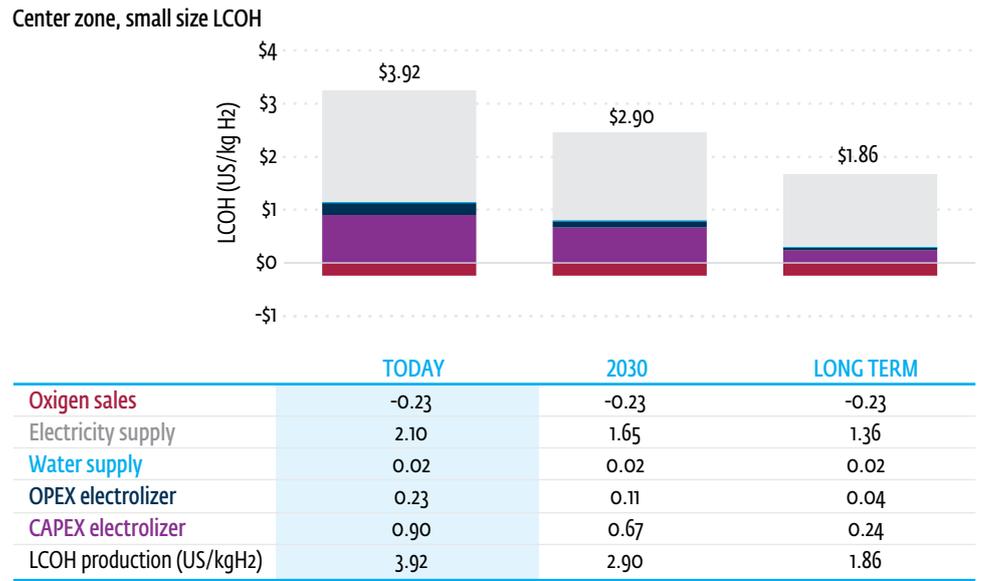
Forklifts fuelled by hydrogen are commercially mature. The main barrier to their generalized use is the logistics of hydrogen supply. Big retailers in Chile are considering this option to decarbonize their operations, but competitive plug-in electric battery forklifts can also take their place. For the moment, no specific projects for hydrogen-based forklift adoption are known. The model used a fleet of 100 forklifts based on GH fuel as input. A similar fleet was considered as a comparison case using electric forklifts. It should be noted that the comparison case does not have a cost projection for each scenario, so it remains fixed over time.

The most significant cost in hydrogen forklifts corresponds to the CAPEX of the fuel cells (FC) for the fleet, which reaches US\$ 2.9 million and remains constant in the three evaluated scenarios, and the CAPEX of compressed hydrogen storage, which has values between US\$145,000 and US\$350,000 depending on the year. For electric forklifts, the highest cost corresponds to the CAPEX of the batteries and chargers, which reaches 1.2 million US\$. Batteries have a replacement CAPEX that must be incurred every 4 years due to their limited useful life.

The operating costs of hydrogen-based forklifts include costs of lost productivity, maintenance, and GH production and storage, while the operating costs of the electric forklifts consider the loss of productivity, operation of the chargers, and electricity.

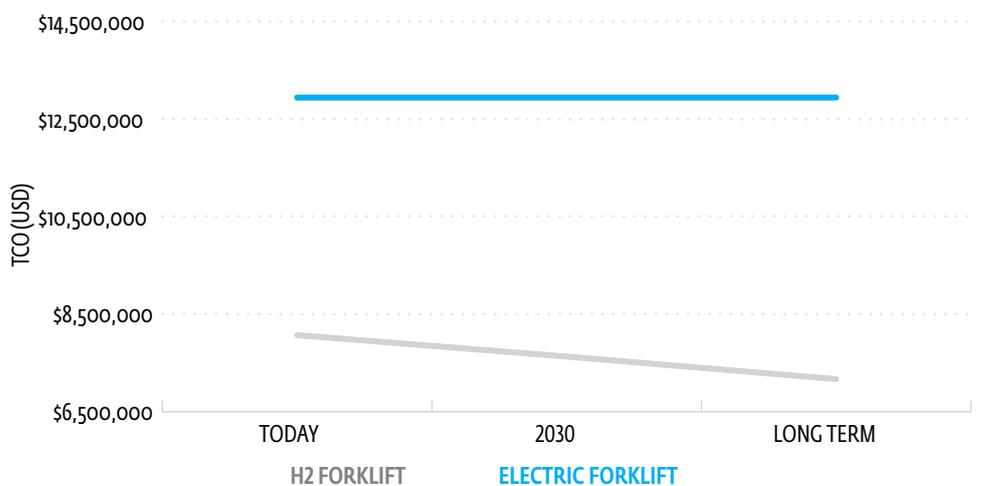
For the LCOH, the production of hydrogen with small electrolyzers and in the central part of the country was considered. The disaggregated costs of the LCOH applied in this model are presented below.

