

Lithium production issues in Chile: Perceptions involving the strategic resource and the common good

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Abstract: This paper presents an analysis of the perceptions of the accelerated demand for lithium and its growing use due to technological advances, and how this demand places the reserves in the northern Chilean salars at the center of debates involving methods of exploitation and commercialization. The objective of this research is to analyze the perceptions of expert professionals in lithium production, to determine the barriers that have prevented Chile from leading the production of this highly demanded mineral. To achieve this, a qualitative approach is proposed under an interpretive paradigm, based on 30 semi-structured interviews with professionals and executives in the mining sector. The data reveals that the predominant positions tend to neutralize each other. On one hand, there is the extractivist economic model that considers mining as a strategic resource for national industry and seeks to strengthen it and make it profitable. On the other hand, there are political-environmental approaches that seek to limit the process through stricter regulations or territorial consultations focused on the common good. In summary, the different conceptions around lithium represent competing ideological models, where the economic and political-environmental debate has not yet defined what is good for our country and needs to be reviewed so as not to miss out on a potentially beneficial strategic opportunity.

Keywords: lithium; strategic resource; technological development; common good; salars and territories.

Introduction

The accelerated demand for resources has sparked numerous debates in Chile and around the world about the ways of harnessing lithium resources, with positions ranging from defending the sovereignty of the resource (political perspective and others) to its potential for industrialization (extractive perspective) and turning it into a focal point for new developments in the country for new technologies. This includes direct use for export as a raw material, taking advantage of the quick profits it offers, and the previously mentioned global needs (Argento and Zícari, 2017). Similarly, environmental issues and territorial disputes are significant for lithium, raising questions about the roles assigned to transnational capital and the types of public policies that could be implemented, as well as the different types of actors in the conflict as evidenced in the strategic lithium policy communicated in 2023 (National Lithium Strategy, 2023). In all cases, these difficulties imply determining what type of economic growth model to adopt, how to distribute the surplus profits generated by lithium, scientific research, the structure of the global market, and the role lithium will play (Agosin, 2023).

Lithium in Chile - Background: As lithium became a key material in the global energy revolution, it aroused interest in the country's political agenda and it was suggested that it should be used as a gateway to the sustainable use of natural resources. The lithium public policy in Chile has evolved since the beginning of production in the 1980s with a subsequent production leap in the 1990s. In this regard, the main milestones of the transformation occurred in national governance, dividing lithium research into four stages or periods (Poveda, 2020): i) Stage 1. Hierarchical Governance: Strategic Resource (1970-1983) ii) Stage 2. Market Governance: Privatization and Production Leap (1984-2004) iii) Stage 3. Hierarchical Governance: Discovery of Lithium (2005-2013) iv) Stage 4. Hierarchical Governance: Lithium Boom (2014-2019). According to Agosin (2023), it is clear that Chile's economy, after experiencing growth at "Asian" rates between 1987 and 1998, has begun to stagnate. In fact, the growth rate between 2013 and 2019 was just 2.0%, barely exceeding the population growth rate, which has been approximately 1.5% due to immigration. To rekindle growth, it is crucial to diversify production and, given that the Chilean economy is small and open, this implies diversifying exports. In this regard, policies focusing on the development of green hydrogen, in which Chile possesses a clear potential comparative advantage, have been proposed. To succeed in this field, the State must coordinate public and private contributions. Additionally, leveraging the country's large lithium deposits and applying a decisive policy of transition towards green mining, partly using green hydrogen to replace hydrocarbon-based fuels, could contribute to Chile revitalizing its growth in the export sector and not losing its comparative advantages in the mining industry.

Method of Extraction - Theory and Definitions: The extraction of lithium from brine through solar evaporation is a slow process that consumes large amounts of water and generates a significant amount of waste. As a result, new extraction methods have been proposed, such as direct lithium extraction, ranging from lithium extraction through the pumping of ions in entropic electrochemical cells of cathodic-type lithium-ion batteries with Li⁺ intercalation electrodes (Calvo, 2023).

