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Evolution of Industrial Policy in Chile: Analysis of the Period 1990-2022

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ABSTRACT

This study provides a comprehensive and critical analysis of the trajectory of industrial policy and technological absorption in Chile over the last three decades. The article examines the paradigm and institutional shift in the promotion of innovation, highlighting significant advances in key sectors of the Chilean economy, such as mining, salmon farming, fruit farming and the emerging green hydrogen sector.

The research underlines the key role of the state in Chile's industrial and technological development, supported by institutions such as CORFO and ANID. Key factors driving this incremental progress include macroeconomic stability, investment in infrastructure, increased R&D funding and policies aimed at fostering innovation. However, to improve the effectiveness of the industrial strategy and address challenges related to regional inequality, a more adaptive and sustained approach is required to fully capitalise on the opportunities offered by the country's resources and capabilities.

Key words: Industrial Policy, Technology Absorption, Innovation, Competitiveness, Economic Development.

JEL classification: E02, O31, 032, P42, L52

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Introduction

This article provides a detailed analysis of the evolution of industrial policy and technological absorptive capacity in Chile from 1990 to 2022, with a particular focus on the transformations and continuities of the National Innovation System (NIS). The main achievements and challenges are identified, and their implications for the future productive development of the country are examined.

First, it explores the historical evolution of industrial policies in Chile, from a liberal approach in the 1990s to strategies more oriented towards innovation and technological development in subsequent decades. Changes in public and private investment in research and development are analyzed, along with government initiatives to foster innovation.

The article also examines the key economic sectors that have been the focus of these policies, such as mining, agriculture, information and communication technologies, renewable energy, and recently green hydrogen. It analyses how these industries have responded to industrial policy stimuli and incorporated new technologies.

A central aspect of the study is the analysis of the role of key institutions in the implementation of these policies, such as the Production Development Corporation (CORFO) and the National Agency for Research and Development (ANID). It examines the institutional evolution over different periods of government and their contribution to strengthening innovation and productive development in the country.

In addition, it addresses persistent challenges in technology absorption and innovation in Chile, such as regional disparities, lack of continuity in some policies and obstacles in technology transfer.

Finally, it discusses lessons learned and future perspectives, offering recommendations for more inclusive and sustainable policies that can enhance innovation and technological development in Chile.

Research Objectives

1. Assess how the industrial policy strategies implemented in Chile from 1990-2022 have evolved, identifying key milestones, changes in priorities and their impact on the National Innovation System (NIS).

2. Examine how industrial policies have influenced the country's capacity to absorb technology and foster innovation in various economic sectors, highlighting the achievements and challenges faced in this process.

3. To analyze how government strategies have contributed to the development of new capacities at the state level, focusing on their role in promoting inclusive and sustainable industrial policies that respond to the country's structural and technological challenges.

Research problem

The relevance of the research problem lies in the need to understand the factors that have limited or enhanced technological development in Chile, a country that has experienced considerable economic growth but is still seeking to consolidate its position in the global economy. By examining the relationship between industrial policies and technological absorptive capacity, this study aims to identify the strengths and weaknesses of the Chilean development model and to derive lessons on the state's capacity to enhance innovation performance.

Hypothesis

Industrial policies implemented by the Chilean state have had a positive impact on technological absorption and innovation, although the effectiveness of these policies has varied over time due to changes in the economic and social context.

Methodology

Following the case study approach proposed by Yin (2018), this research focuses on the case of Chile to examine in detail the interrelationship between industrial policy and technological absorption in a specific context. By exploring the particularities of the Chilean case, it seeks to understand how historical, institutional, and socio-economic factors have influenced the configuration and outcomes of these policies. The case study allows us to transcend generalizations and offer a more complete and nuanced view of the phenomenon under study.

Research Design

A mixed case study has been carried out to analyze industrial policy and technological absorption in Chile. This methodological design allows for the generation of both theoretical and applied knowledge, contributing to the construction of more robust analytical frameworks and the formulation of public policy recommendations. The choice of Chile as a case study is justified by its relevance in the Latin American context and its potential to contribute to the general understanding of industrialization and technological development processes in emerging countries.

Data Collection:

Documentary analysis: A comprehensive review of official documents was carried out, including:

- National Development plans.
- Government reports on industrial and technology policy.
- Statistics from the Central Bank of Chile and international organizations (ECLAC, OECD).
- Relevant legislation and public policy documents.
- Analysis of databases on R&D investment, industrial policy investment, scientific publications and innovation and competitiveness indicators.

Limitations

This study is limited by the time analyzed and the available data sources. While an effort has been made to collect comprehensive information, it is possible that there are gaps in the data that may affect the interpretation of the results. Furthermore, the qualitative approach of the study, while allowing for an in-depth exploration of the phenomena, may be subject to interpretative biases. Nevertheless, the findings obtained provide a valuable contribution to the field of industrial policy and technology development studies.

Literature review

The literature on industrial policy and technological absorption has been extensively analyzed in both developed and developing country contexts. Rodrik argues that industrial policy should be adaptive, focusing on the development of local capabilities and selecting strategic sectors that facilitate technological absorption (Rodrik 2004). Amsden highlights how Asian countries have used active industrial policies to encourage technology absorption, arguing that "the role of the state is crucial in guiding investment in high-tech sectors" (Amsden 2001, 112). Lin proposes a structural economics approach that emphasizes identifying comparative advantages and promoting sectors that facilitate technology transfer. (Lin 2012).

In a more theoretical framework, Nelson and Winter discuss technology absorptive capacity as a key determinant of economic growth and innovation (Nelson and Winter 1982). Crespi and Tello examine the relationship between innovation and productivity in Latin America, concluding that "industrial policy should facilitate the absorption of foreign technologies to improve competitiveness" (Crespi and Tello 2014, 8). Fagerberg reinforces this idea by arguing that industrial policies should focus on improving the absorptive capacity of firms to increase competitiveness (Fagerberg 1994).

Malerba explores how sectoral innovation systems affect technological absorption, suggesting that effective industrial policy must consider the specific dynamics of each sector (Malerba 2002). Likewise, Katz analyses the relationship between structural reforms and economic growth, highlighting that technology absorption is essential for sustainable development in transition economies (Katz 2001). Taken together, these studies underline the importance of a comprehensive and adaptive approach in the formulation of industrial policies that foster innovation and the development of local capabilities.