FIGURE D.1 DISAGGREGATED COSTS OF LCOH USED IN FORKLIFTS MODEL



Source: ImplementaSur, 2021

FIGURE D.2 COMPARISON OF GH AND ELECTRIC FORKLIFTS TCO THROUGH TIME



Source: ImplementaSur, 2021

The TCO of GH-based forklifts decreases over time due to the decrease in LCOH and hydrogen storage costs. Despite the above, the TCO of hydrogen forklifts is always lower than the TCO of electric forklifts, which remains fixed among the three scenarios. The reason behind the high TCO of the electric forklifts is that the battery replacement CAPEX must be incurred four times throughout the 20 years of the project.

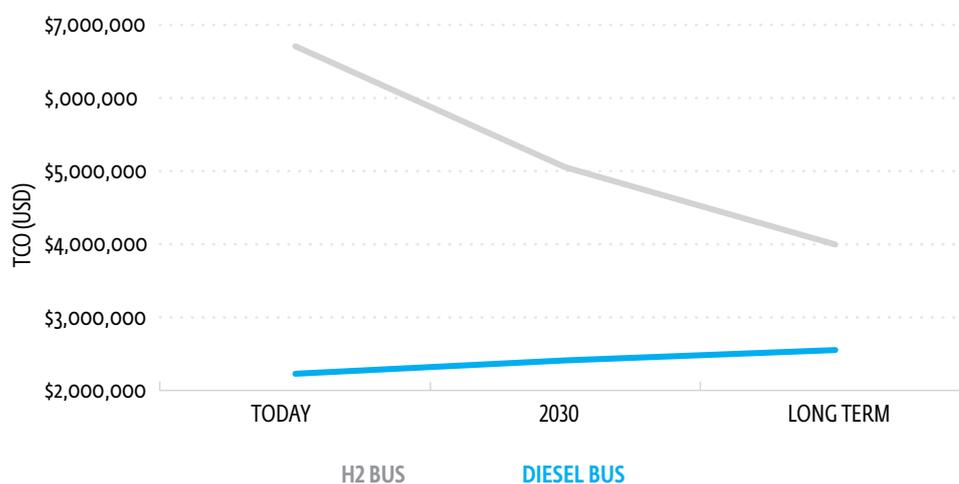
Hydrogen Fuel Cell (FC) buses

This application case considered a fleet of five buses as input. This same fleet was used for the diesel buses comparison case. The most significant cost in hydrogen buses corresponds to the CAPEX of the bus itself, followed by the cost distribution of GH. For the fleet, a total value of US\$2.3 million to US\$4.1 million is reached, depending on the scenario. The same occurs for diesel buses, in which case a CAPEX of US\$1 million is reached for the fleet in all scenarios. Both cases consider a replacement CAPEX of 90 percent of the original CAPEX 10 years after the beginning of the project.

The OPEX of hydrogen-based buses considers the operating costs of fuel cells, distribution, batteries, and hydrogen production and storage. In the case of diesel buses, the cost of diesel associated with the consumption of the fleet is considered.

Like the forklifts case study, for the LCOH, the production of hydrogen with small electrolyzers and in the central part of the country was considered. Therefore, the disaggregated costs of the LCOH applied in this model can be seen in figure D.1.

FIGURE D.3 COMPARISON OF GH AND DIESEL BUSES TCO THROUGH TIME



Source: ImplementaSur, 2021

Both the CAPEX and OPEX of the hydrogen-based bus fleet decrease over time, whereas the OPEX of this fleet is lower than the one of diesel buses in the long term, but the low CAPEX of diesel buses allows their TCO to remain lower in all scenarios. The TCO of diesel buses increases due to higher diesel prices over time.