Lithium is found in brines and minerals, and commercial extraction can be performed in various ways. Brine extraction is the most economical and common method of mineral production. There are several methods for extracting lithium from brines, depending on the levels of other elements in the extracted deposit. Lithium carbonate and lithium chloride are extracted from brine to obtain lithium hydroxide and metallic lithium. A pump is used to extract the brine, which is transported via pipes to a pool similar to a sink and left for the water to evaporate, leaving table salt (sodium chloride) in solid form. These pools, characterized by their blue and turquoise hues, are typical of lithium mining and are found in the Andean region of northern Argentina, Chile, and Bolivia. Subsequently, it is necessary to separate the various elements, including potassium, magnesium, lime, and sulfate, for which lime is used. After separation and reduction, liquid lithium is obtained, and solvent extraction begins in the processing plant to achieve lithium with a purity of 97%. During this process, sodium carbonate is added at a temperature between 60°C and 80°C to extract the remaining sodium carbonate in the process, resulting in the final product, lithium carbonate (Aguilar and Zeller, 2012).

Regulatory Framework - Strategic Resources: In Chile lithium extraction from salars is subject to specific regulations. Due to this normative framework, since the 1980s, the State has signed agreements with private companies, namely Albemarle and SQM, in which development guidelines have been established, stipulating territorial volumes and brine extraction rates, rental characteristics, and activity taxes (Obaya and Pascuini, 2020).

Economy of Lithium and Perspectives: Various studies, such as Nacif (2018), show that China has emerged as a prominent actor in the global economic scene recently. Its relationship with Latin America presents concrete opportunities, such as the demand for natural resources and energy, generating foreign currency income, but also brings threats. A phenomenon known as reprimarization has emerged, displacing manufacturing production and export, and reproducing a center-periphery dynamic.

The analysis of this phenomenon becomes relevant in the case of lithium, as the triangle formed by the lithium-rich salars in Argentina, Bolivia, and Chile has become a crucial source for energy transition. Chinese companies, both state-owned and private, have invested in all three countries to secure lithium reserves. Moreover, China is the main demander of lithium, giving it a key role in the entire marketing chain (Barberón, 2022; Fornillo and Gamba, 2019).

Although the three countries under study are progressing in exporting carbonate and, in the case of Chile, also lithium hydroxide, advances in adding value to the chain are so far fragmentary and limited (Slipak and Urrutia, 2019).

According to information collected by the Undersecretary of International Economic Relations (2023), during 2021, the value of exports of lithium carbonate with a purity equal to or greater than 99.2% amounted to 535.2 million US dollars, while in 2022 this value reached 3,647.5 million dollars, which represents an increase of 581%. Regarding lithium hydroxide with a purity equal to or greater than 56.5%, its exports increased from 95.4 million dollars in 2021 to 437.2 million dollars in 2022, equivalent to an increase of 358%.

This considerable increase in the total exported value can be explained by the increase in prices at the beginning of 2022. For example, the average price of lithium carbonate with a purity greater than 99.2% was 6,721 dollars in 2021, while in 2022 increased to an average of 34,370 dollars.

In terms of volumes, although a slight upward trend is observed, they did not increase as significantly as prices. In 2021, 79,628 tons of carbonate with a purity greater than 99.2% were exported, while in 2022 this figure rose to 106,125 tons. Regarding lithium hydroxide, the exported volume increased from 11,264 tons in 2021 to 14,988 tons in 2022, while the exported value increased from 95.4 million to 437.2 million dollars between 2021 and 2022.

Impact on Local Communities and the Environment: The lithium triangle formed by Argentina, Bolivia, and Chile contains 80% of the world's lithium, a highly profitable and easily extractable strategic resource. These countries see

lithium as an opportunity to promote technological equalization and endogenous development. The introduction of mining in the southern and northern communities of the Salar de Atacama, for example, has caused a social impact that has changed the pace of life of the inhabitants, both through the extractive companies themselves and those who serve them, generating a massive turnover of workers, which in turn has led to the masculinization of the region (Azócar-Duarte, 2022). However, despite the efforts of the region's progressive governments, the neo-extractivist approach persists, leading to the overexploitation of natural resources and privatization of the economy. Lithium represents the potential for a different kind of development, beyond increasing the gross national product, seeking environmental sustainability and equalization with modern societies in terms of consumption (Fornillo, 2018).