It is important to confirm that studies on industrial policy and technological absorption have been approached from various theoretical perspectives that enrich our understanding of these phenomena. Evolutionary theory, represented by authors such as Giovanni Dosi and Richard Nelson, emphasizes the dynamic nature of innovation, suggesting that industrial policies must be flexible to adapt to changes in the economic and technological environment (Dosi 1988; Nelson 1993). On the other hand, the theory of national innovation systems, developed by Christopher Freeman and Bengt-Åke Lundvall, stresses the importance of interactions between key actors, such as firms and governments, in creating an environment conducive to technological absorption (Freeman 1987; Lundvall 1992). Similarly, Cohen and Levinthal (1990) introduce the concept of technological absorptive capacity, which refers to the ability of organizations to recognize and assimilate new information, stressing the need for policies that foster the development of competencies and skills.

In turn, the open innovation approach, proposed by Henry Chesbrough, suggests that firms should integrate both internal and external ideas to advance their innovation, which implies that industrial policy should facilitate collaborative networks (Chesbrough 2003). Mariana Mazzucato (2013), from the entrepreneurial state theory, argues that the state should play an active role as a strategic investor in innovation, which is crucial for technological absorption. Finally, the neo-institutional approach, represented by Douglass North, highlights how institutions influence economic behavior, suggesting that industrial policy must consider the institutional context in which it operates (North 1990). Together, these perspectives offer a diverse theoretical framework that illuminates the complexity of the interaction between industrial policy and technological absorption in economic development.

With these approaches to the literature as a premise, some of these areas as applied to the Chilean context are examined below.

Industrial Policy in Chile

Industrial policy refers to the strategies and measures implemented by the state to foster the development of specific sectors of the economy to increase competitiveness and promote innovation.

French-Davis (2004) argues that, after the return to democracy in 1990, Chile experienced a remarkable change in its approach to industrial policy. Initially, a neoliberal model that prioritized market liberalization was implemented. However, as the country faced various economic and technological challenges, the need for a more proactive approach became apparent. According to Rodríguez, the state began to play a more active role in promoting innovation, recognizing that global competition demands not only a favourable business environment, but also direct support in strategic areas.

Benavente (2008) highlights the importance of CORFO as a key actor in this process. This institution has been essential in the development of programmes that connect firms with research and development centres, thus facilitating technology transfer. Benavente argues that these initiatives have not only contributed to the modernization of various industrial sectors but have also helped to create a stronger innovation ecosystem.

Technology Absorption and Competitiveness

Technological absorption is defined as the ability of a country or firm to assimilate and use technologies developed in other contexts. This process is fundamental to economic growth, as it enables nations to improve their productivity and competitiveness.

Guimón, Chaminade, Maggi, and Salazar-Elena (2018) indicates that technological absorptive capacity in Chile is determined by several factors, including technological infrastructure, human capital, and public policies. His research reveals that, despite significant investments in education and training, there are still gaps in technical skills, particularly in the most vulnerable sectors.

Novoa (2020) conduct an empirical analysis that shows that state policies have improved the technological absorptive capacity of Chilean firms, although they caution that this improvement is not uniformly distributed. In their study, they identify that sectors such as mining and agriculture have made significant progress, while others, such as manufacturing, still face barriers to adopting new technologies. This suggests that policies need to be more targeted and tailored to the needs of each sector.

French-Davis (2004) argues that industrial policy in Chile has historically been weak, primarily due to an excessive emphasis on trade and investment liberalization, which has constrained the country's ability to establish a robust industrial base. He argues that it is crucial for Chile to implement policies that encourage innovation and technology absorption, especially in strategic sectors such as mining and agriculture.

Benavente (2006) emphasizes the importance of technological absorptive capacity in Chilean firms, noting that the ability to assimilate and apply foreign technologies is crucial for enhancing competitiveness. Benavente argues that policies should focus on strengthening human capital and creating collaborative networks between firms and research centres, which would facilitate technology transfer and organizational learning. This approach aligns with the notion that an effective national innovation system should include not only firms, but also universities and other institutions that support research and development (Benavente 2006).

In addition, authors such as Meller (2001) have argued that institutions in Chile must evolve to support a more conducive environment for innovation. Meller stresses that the quality of institutions is determinant for the functioning of a national innovation system, and that public policies should be designed to strengthen these institutions, promoting cooperation between the public and private sector. This view is supported by the work of other researchers, such as Salazar and Rojas (2008), who stress that the development of technological capabilities in Chile depends to a large extent on an institutional framework that fosters innovation and collaboration.

Ultimately, the work of French-Davis, Benavente and others highlights the need for a comprehensive approach that combines effective industrial policies, the strengthening of absorptive capacity and a strong institutional framework to promote innovation and economic development in the country.

Impact of Public Policies on Innovation

Public policies are crucial to establish an environment conducive to innovation. Valdés (2019, 50) investigates how innovation policies in Chile have contributed to creating an ecosystem conducive to technological development. His analysis shows that, despite progress in creating incentives for research and development, collaboration between the public and private sector remains limited. Valdés argues that the lack of synergies between these sectors has constrained the country's innovative potential.

Fernandez and Silva (2020, 65) analyze the relationship between industrial policies and economic performance, concluding that the policies implemented have had a positive impact on innovation. However, they note that the

effectiveness of these policies has varied due to changes in the economic context, such as financial crises and political changes. This finding underlines the need for a more flexible and adaptive approach to policy formulation.

Future Challenges and Opportunities

Despite the efforts made, the literature indicates that Chile faces significant challenges in terms of innovation and competitiveness. Morales argues that the lack of continuity in government policies has affected the country's ability to maintain sustained growth in innovation. Political instability and changes in government priorities have led to a fragmentation of efforts, making it difficult to implement long-term strategies (Morales 2021, 15).

Rojas stresses the need for more inclusive policies that address regional and sectoral inequalities in access to technology and resources. His research suggests that policies should be designed to benefit not only large firms, but also small and medium-sized enterprises (SMEs), which often face limitations in accessing finance and technological resources (Rojas 2022, 105).