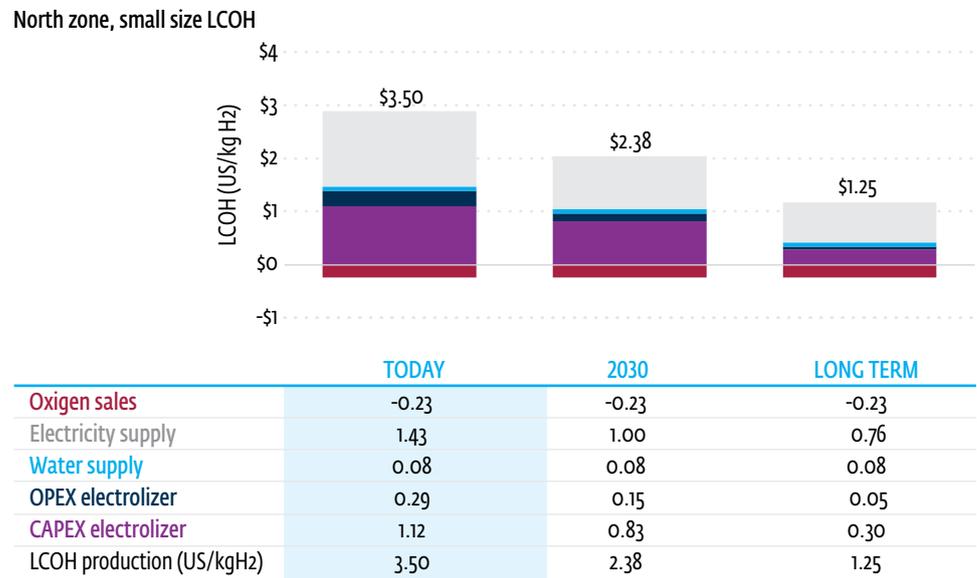
Hybrid hydrogen CAEX trucks

This application case considered the purchase and use of one CAEX truck using a 60 percent of GH and 40 percent of diesel fuel, versus a diesel CAEX truck. The most significant cost in the hybrid CAEX corresponds to the CAPEX of distribution of GH at high pressure, reaching a value between US\$0.522 million and US\$1.1 million depending on the scenario. For the CAEX to diesel, the highest cost corresponds to the purchase of fuel, which has values between US\$0.86 million and US\$1.6 million depending on the scenario.

The operational costs of the hybrid CAEX consist of the cost of production and storage of GH, distribution and the cost of diesel for 40 percent of the energy consumption. For the hybrid CAEX the operating costs correspond only to the annual diesel purchase.

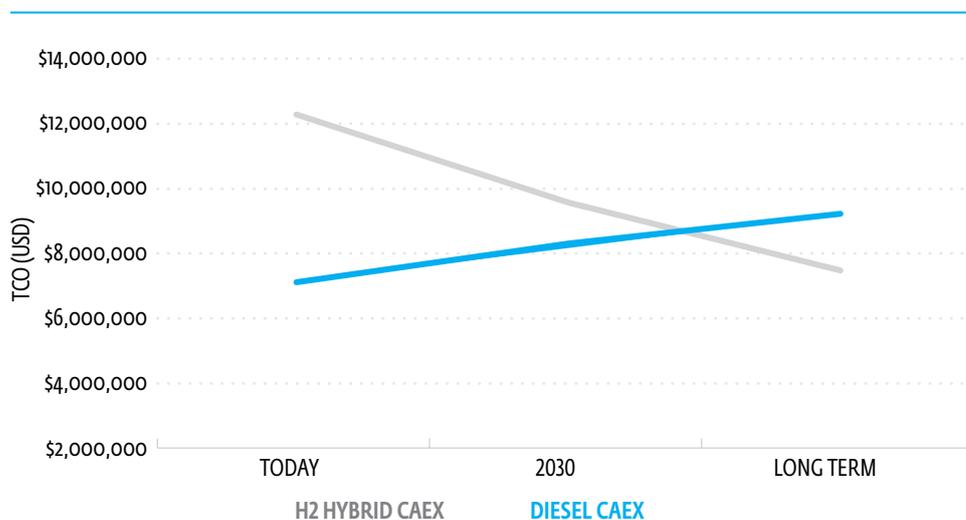
For the LCOH, the production of hydrogen with small electrolyzers and in the northern part of the country was considered. The disaggregated costs of the LCOH applied in this model are presented below.