The Chilean Context: Lithium mining in the Salars de Atacama is based on a process of dispossession of common interests. After state enclosure and subsequent privatization, extractive activities altered ecosystem levels where these cultural practices could no longer continue, generating respective socio-environmental impacts (Azócar-Duarte, 2022). Lithium exploitation in the "lithium triangle" is at different stages of development, for example, between the Salar de Uyuni in Bolivia and the Salar de Atacama in Chile, the latter having been involved in lithium exploitation for several decades. Lithium extraction and refining in the Salar de Atacama are in the hands of two private companies: Sociedad Chilena de Litio (Rockwood Lithium) and Sociedad Química y Minera de Chile (SQM), which originated as a state-owned company. SQM is one of the world's leading companies dedicated to the exploitation, production, and sale of refined lithium in the form of lithium carbonate and hydroxide (Göbel, 2014; Azócar, 2022).

Success Cases: The Salar de Atacama is considered the most attractive lithium deposit in the world. It holds the largest known lithium reserves, and its exploitation can be carried out at lower costs than other locations due to advantages such as high concentrations, high evaporation rates, low presence of magnesium, and easy access to ports. Currently, lithium extraction in the Salar de Atacama is contractually authorized to SOQUIMICH and SCL, but it represents only a small fraction of the salar's reserves (less than 10%). Therefore, a national lithium policy is needed to define the modalities and timelines for complete sustainable exploitation of the resource in the Salar de Atacama. The best way to ensure that the economic benefits of lithium remain in the hands of the State is through the creation of a National Lithium Company, which would manage all national reserves of this mineral (Titelman, 2013).

Understanding this reality, and considering the literature review presented, the following contextual question can be raised: What are the variables that explain the barriers preventing the mass production of lithium in Chile? Indeed, the main motivation for conducting this research has been the recognition of lithium as a strategic mineral, and its scarcity can be considered as an irreplaceable or hardly replaceable mineral, in addition to being unevenly distributed. On one hand, the growing demand for the manufacture of batteries for various technological devices and the automotive industry could make it a scarce mineral in a limited time, but it must be considered that Chile possesses the world's largest reserves of this mineral, which necessarily invites the creation of a plan to successfully address productive barriers.

Therefore, a prioritization of barriers and the proposal of a development plan to address them is proposed. In this sense, this work contributes to the understanding of the strategic or key variables that are hindering a process of mass production of this mineral. Understanding this, the objective of this work is to analyze the perceptions of expert professionals in lithium production who are actively involved in Chilean mining production, to determine the barriers and limitations of a political, social-environmental, economic, and technical nature that have prevented Chile from leading the production of this mineral.

Materials and Methods

A qualitative methodology was chosen as it is most appropriate for understanding social phenomena in depth (Flores-Cerna *et al.*, 2022). An interpretive approach was employed, since it would allow us to attribute meaning to the objects of study and to uncover their importance to those who have experienced them (Rojas-Romero *et al.*, 2021). With this, typical case sampling among professionals related to the mining industry was carried out for convenience. Professionals with an average of more than 12 years of experience were selected, and a total of 30 key informants participated. This study was conducted in the field of professionals linked to the mining industry, whose connections allow understanding of the problem from various perspectives - operational and strategic in business, governmental, and geopolitical terms. Semi-structured interviews were used to explore the informants' perspectives, focusing especially on the perceived

barriers in lithium exploitation. In addition, a focus group was used to expand and complement the information obtained in the interviews, as well as to validate it. The interviews consisted of 5 questions, which are detailed below.

1. *Where does the problem associated with lithium extraction today come from?*
2. *In practice, how does the regulatory framework for its exploitation operate today?*
3. *Do you have specific proposals for short-term, high-impact improvement or change? What are they?*
4. *What kind of threat or risk could a massive lithium extraction plan pose to the organization?*
5. *How do you see lithium production in relation to sustainability?*

To record the information, different sources such as written documents, video, and audio recordings were used. To analyze the collected data, a process of categorization using a deductive approach was carried out. Criteria were extracted that allowed observing the development of the lithium exploitation process in its various areas. In addition, attention was paid to possible situations that could arise from these documents and observations, through an inductive process. The categorization performed consisted of selecting relevant factors and elements, but it is recognized that this can be even more diverse due to the breadth of the construct and its practice. Informed and voluntary participation of the professionals involved was ensured, measures were taken to guarantee the confidentiality of the information, and the findings were validated with the participants themselves.