In synthesizing this industrial policy, it is crucial to consider the economic evidence that underpins it. The evolution of investment in industrial policy in Chile since 1990 has been marked by steady growth, reflecting a commitment by the state to diversify and modernize its economy. According to the Central Bank of Chile, investment has risen from USD 500 million in 1990 to USD 1.5 billion in 2020, indicating a growing focus on infrastructure and sustainability (Central Bank of Chile 2021, 45).

This increase in investment suggests a growing awareness of the importance of industrial policy for the country's economic development. However, as Morales and Rojas point out, significant challenges remain in terms of policy continuity and equity in access to the benefits of these investments. The gap between the investment made and the results obtained in terms of innovation and competitiveness underlines the need to re-evaluate and adjust industrial policy strategies to maximize their impact and ensure a more equitable distribution of their benefits.

Table N°1
Industrial Policy Investment Evolution (1990-2020)

Year	Investment in industrial policy (USD million)	Comments
1990	500	Start of economic modernización

2000	700	Increased investment in infrastructure
2010	1,200	Focus on sector diversification
2020	1,500	Promoting innovation and sustainability

Source: Central Bank of Chile, 2021; ECLAC, 2020.

Investment in science, technology, and innovation (STI) has also shown an upward trend, from USD 150 million in 1990 to USD 800 million in 2020. This increase has been driven by policies that encourage research and development, as well as collaboration with the private sector (WIPO, 2023). The Economic Commission for Latin America and the Caribbean (ECLAC) stresses that this investment is crucial for the country's sustainable development and competitiveness in a global context (ECLAC, 2021).

Table N°2
Investment in Science, Technology, and Innovation (1990-2020)

Year	Investment in STI (USD million)	Comments
1990	150	Low initial investment in R&D
2000	250	Moderate R&D growth
2010	500	Significant increase in funding
2020	800	Focus on high-tech projects

Source: ECLAC, 2021; WIPO, 2023.

Continuity in Approaches and Strategies

Throughout the different governments, both continuities and discontinuities in industrial and technological policies can be identified. In this sense, despite changes in administration, there has been a general recognition of the importance of innovation and industrial modernization. Institutions such as CORFO have maintained their relevance in the implementation of R&D support policies and public-private collaboration.

Notwithstanding the above, each government has had its own approach and priorities, which has led to changes in policy implementation. For example, the more neoliberal orientation of Piñera's first government contrasted with the more inclusive and sustainable approach of Bachelet's second term and Boric's current administration. Additionally, the response to the social crisis of 2019 has influenced the reorientation of policy priorities towards a focus on equity and sustainability.

In Chile, the search for continuity in industrial and technological policies in Chile since 1990 has been a complex process, marked by changes in governmental approaches and socio-economic conditions. In a broader framework, a brief analysis of how this continuity has been managed over the years is presented.

Policy Continuity

Recognition of Innovation as a Strategic Pillar

Since the beginning of democracy, there has been a consensus on the importance of innovation for economic growth. Through different administrations, there has been a continued focus on fostering research and development (R&D), with institutions such as CORFO playing a key role in the implementation of support programmes.

Strong Institutionality

The creation and strengthening of institutions dedicated to innovation and technological development, such as CORFO and, more recently, the National Agency for Research and Development (ANID), has allowed for continuity in the approach to industrial modernization. These institutions have adapted their programmes to the changing needs of the country, while maintaining a focus on public-private collaboration.

SME Support Programmes

Over the past decades, governments have implemented several initiatives aimed at strengthening the innovation capacity of small and medium-sized enterprises (SMEs). These policies have ranged from the provision of direct financing to the creation of support programmes that facilitate access to advanced technologies and new markets. According to Barra (2021), these strategies have increasingly aligned with the emerging metrics of the "new economy", which emphasize factors such as digitalization, sustainability, and adaptability in a changing global environment. This approach reflects a growing recognition of the crucial role that SMEs play in the innovation ecosystem and their potential to drive economic growth and national competitiveness (Barra, 2021).

Responses to Social and Economic Crises

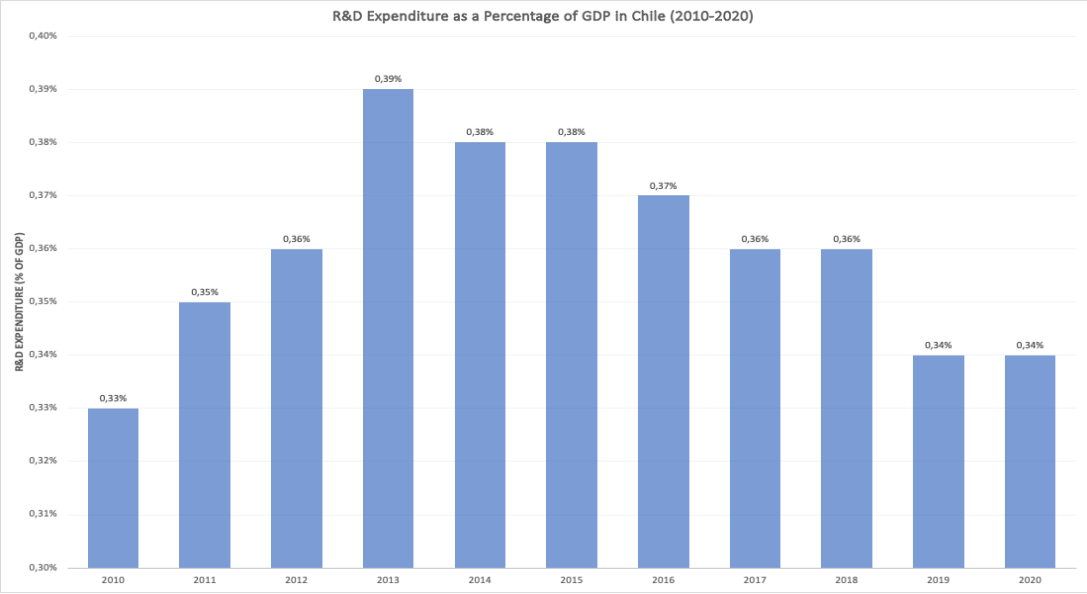
The social crisis that erupted in Chile in October 2019 marked a turning point in the formulation of public policies, including those related to technological development and innovation. This event catalyzed a profound reflection on the role of technology in society and its potential to address structural inequalities (Muñoz, 2021, 78). As a result, there was a significant reorientation of innovation policies, which began to explicitly priorities' equity and social justice.