FIGURE D.4 DISAGGREGATED COSTS OF LCOH USED IN CAEX MODEL



Source: ImplementaSur, 2021

FIGURE D.5 COMPARISON OF GH HYBRID CAEX AND DIESEL CAEX TCO THROUGH TIME



Source: ImplementaSur, 2021

The TCO of the hybrid CAEX is higher in the first two scenarios considered. This is due to the high CAPEX associated with the distribution of high-pressure hydrogen for the trucks. Over time the costs of distribution, together with the LCOH, decrease while the price of diesel increases, which leads to the hybrid CAEX having a lower TCO than diesel CAEX not long after the 2030 scenario.

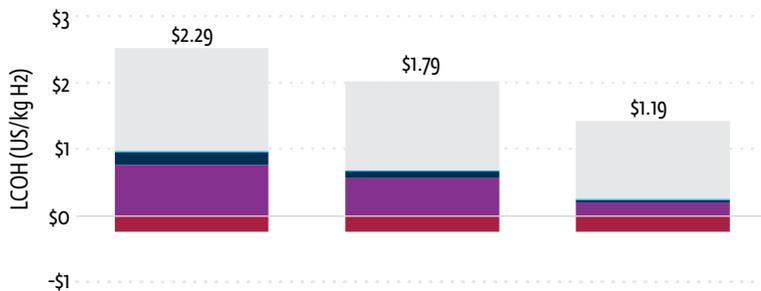
CASES BASED ON LEVELIZED COST (LC)

Export

A case study of GH export using ammonia was analyzed. For this case, the transport of 17,840 tons of GH to Japan (17,500 km away) was proposed. For today's scenario, the use of Liquefied Natural Gas ships adapted to transport hydrogen with a capacity of 2,500 m³ was considered, while for 2030 and in the long term, ships dedicated to the transport of each vector were considered, with a capacity of 53,000 m³ in the case of ammonia (Gallardo et al. 2021). For the LCOH, the production of hydrogen with large electrolyzers (greater than 10 MW) and in the Patagonia region of Chile was considered. The disaggregated costs of the LCOH applied in this model are presented below.

FIGURE D.6 DISAGGREGATED COSTS OF LCOH USED IN EXPORT MODEL

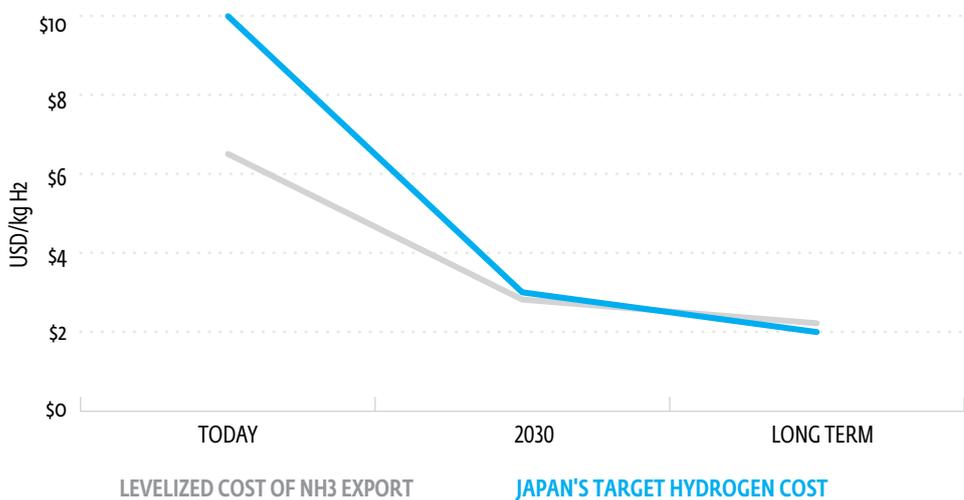
Patagonia zone, large size LCOH



	TODAY	2030	LONG TERM
O2 sales	-0.23	-0.23	-0.23
Electricity supply	1.54	1.33	1.16
Water supply	0.02	0.02	0.02
OPEX electrolizer	0.19	0.09	0.03
CAPEX electrolizer	0.77	0.57	0.20
LCOH production (US/kgH2)	2.29	1.79	1.19