Results and Discussion

Below, we present the results corresponding to the five guiding questions of the questionnaire. With the aim of clear exposition and more comprehensible reading for this project, we have chosen to incorporate only the data relevant to this study. Figure 1 shows the main categories into which the responses to each interview question were organized. In the following section, the different responses for each category are presented in more detail; in order to ensure clarity, only the data that was considered relevant to each question is incorporated.

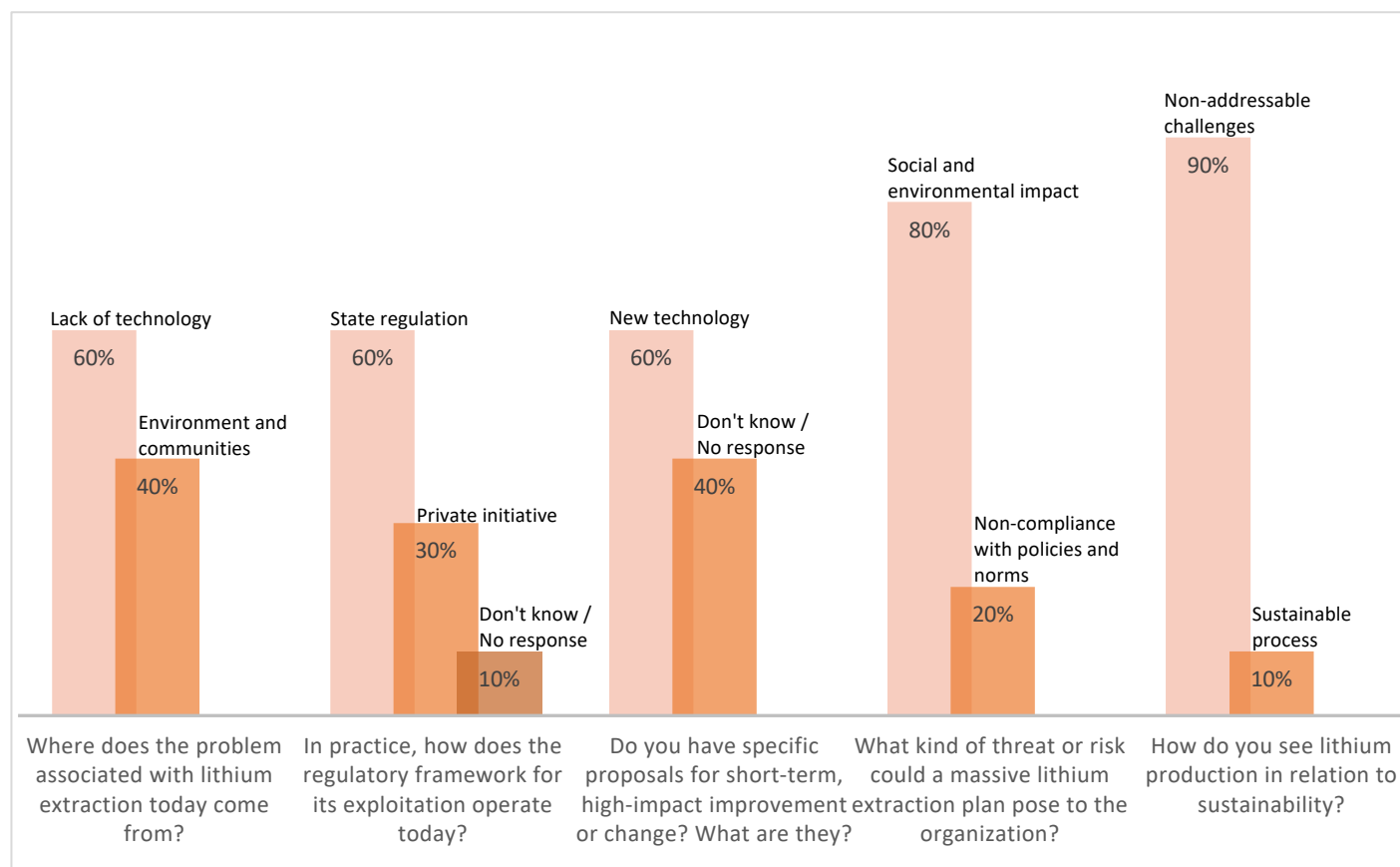


Figure 1. Categories and Representations

Item 1: Where does the problem associated with lithium extraction today come from?