President Gabriel Boric's government, which began in March 2022, has implemented a notable shift in Chile's innovation agenda, systematically integrating the social concerns that emerged after the 2019 crisis (MinCiencia, 2023). This approach marks a paradigm shift from previous administrations, which prioritized mainly economic growth and competitiveness. The new strategy seeks to align technological development with broader social goals, substantially increasing investment in R&D and focusing on solutions that address inequality, improve the quality of life in marginalized areas and foster a more inclusive and sustainable economy. This reorientation reflects a renewed commitment to innovation that not only advances economic progress, but also directly contributes to social well-being and equity.

R&D investment as a percentage of GDP

Investment in Research and Development (R&D) in Chile has been highly volatile over the years, but in the last decade there has been a trend towards stabilization, although at levels still below the OECD average. This trend is illustrated in graph number 1:

Graph 1
R&D Expenditure as a Percentage of GDP in Chile (2010-2020)



Source: Own elaboration based on Survey on Expenditure and Personnel in Research and Development (R&D), 2021. MinCiencia.

The graphical representation of these data highlights the trend towards stabilization of R&D expenditure as a percentage of GDP. However, despite this stability, the level of R&D investment remains low compared to developed economies, raising concerns about Chile's capacity to compete globally in innovation and technological development.

The social and economic impact of this situation is significant. Stabilization of R&D spending can perpetuate inequalities in access to technology and knowledge, especially in less developed regions of the country. This phenomenon has led to the implementation of public policies that seek to decentralize investment in science and technology, with the aim of improving equity in the distribution of knowledge.

On the other hand, the moderate level of R&D spending limits Chile's ability to diversify its economy, which remains heavily dependent on traditional sectors such as mining. To counter this situation, public policies have tried to diversify research areas, promoting emerging sectors such as renewable energy, biotechnology, and digital technology.

However, the variability in R&D investment in Chile reflects the changing priorities of governments over time. The general trend has been towards increasing investment, but with periods of cutbacks that have affected the continuity of innovation and development efforts. The creation of institutions such as ANID and the implementation of support policies have been instrumental in fostering R&D investment, although their effectiveness has depended on the country's political and economic stability.

This R&D investment path in Chile has shown trends of growth and recession, influenced by the policies of each government. For example:

Michelle Bachelet's government (2014-2018): A significant increase in investment was observed, with a focus on innovation and sustainable development (Valdés, 2019).

Sebastián Piñera's government (2010-2014 and 2018-2022): During his first term, he focused on deregulation, which led to a decrease in public investment in R&D (Pizarro, 2010). However, in his second term, he reversed this trend, increasing investment again.

Social Crisis of 2019: This crisis led to a reorientation of policies, prioritizing equity in R&D investment.

Ultimately, the trend towards stabilization of R&D expenditure in Chile has had a profound influence on public policymaking. This situation underlines the urgent need to increase and make R&D investment more efficient to achieve more equitable and sustainable economic and social development. Despite the progress made, such as the creation of the Ministry of Science and the promotion of public-private collaboration, challenges remain in terms of increasing total investment and improving its impact on innovation and competitiveness in the country.

Evolution of Industrial and Technological Policy in Chile by government period

Concertación governments (1990-2010)

During the Concertación governments, which lasted from 1990 to 2010, an industrial policy approach was promoted that, although initially based on neoliberal principles, began to incorporate elements of state intervention. Rodríguez (2015, 45) notes that, in this period, it sought to balance market liberalization with support for strategic sectors through CORFO, which implemented programmes to foster innovation and industrial modernization. The creation of incentives for research and development (R&D) reflected an effort to improve the competitiveness of Chilean industry in a global context.

Government of Sebastián Piñera (2010-2014)

The first government of Sebastián Piñera marked a shift towards a more market-oriented approach. Policies were promoted that aimed to reduce state intervention and encourage private investment. However, despite this orientation, some innovation programmes were maintained and support for strategic sectors continued. Pizarro (2010, 80) notes that, although there was an emphasis on deregulation, the government also recognized the importance of innovation for economic growth.

Government of Michelle Bachelet (2014-2018)

Michelle Bachelet's second term brought with it a renewed focus on industrial and technology policy, with an emphasis on inclusion and sustainable development. Initiatives were implemented to strengthen collaboration between the public and private sector, as well as to support SMEs. Valdés (2019, 50) highlights that aim was to promote a more diversified economy less dependent on natural resources, which involved an increase in investment in R&D and the creation of new institutions such as the Ministry of Science, Technology, Knowledge, and Innovation.

Government of Sebastián Piñera (2018-2022)

Piñera's second government continued with the innovation agenda, but faced significant challenges, including the social crisis of 2019. Despite this, a focus on digitalization and modernization of the economy was maintained. González and Vargas (2018, 22) argue that, although there was an attempt to maintain continuity in innovation policies, the response to social and economic demands led to a reorientation of priorities.

Government of Gabriel Boric (2022-present)

Gabriel Boric's government has emphasized the need for a more inclusive and sustainable industrial policy. Initiatives have been proposed that seek to strengthen R&D, as well as address inequalities in access to technology. Rojas (2022, 105) notes that the current administration is trying to integrate industrial policy with a focus on social justice and environmental sustainability, which represents a significant shift from previous approaches.

Institutions involved in the development of industrial and technology absorption policies

In Chile, various institutions have played a crucial role in investing in industrial policy and science, technology, and innovation since 1990. Among the most prominent is the Ministry of Economy, which has led the formulation of industrial policies and promoted public-private collaboration to foster the development of strategic sectors. The Production Development Corporation (CORFO) has been fundamental in the implementation of financing and support programmes for innovation, providing resources for research and development projects in companies, especially in small and medium-sized ones (Pérez, 1995, 235).

In addition, the National Agency for Research and Development (ANID), created in 2020, has concentrated efforts on promoting science and technology, administering funds that stimulate scientific research and technological development in the country (González, 2011, 8). On the other hand, the National Commission for Science and Technology (CONICYT), which operated until its dissolution in 2018, played a crucial role in the planning and implementation of science and technology policies, supporting the development of human capital and the creation of research networks (CONICYT, 1994).