Source: ImplementaSur, 2021

FIGURE D.7 LEVELIZED COST OF LH2 EXPORT THROUGH TIME



Source: ImplementaSur, 2021

For today's scenario, the highest cost corresponds to the CAPEX of the ships (2.1 US\$/kg GH), with the cost of fuel being very close (1.97 kg GH). For the 2030 and long-term scenarios, due to the greater capacity of the ships, the number of annual trips is reduced and consequently the cost of fuel loses significance. Additionally, the levelized cost of compressed hydrogen storage at high and low pressure and the distribution via dedicated trucks to the port of export (150 km) was considered.

Levelized export costs are 6.5, 2.8, and 2.2 US\$/kg GH for today, 2030, and in the long term, respectively. In all scenarios, these costs are competitive with the hydrogen cost targets in Japan, since Japan's LCOH is currently 10 US\$/kg GH, with plans to reduce it to 3 US\$/kg GH by 2030 and 2 US\$/kg GH in the long term⁷.

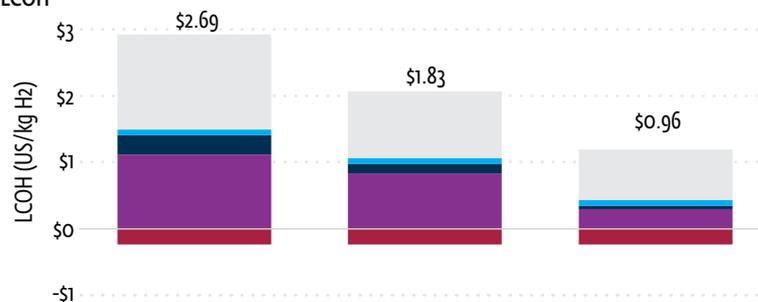
Ammonia production

A production of 26,400 tons of NH₃ year in the northern part of the country (Taltal region) was assumed, with a combined installed capacity between the Haber Bosch plant (HB) and the Air Separation Unit (ASU) of 23.6 MW and a flexibility of 80 percent, which means greater storage capacity.

For the LCOH, the production of hydrogen with large electrolyzers (greater than 10 MW) and in the north of Chile was considered. The disaggregated costs of the LCOH applied in this model are presented below.

FIGURE D.8 DISAGGREGATED COSTS OF LCOH USED IN AMMONIA PRODUCTION MODEL

North zone, large size LCOH

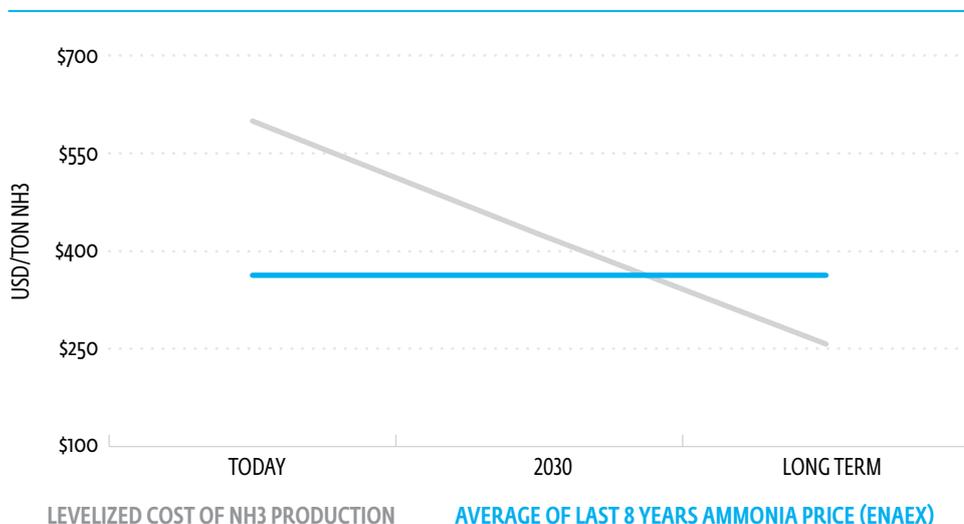


	TODAY	2030	LONG TERM
Oxygen sales	-0.23	-0.23	-0.23
Electricity supply	1.43	1.00	0.76
Water supply	0.08	0.08	0.08
OPEX electrolyzer	0.29	0.15	0.05
CAPEX electrolyzer	1.12	0.83	0.30
LCOH production (US/kgHz)	2.69	1.83	0.96