Reviewing the general results of the first question of the questionnaire (Table I), we find that 18 of the 30 respondents associate the current problem in lithium extraction with the lack of technology in the mineral extraction processes, and hence the inefficiency of the process. In the responses categorized in this section, we find very similar phrases among the key informants, such as:

"I believe that the problem associated with lithium extraction today mainly comes from the lack of technology in the brine extraction processes" (Interviewee 10) and "The problem comes from the processing times and obtaining the processed mineral, since the demand is high and the processing times are slow, which in the medium term leads to looking for a substitute of lower value and with much more efficient processing time" (Interviewee 6).

The other notable issue in the results was associated with environmental impact and communities in the areas surrounding the extraction zones, as reflected in comments like these:

"The majority of lithium extraction is from arid deserts where water is used, which is scarce and threatens the flora and fauna of vulnerable ecosystems. In addition, it affects indigenous communities in the area" (Interviewee 3) and "The problem lies in soil contamination with hazardous waste, alteration of the natural surface water flow, disruption of the water balance, and impact on native flora and communities in the area" (Interviewee 7).

Item 2: In practice, how does the regulatory framework for its exploitation operate today?

Reviewing the general results of the second question of the questionnaire (Table I), we find that most of the respondents (21/30) are aware of how the regulatory framework for lithium exploitation operates, being public-private and regulated by the State, as well as knowing the two companies that are currently authorized for the extraction and marketing of the mineral. The responses in this category included:

"Since 1979, the extraction and marketing of lithium have been reserved by the State as it was declared non-concessionable; however, in 1980 the first contract with Albemarle was established in the constitution to exploit lithium through special exploitation contracts" (Interviewee 4) and "As it has been declared by the State as a non-concessionable mineral, its extraction is reserved exclusively for the State, that is why currently there are only two companies with permits for its extraction in the Salar de Atacama, which are SQM and Albemarle" (Interviewee 15).

Item 3: Do you have specific proposals for short-term, high-impact improvement or change? What are they?

In their responses to this question, 21 of the 30 respondents propose as a central axis, the application of new technologies with the goal of reducing pollution, protecting natural resources, and shortening the mineral processing time. Here are some examples of their comments:

"In my opinion, there are no short-term measures other than reducing the contamination of the salars and respecting indigenous peoples. However, we should innovate in technology to avoid the evaporation of the brines and reduce the lithium extraction time, which is about 18 months" (Interviewee 3) and "A major improvement would be to seek new technologies and change materials to protect underground aquifers, as a way of protecting the Salar" (Interviewee 8).

Another notable issue in the results is that the second category is associated with updating legal regulations and allowing private investment in the industry, with the aim of improving productivity levels, as stated, for example:

"To encourage private investment, with good tax collection, without the State apparatus directly operating in the extraction, to eliminate State expenses and generate tax revenues by encouraging private parties to invest and have good productivity levels" (Interviewee 15) and "To update the legal regulations, streamline the

awarding processes with clear, efficient rules, including for the environmental and social impact, and improvement proposals from private investors. Incentives in tax reductions, according to production levels that leave significant tax revenues, thus encouraging production, with good profitability for private parties and for the treasury a good source of revenue" (Interviewee 9).

Item 4: What kind of threat or risk could a massive lithium extraction plan pose to the organization?

In this section, 24 of the 30 respondents mentioned that a massive lithium extraction plan could cause considerable environmental and social impact, which could lead to the devastation of the ecosystem and significantly affect the communities in the area. Some typical responses included:

"A massive lithium extraction plan would produce a devastation of the ecosystem and this non-renewable resource, generating a negative impact related to environmental pollution and a water imbalance in the sector" (Interviewee 1) and "A massive lithium extraction plan would lead to overexploitation, accumulation of excess mineral stock, with the respective drop in prices and a high environmental impact, in addition to the impact on communities near the deposits" (Interviewee 11).