These institutions, through their programmes and policies, have contributed significantly to the evolution of investment in innovation and industrial development in Chile, promoting a more competitive and sustainable environment.

Priority production and technology sectors in industrial and technology policies

In Chile, industrial and technological policies have undergone a significant evolution, moving towards the prioritization of key sectors with the dual objective of diversifying the economy and promoting sustainable development.

During the 1990s, Chilean industrial policy was characterized by the consolidation of the neoliberal model initiated in previous decades. This process

was preceded by the industrialization and deindustrialization of the 1970s, where the economy reached its maximum level of industrialization before being hit by the economic crisis and neoliberal policies. In the 1980s, a structural shift occurred with the opening of the economy, reducing state intervention, and orienting the economy towards natural resource-intensive sectors, which displaced manufacturing. Since the 1990s, the focus of industrial and technological policies implemented has been more horizontal, focused on improving the enabling conditions in the environment to facilitate innovation and entrepreneurship, without focusing state efforts on specific economic sectors.

In this century, the 2000s in Chile were marked by a boom in natural resources, which intensified the country's dependence on these sectors and accentuated deindustrialization. Investment in technology and high-productivity sectors was limited, affecting long-term productivity growth. Meanwhile, during the 2010s, attempts at productive transformation emerged, recognizing the limitations of the natural resource-based model. And in the current decade (2020s), the country faces the challenges of the Fourth Industrial Revolution, focusing on digitalization and Industry 4.0, but with significant structural challenges, given that the country's industrialization process was incomplete. It is only since the 2000s that the Chilean state has begun to incorporate more selective policies aimed at developing specific priority sectors. The Economic Commission for Latin America and the Caribbean (ECLAC, 2020) has identified these priority sectors, which include mining, agriculture and agro-industry, information, and communication technologies, renewable energy, advanced manufacturing, global services, and tourism.

In recent years, Chile has encountered several challenges and limitations in its industrial and technological policies, which have been identified as areas of underperformance relative to other countries. Key issues include a tendency toward premature or truncated industrialization, characterized by a reduction in the share of the manufacturing sector in the economy before reaching a high level of per capita income, coupled with limited productive diversification into higher value-added and technology sectors. Additionally, there has been inadequate investment in developing advanced technological capabilities for a more innovative industrial base, along with relatively low expenditure on research and development compared to other nations. Furthermore, the lack of effective coordination between industrial and technological policies, combined with the absence of a comprehensive strategy that coherently integrates initiatives in innovation, education, infrastructure, and financing, has impeded the creation of necessary synergies for sustained technological development (Ministry of Economy, 2023).

Notwithstanding the above, there are certain cases in which the Chilean state has facilitated the creation of new industries from very early on, through its role as promoter, albeit with an intervention full of mixed results.

Mining, a traditional pillar of the Chilean economy and one of the world's leading copper producers, has received special attention in these policies. Initiatives have been implemented to improve sustainability and efficiency in the extraction processes. In parallel, agriculture, another important export sector, has been the subject of policies that encourage the adoption of technologies to improve both production and product quality. The Organization for Economic Co-operation and Development (OECD, 2018) has underlined the relevance of these traditional sectors in the country's productive structure.

In the field of emerging technologies, ICTs have experienced accelerated growth, acting as a catalyst for digitization in various economic sectors. Although ECLAC notes that specific promotion policies for the ICT industry are less frequent, its potential as an economic driver is widely recognized. Similarly, the renewable energy sector has received a significant boost, taking advantage of Chile's natural capacity in this field. The OECD has identified this sector as crucial for a resilient economic recovery in the post-pandemic context.

This strategy of diversification and focus on high-tech sectors reflects Chile's conscious effort to move towards a more innovative and resilient economy. The country seeks to adapt to global trends while capitalizing on its comparative advantages in natural resources and human capital.

To implement these policies, Chile has deployed a variety of strategies and instruments. These include fiscal and financial incentives, innovation support programmes, promotion of public-private partnerships, infrastructure development, training and human capital formation, sustainability policies and export promotion.

Fiscal incentives, such as credits and subsidies, have played a crucial role in stimulating investment in research and development (R&D), especially in small and medium-sized enterprises (SMEs). Government programmes, such as those implemented by the Chilean Economic Development Agency (CORFO) and the National Research and Development Agency (ANID), have provided financial support, and fostered collaboration between companies and research centres, thus strengthening the country's innovation ecosystem.

In the area of infrastructure, technological capacity building and the improvement of digital infrastructure have been key to facilitating access to advanced technologies. In parallel, special emphasis has been placed on workforce training, with the aim of aligning workers' skills with the changing demands of the labour market.

Sustainability policies have played an important role in promoting responsible practices in key sectors such as mining. These initiatives seek to balance

economic growth with environmental protection and social welfare. In addition, export promotion strategies have allowed Chilean companies to diversify their markets, reducing dependence on specific sectors or markets.

Taken together, these policies and strategies reflect a comprehensive approach by Chile to foster sustainable and diversified economic development. By combining support for traditional sectors with the promotion of emerging industries and advanced technologies, Chile seeks to position itself as an innovative and competitive economy on the global stage of the 21st century.

Key Lessons Learned

Since the 1980s, Chile has implemented a comprehensive set of strategic measures aimed at advancing its industrial development, attracting foreign investment, and enhancing its technological absorption capacity. These initiatives, enacted with increased vigor following the economic crisis of the 1980s, laid the foundations for a profound economic transformation. From the 1990s onwards, these policies facilitated sustainable growth and enabled the country to successfully integrate into an increasingly competitive and technologically advanced global environment.

Trade Openness and Macroeconomic Stability

One of the first measures was trade liberalization, which removed tariff barriers and facilitated the signing of free trade agreements. Barra (2021) point out that this “allowed wider access to international markets and fostered competition”. At the same time, macroeconomic stability policies were established, focusing on controlling inflation and reducing the fiscal deficit, creating a predictable and secure environment for investors (Pérez 1995).

Incentives and Privatization

The government introduced tax incentives and subsidies for strategic sectors such as mining and manufacturing, seeking to stimulate investment and innovation (González 2011). In addition, the privatization of state-owned enterprises improved management efficiency and reduced the state's tax burden, thus attracting private investment (Maldonado 2020).