Source: ImplementaSur, 2021

7. Arias, J. 2019. "Hydrogen and Fuel Cells in Japan". EU-Japan Centre for Industrial Cooperation.

FIGURE D.9 LEVELIZED COST OF AMMONIA PRODUCTION THROUGH TIME



Source: ImplementaSur, 2021

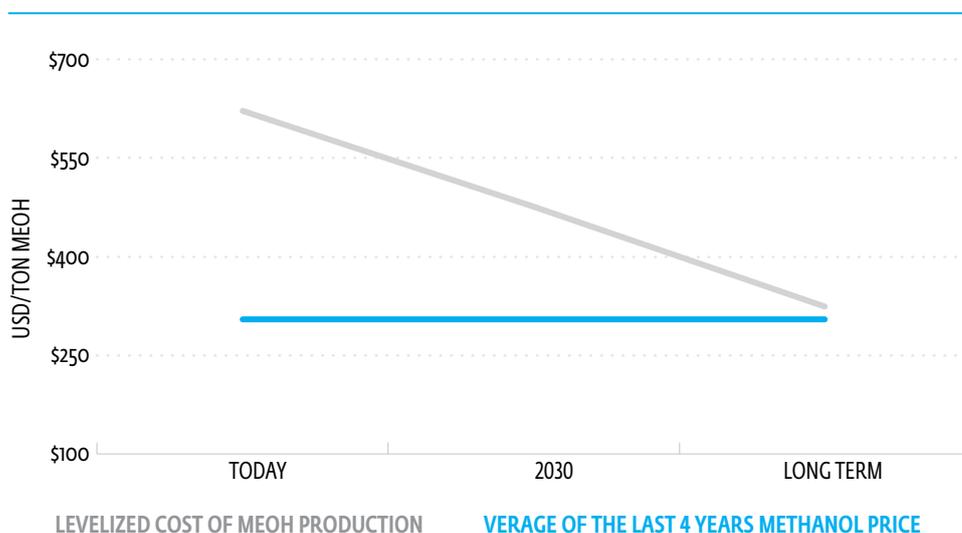
The highest cost corresponds to the LCOH, for which a production in the north of the country with large electrolyzers is considered. The second-highest cost corresponds to the energy associated with the consumption of the HB plant and the ASU, which decreases over time. In addition, the operating costs of both units and the storage of NH3 were considered.

The levelized costs of methanol production are 599, 425 and 258 US\$/ton NH3 for today, 2030, and long term, respectively. These are comparable to the prices in the industry in the last eight years, which range between 234 and 549 US\$/ton NH3.

Methanol production

For this case, an annual production of one ton of methanol (MeOH) was used, with a flexibility of 60 percent, and located in the Chilean Patagonia. The highest cost corresponds to the LCOH, which reaches values between 219 and 421 US\$/ton MeOH, depending on the scenario. In second place is the levelized cost of the methanol reactor which varies between 47 and 112 US\$/ton MeOH. In addition, electricity and storage costs in the form of low pressure compressed hydrogen are considered.

For the LCOH, the production of hydrogen with large electrolyzers (greater than 10 MW) and in the Patagonia of Chile was considered. Therefore, the disaggregated costs of the LCOH applied in this model can be seen in figure D.6.

FIGURE D.10 LEVELIZED COST OF METHANOL PRODUCTION THROUGH TIME

Source: ImplementaSur, 2021

The levelized costs of methanol production are 621, 476 and 324 US\$/ton MeOH for today, 2030, and long term, respectively. These costs are comparable to those of the industry, which range between 242 and 405 US\$/ton MeOH over the last four years⁸.

Backup generation

A backup generation model was generated using batteries and fuel cells, which were compared with diesel generation. For the case presented in figure D.7, 252 hours of annual generation were considered and, as for figures D.9 and D.10, an installed capacity of 1 MW.

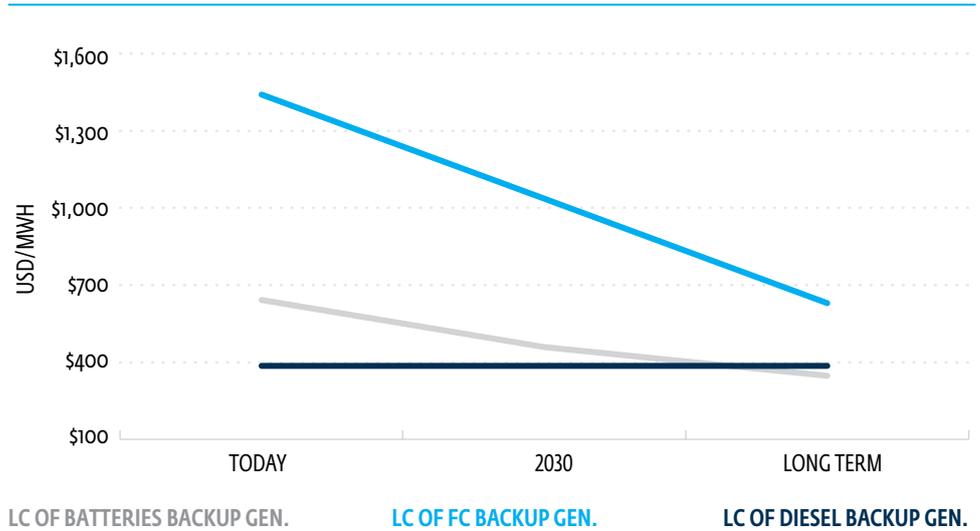
The most considerable costs correspond to the CAPEX of batteries and FC, as well as that of the electrolyzer in the case of FC. In the same way, roundtrip efficiency has a great influence, this is 95 percent for batteries and 35 percent for FC. Additionally, the operating costs of electricity, fuel in the case of diesel, and use of equipment are considered.

For the LCOH, the production of hydrogen with large electrolyzers (greater than 10 MW) and in the north of Chile was considered; the disaggregated costs of the LCOH applied in this model can be seen in figure D.8.

8. This assumes CO₂ is sourced from an industrial flow. If a direct air capture would apply, this would add 300 – 600 US\$/t of MeOH.

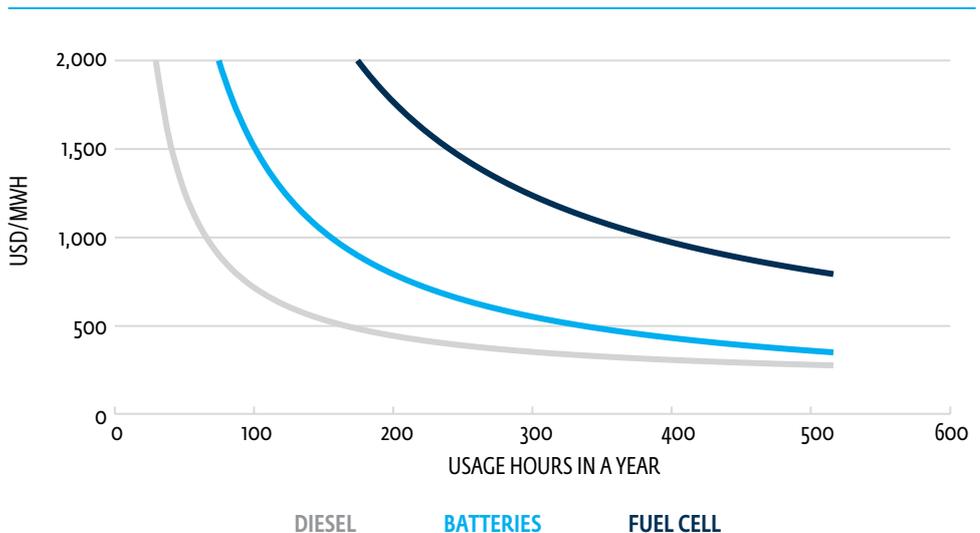
Figures D.11, D.12, and D.13 illustrate that battery backup generation has lower levelized costs than FC in every scenario. In the same way, in figures D.12 and D.13 it is appreciated that the longer the hours of use in a year, the more cost efficient batteries become, both in today's scenario (figure D.12) and in the long term (figure D.13).