Investment in Infrastructure and Technological Development

Significant investments were made in critical infrastructure, such as transportations and telecommunications, to enhance the competitiveness of local industries and facilitate trade. Additionally, research and development (R&D) were promoted through support programmes and collaboration between the private sector and academia, thereby facilitating technology transfer.

Importance of Technology Absorption Capacity

Barra (2021) emphasizes that "technological absorption capacity is crucial for Chile to be able to compete in an increasingly demanding international environment". This capacity has become fundamental for innovation and sustainable growth in a globalized context.

Key Mechanisms for Absorption

Fagerberg (2004, 45) stresses that "the creation of innovation networks and the strengthening of human capital are essential to improve absorptive capacity". In Chile, human capital formation, university-industry collaboration and investment in R&D have been essential mechanisms for this purpose.

Sectoral Successes and Challenges

Industries such as salmon have achieved remarkable success in technological absorption through technology transfer and the formation of collaborative networks (Maldonado 2020). However, other sectors, such as copper, still face challenges in coordinating efforts to maximize technological absorption. In its early stages, the development of the salmon industry in Chile was driven by a strategic vision supported by the state, under public-private collaboration.

The Chilean government, recognizing the country's potential as a salmon producer, fostered a favorable environment for the growth of this emerging industry. Policies were implemented to attract foreign investment, particularly from Japan and Norway, which brought advanced technology and specialized knowledge in aquaculture. The role of the Chilean state extended beyond mere promotion and regulation; it acted as a catalyst in the establishment of a new industry, initially located in southern Chile and Patagonia. Although this industry had few productive and technological linkages with regional economies, its development primarily benefited from the natural environment conducive to aquaculture, characterized by cold, clean, and protected waters, as well as a climate suitable for salmon farming.

Among the key factors, in addition to the favorable natural conditions, was the rapid adoption of advanced aquaculture technologies and investment in research and development, which enabled the industry to optimize production and enhance salmon quality. Additionally, international cooperation supported the transfer of technology and knowledge.

The country also established a robust export infrastructure, including ports, processing plants and efficient logistics, which allowed Chilean salmon to reach global markets quickly and freshly. And the industry managed to diversify its export markets, reaching consumers in the United States, Europe, Asia, and Latin

America, which helped mitigate commercial risks associated with dependence on a single market. Vertical integration and export orientation, driven by public policies and the participation of private actors, allowed the industry not only to be profitable, but also to contribute significantly to Chile's trade balance. This collaborative approach allowed maximizing the value generated by the industry, both for companies and for the national economy. Through investments in research, infrastructure and incentive policies, the state helped the private sector to take the initial risks and bring the industry to a globally competitive level.

However, this initial success of industrial development policies was exposed to failures due to the lack of a focus on long-term sustainability. Deficiencies in regulation, among other factors, led to a crisis in the Chilean salmon industry. In this regard, the ISA Virus crisis in 2007, for example, highlighted the consequences of insufficient oversight and the uncontrolled expansion of the industry and companies in their exploration of natural resources.

The state failed to implement and enforce sufficiently strict regulations to prevent the proliferation of diseases, resulting in a health crisis that affected both the industry and the natural environment and local communities, leading to the erosion of the value created and negative externalities.

The state's approach was too oriented towards maximizing short-term economic value through the expansion of salmon production and exports, without an equivalent commitment to long-term public value creation.

In response to this crisis, CORFO created technological business consortia to support the innovative development of the industry by incorporating accumulated knowledge and expertise. These efforts helped develop activities related to the country's food and aquaculture health, in direct collaboration with the industry. Following the crises, the industry began adopting more sustainable practices and the state also strengthened regulations to ensure greater environmental and social responsibility.

The adoption of new technologies, improvements in biosafety, better alignment in health surveillance and in the development of higher value-added products reflect a renewal of the industry that seeks not only profitability, but also long-term sustainability. This more balanced approach between economic growth and social responsibility is key to ensuring that the value created by Chile's salmon industry is lasting and beneficial for all stakeholders. However, despite all this, the state does not sufficiently foster the development of local capacities in sustainable aquaculture technology and knowledge, so that an over-reliance on foreign technologies and knowledge has remained, which has sub-optimized the use and development of more decentralized capacities to innovate and adapt local economies to global challenges to ensure more equitable, autonomous, and resilient economic, environmental, and social growth.

Another case of industrial development policy, which constitutes a relevant technological absorption commitment, can be found in the recent development of the green hydrogen industry.

In 2021, the Chilean State promoted the industrialization of green hydrogen, starting with the approval of a public agenda to support policy reforms aimed at accelerating the decarbonization of the energy matrix and its transition towards carbon neutrality. The role of the state has been crucial in regulation, financing, support for research and development, and in creating a favourable environment for the growth of the green hydrogen industry.

State action has been marked by the implementation of industrial and innovation policies that seek to unlock market failures and create enabling conditions to accelerate private investment and the expansion of the green hydrogen market. These policies also promote the development and adoption of technologies that are not yet fully mature, including the necessary regulation to facilitate the development of this new industry. Moreover, it promotes technological innovation and research and development around green hydrogen. This includes supporting knowledge creation, talent development and overcoming technological and regulatory barriers. Technology gaps have also been identified and recommendations for public policies to address these areas have been formulated. These recommendations suggest an active role in facilitating the technological development and capacity-building necessary for the implementation of the green hydrogen industry.

The Chilean government has taken steps to map and develop the green hydrogen value chain in the country, identifying the technologies and technology platforms needed for hydrogen production, transport, and utilization. This includes a focus on strengthening local suppliers and ensuring that the necessary infrastructure is in place for the effective deployment of the industry. By 2050, green hydrogen could contribute up to 10% of national GDP, with several economic activities clustered around this industry, such as: mining, energy, transport and logistics, industrial applications.

Mining is one of the main industries interested in using green hydrogen to decarbonize their processes. Projects such as Siderurgica Huachipato's project to produce green steel are examples of the integration of hydrogen in the production of minerals and metals.

Energy generation and storage, comprising the production of hydrogen through electrolysis, a process that is strongly connected to the renewable energy sector, especially solar and wind, which are essential to supply the electricity required for electrolysis.