FIGURE D.11 LEVELIZED COST OF BACKUP GENERATION ELECTRICITY THROUGH TIME



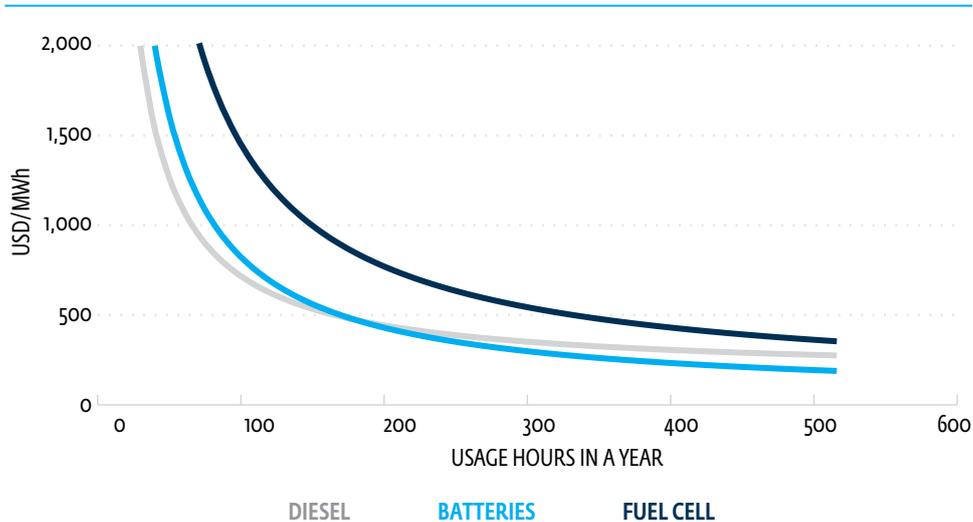
Source: ImplementaSur, 2021

FIGURE D.12 LEVELIZED COST OF BACKUP GENERATION ELECTRICITY TODAY



Source: ImplementaSur, 2021

FIGURE D.13 LEVELIZED COST OF BACKUP GENERATION ELECTRICITY IN THE LONG TERM



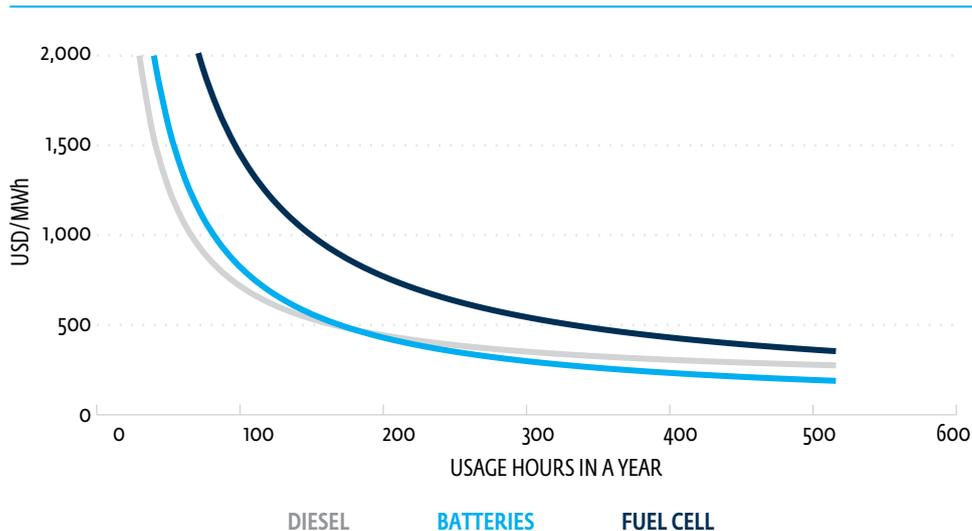
Source: ImplementaSur, 2021

GH blending into gas grids

The national GH strategy declares a target of 20 percent blending as GH becomes economical. In order to evaluate the economic feasibility of this scenario, the current level price of Liquefied Natural Gas (LNG) in Antofagasta Region was considered and compared with the LCOH of GH production in the northern part of the country with large electrolyzers. The comparison of the three LCOH scenarios with the fixed price of LNG is shown in figure D.14.

For the model, a 60 percent reduction in the retail price for end-users was considered, in order to discount the distribution costs passed on to customers and obtain the purchase cost of LNG.

FIGURE D.14 LEVELIZED COST OF LNG VS LCOH



Source: ImplementaSur, 2021

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