Energy production and storage, including hydrogen production through electrolysis, are closely linked to the renewable energy industry, particularly solar and wind power, which are crucial for supplying the electricity needed for electrolysis.

Globally, the applications of green hydrogen extend to the production of green ammonia, oil refining, as well as the manufacturing of cement and methanol, among other products. These sectors are being targeted for the adoption of hydrogen as a strategy to reduce their carbon footprint. Additionally, the manufacturing of equipment such as electrolyzers, which are essential for green hydrogen production, is experiencing global expansion. In this context, countries like the United States, Germany, Japan, and China are leading the production of these technological components.

Persistent Barriers and Emerging Opportunities

Despite progress, Ramirez (2010, 85) identifies that "weaknesses in research infrastructure and limited public-private collaboration are significant obstacles" to technological absorption in Chile. However, González (2011) points out that sectors such as renewable energy and information technology present promising opportunities, arguing that "the promotion of policies that encourage investment in these areas may be key to improving absorptive capacity and fostering economic growth" (120).

Overcoming Difficulties in Industrial Policy and Technology Absorption in Chile

The evolution of industrial policy and technological absorption in Chile has been characterized by various challenges that necessitated adaptive strategies over time. Since the return to democracy in 1990, Chile has faced the challenge of transforming its economic model-from one focused on liberalization and market opening to one that fosters innovation and industrial competitiveness (Pérez 1995). A major obstacle has been the low investment in research and development (R&D), which has remained below the OECD average, thereby limiting firms' ability to adopt and adapt foreign technologies (CORFO 2018).

To address these challenges, the Chilean government implemented several strategic policies. The establishment of the Chilean Economic Development Agency (CORFO) was a pivotal milestone, as this entity has promoted innovation and facilitated collaboration between businesses and universities. Through subsidy programs and funding for R&D projects, CORFO has successfully encouraged private investment in technology and enhanced the country's absorption capacity (Maldonado 2020). Additionally, the State Law for the Promotion of R&D, enacted in 2009, was designed to create a legal framework

that further incentivized investment in this field, leading to a gradual increase in R&D investment in Chile (González 2011).

Over time, the evolution of industrial policy has been a dynamic process. In the 1990s, Chile focused mainly on economic liberalization, but over time the need for a more comprehensive approach that includes innovation as an engine of growth became evident. This paradigm shift has been reflected in the adoption of more proactive policies and the establishment of strategic alliances between the public and private sectors, as well as the promotion of collaborative networks for technological development (Amsden 2001).

However, despite this progress, challenges remain. The lack of co-ordination between different policies and the need for greater investment in human capital remain significant barriers to technological absorption. The Chilean experience shows that, although progress has been made, the evolution of industrial policy and technological absorptive capacity requires continued commitment and constant adaptation to changing conditions in the global environment (Ramirez 2010).

Everything seems to indicate that the history of industrial policy and technological absorption in Chile is a narrative of overcoming difficulties through the implementation of strategic policies and adaptation to an evolving economic context. This process has allowed the country to move towards a more sustainable and innovative model, although it still faces the unequal regional distribution of technological capabilities, insufficient linkages between academia and industry, and continued dependence on natural resources that have hindered the full development of a robust and diversified innovation ecosystem. Consequently, although Chile has improved its position in terms of technological absorption, it still faces considerable challenges to achieve sustainable innovation-based competitiveness in the global context.

Discussion

The results of this research on the evolution of industrial policy and technology absorption in Chile reveal a complex and multifaceted trajectory, reflecting both significant advances and persistent challenges. This discussion aims to situate these findings within the broader context of existing literature on economic development and innovation in the country.

First, the substantial increase in investment in industrial policy, from USD 500 million in 1990 to USD 1.5 billion in 2020, suggests a growing commitment by the Chilean state to foster innovation and technological development. This increase aligns with the observations of Peres, Wilson and Primi (2019), who argue that Latin American countries have increasingly recognized the importance of active industrial policies for economic development (Peres et al., 2019). However, as

Crespi, Fernández-Arias and Stein (2014) point out, merely increasing investment does not guarantee effective results without adequate institutional coordination and a clear strategic vision (Crespi, 2014).

The identification of priority sectors such as mining, agriculture, ICT and, more recently, green hydrogen in Chilean industrial policy reflects a "smart specialization" approach akin to the one proposed by Foray (2015) for European economies. However, our findings indicate that the implementation of this approach in Chile has faced significant challenges, especially in terms of cross-sectoral coordination and adaptation to local conditions, points that have also been highlighted by Aghion et al. (2021) in their analysis of industrial policies in emerging economies.

A crucial finding of this study is the persistence of regional inequalities in access to technology and resources for innovation, despite industrial policy efforts. This phenomenon aligns Iammarino et al.'s (2019) observations on the "geography of discontent" in both advanced and emerging economies, where regional disparities in technological development can exacerbate socio-economic tensions. In the Chilean case, these disparities raise questions about the effectiveness of decentralization policies and the role of sub-national governments in promoting innovation, a topic that deserves further research.

Our findings also indicate that the lack of continuity in some government initiatives has hindered the consolidation of a robust innovation ecosystem. This phenomenon resembles what Katz (2015) has described as the "mid-level capabilities trap" in Latin America, where countries make initial advances in technological development, but then face difficulties in maintaining momentum and reaching more advanced levels of innovation.

A particularly interesting aspect of our reflections is the tension between Chile's trade openness and its efforts to develop endogenous technological capabilities. While openness has facilitated the import of advanced technologies, it has also posed challenges for the development of local high-tech industries. This dilemma aligns with Lee's (2019) observations on technological catch-up strategies in emerging economies, where careful calibration between openness and selective[2] protection is crucial.

The findings also highlight the complexity of implementing effective industrial policies in a context of rapid technological change and economic globalization. The case of Chile illustrates both the potential and the challenges of innovation-based development strategies in Latin America. Future studies could benefit from a more detailed comparative analysis with other countries in the region, as

[2] "Careful calibration" implies that governments and policies should adjust the degree of openness and protection in a way that maximizes the benefits of access to international technologies and markets while protecting and supporting local industries so that they can develop and compete effectively.

well as a deeper exploration of the mechanisms of technology transfer between sectors and regions within the country.

In this context, Chile is at a critical juncture in its economic development. Therefore, it is essential that the country progresses toward more innovative and disruptive industries capable of generating superior value in the global market. In this regard, state capacity becomes a crucial factor in designing and implementing an effective and sustainable industrial strategy, which, for instance, could drive the development of the green hydrogen sector.

To achieve this transition, it is necessary to articulate a comprehensive policy that combines strategic incentives, promotes synergistic collaboration between the public and private sectors, and develops a robust infrastructure to support long-term sustainable economic growth. This policy must be underpinned by a strong institutional framework that is adaptable to a rapidly changing global environment.

The success of these strategies depends crucially on the capacity of the state to address existing challenges with determination and effectiveness. This implies not only the formulation of sound policies, but also effective and coordinated management of national resources. It requires a strong commitment to transparency, accountability and continuous evaluation of policies implemented.

A comprehensive and proactive approach is essential to catalyze sustained economic growth, enhance Chile's international competitiveness, and ensure the long-term prosperity of its economy. This challenge requires a clear vision, decisive leadership, and the active participation of all sectors of Chilean society, including government, business, academia, and civil society

Conclusions

The research provides a comprehensive analysis of the progress, obstacles, and future challenges in the country's industrial and technological development. The findings lead to significant conclusions with implications for both Chile and other developing countries aiming to strengthen their technological and innovative capabilities.

First, Chile has made substantial efforts to move from a mainly natural resource-based economy to a more diversified and innovation-oriented one. The significant increase in investment in industrial policy and the establishment of key institutions such as CORFO and ANID are testimony to this commitment. However, the results of these initiatives have been mixed, underlining the inherent complexity of implementing effective industrial policies in a context of rapid technological and global economic change.

A crucial finding is the persistence of regional disparities in terms of technological and innovation capabilities. Despite decentralization efforts, the concentration of resources and capabilities in the Santiago metropolitan region remains a significant challenge. This situation highlights the need for more targeted policies adapted to local realities to foster robust innovation ecosystems across the national territory.

The evolution of the priority sectors identified in Chile's industrial policy - mining, agriculture, ICTs, and renewable energy - demonstrates both successes and areas of opportunity. While sectors such as mining have made significant progress in the adoption of advanced technologies, others, such as ICTs, still face challenges in developing a strong local industrial base. This suggests the need for a more nuanced and adaptive approach to industrial policy that can respond to the specific dynamics of each sector (Novoa, 2021).

A particularly relevant aspect of our findings is the tension between Chile's trade openness and the development of endogenous technological capabilities. While openness has facilitated the import of advanced technologies, it has also posed challenges for the growth of local high-tech industries. These dynamic underscores the importance of finding the right balance between global integration and strengthening domestic technological capabilities.

The research also reveals that, despite progress, Chile still faces significant obstacles in the effective transfer of technology and knowledge between academia and the productive sector. Improving these connections emerges as a critical area for future policy, essential for translating research into commercially viable and socially beneficial innovations.

The study also underlines the importance of institutional learning and adaptability in public policy. The evolution of the state shows that industrial and innovation policies must be flexible and adjust to changing economic and social conditions. However, the discontinuity of some government initiatives highlights the need for long-term commitment and a coherent strategic vision that transcends political cycles.

In conclusion, Chile's experience offers valuable lessons for other developing countries seeking to strengthen their national innovation systems. The findings underline the importance of:

- Develop industrial and innovation policies that are adaptive and sensitive to the local context.
- Proactively address regional disparities to foster more balanced technological development.
- Strengthen links between academia, industry, and government to improve knowledge and technology transfer.

- Maintain a balance between economic openness and the development of endogenous technological capabilities.
- Ensure continuity and coherence of policies in the long term, beyond political cycles.
- Looking ahead, Chile is in a crucial position to capitalize on its achievements and address persistent challenges on its path towards a knowledge and innovation-based economy. Success in this transition will not only be critical for Chile's sustainable economic development but could also provide a valuable model for other countries in Latin America and beyond.

Based on the literature review, documentary analysis and discussion, we can state that the research objectives have been achieved to a large extent:

- Industrial policy developments: The study has provided a detailed analysis of how industrial policies in Chile have evolved during the study period, highlighting the increase in investment and the creation of key institutions such as CORFO and ANID.

- Impact on technology absorption: The impact of these policies has been assessed, noting both progress (such as in the mining sector) and areas where progress has been more limited (such as in the development of a robust local ICT industry).

- Challenges and opportunities: The study has clearly identified key challenges, such as regional disparities and the need to improve knowledge transfer between academia and industry. It has also identified opportunities for the future, such as adapting to new and emerging technologies.

As for the inferred hypothesis, the results seem to confirm the following:

- It confirms that industrial policies have contributed to technological absorption, as evidenced by increased investment and the development of priority sectors.
- The persistence of major challenges, especially in terms of regional inequalities, is confirmed.
- Knowledge transfer between sectors has been identified as an area requiring further attention, which also supports the hypothesis.
- However, it is important to note that the research has also revealed additional complexities not captured in the initial hypothesis, such as the tension between trade openness and the development of endogenous technological capabilities.

We can conclude that the research objectives have been satisfactorily met, providing a comprehensive and nuanced analysis of industrial policy and technological absorption in Chile. The hypothesis, while generally supported by the findings, could be refined to better capture the complexities and nuances revealed by the study. This partial confirmation and identification of additional aspects underscores the value of the research in deepening the subject of the study and opening new avenues for future research.

Finally, the article contributes significantly to our understanding of the processes of technological development and innovation in Chile, offering valuable insights for academics, policy makers and practitioners in the field of economic development and industrial policy.

Future lines of research

This study opens new avenues for future research, including more detailed comparative analyses with other countries in the region, longitudinal studies on the long-term impact of specific policies, and deeper explorations of technology transfer mechanisms across sectors and regions. In addition, future research could examine how new emerging technologies, such as artificial intelligence and biotechnology, are being integrated into Chile's technology development strategy.

Future research could also focus on how Chile is integrating and adapting to emerging technologies such as artificial intelligence, biotechnology, or the circular economy in its industrial development strategy. Furthermore, a detailed analysis of the interaction between trade openness policies and the development of endogenous technological capabilities could provide valuable insights for other countries seeking to balance global integration with the strengthening of their industrial policies.

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