On the other hand, some key informants believe that a massive extraction plan would lead to non-compliance with current regulations:

"A massive lithium extraction plan could lead to non-compliance with policies and regulatory norms, the same thing that has happened with copper extraction in our country" (Interviewee 16).

Item 5: How do you see lithium production in relation to sustainability?

For this question, almost all of the respondents affirmed that lithium production can be a great contribution to reducing the carbon footprint, but that there are many challenges associated with achieving this, as evidenced by opinions such as:

"Lithium production can play an important role in the transition to a low-carbon and sustainable economy. However, to ensure sustainability, it is essential to address the environmental, social, and economic challenges associated with its extraction and production. This means adopting sustainable practices, respecting the rights of local communities, and promoting equitable economic development" (Interviewee 12) and "Companies must have a vision of sustainability, respect for the environment and communities, along with innovative technology applicable to lithium exploitation and extraction, adding value to the extraction or obtaining of wealth, encouraging the creation of the industry of products related to lithium and thus create employment and add value to the raw material" (Interviewee 25).

The results obtained from this exploratory study show interesting findings regarding how the lithium industry in Chile is perceived, such as the lack of advanced technology for obtaining the mineral, and therefore the inefficiency of the process, and concern for environmental impact and communities. Particularly concerning is the possibility of massive lithium extraction, which could cause significant environmental and social impacts. There is also understanding of the public-private operation regulated by the State, and the need to reduce environmental pollution and protect natural resources, as well as to decrease the processing time of the mineral. It is perceived that the lack of an update in legal regulations to facilitate up private investment in the industry is resulting in difficulties in reducing the carbon footprint. These findings are in line with the results proposed by (ECLAC, 2023; Romero *et al.*, 2019), where the same concerns are held for different contexts.

The study of perceptions reveals several key challenges in lithium production, highlighting the need to comprehensively address technological development, infrastructure, and the training of qualified personnel. Special attention must be paid to extraction costs, as these could exceed those of nearby competitors (Amato *et al.*, 2021), which could affect the economic viability of lithium production.

In terms of environmental impact, lithium exploitation has been criticized, especially due to the use of non-renewable resources, such as water, and its impact on the environment. Lithium extraction is directly linked to water resource management, becoming a strategic natural resource with direct implications for national interests and the country's capabilities. In addition, extraction infrastructure can have significant impacts on the flora and fauna of previously unaffected areas, turning these impacts into socio-environmental problems (Kaunda, 2020).

Another critical aspect is the perception and tensions generated in local communities. Although the industrialization of lithium could boost the country's economic development, concerns and debates within local communities and environmental groups have generated social and political tensions. The relativization of impacts and the compensation of social shortcomings to neutralize possible claims in favor of environmental preservation are phenomena present in this scenario (Liu and Agusdinata, 2020).

In the national context, Chile perceives itself as the world's leading lithium producer, and the National Strategy proposed in 2023 seeks to enhance the country's wealth through the development of this key industry. This approach is seen as a fundamental step in linking Chile's economic growth with the transition to a global green economy, highlighting the strategic importance of lithium in the government's agenda (National Lithium Strategy, 2023). However, to become the main global lithium producer, or to sustain that productive role, the recently proposed strategy is perceived as insufficient and would require a review to speed up private investment in this industry.

Conclusions

This study establishes that the variables perceived as most important and explaining the barriers preventing the mass production of lithium in Chile in a prioritized manner are:

- Lack of appropriate technology for the processes of obtaining the mineral;
- Updating the legal regulations to speed up private investment;
- Environmental impact;
- The need to reduce the carbon footprint;
- Social and community implications.

To this end, the perceptions of expert professionals in lithium production were analyzed to determine the main barriers that have prevented Chile from leading the production of this mineral in recent decades. Indeed, the lack of incorporation of technologies and a regulatory framework that unites efforts focused on the sustainable development of this mining industry, which has not happened with copper, are identified as the main obstacles. Consequently, this study contributes to improving the understanding of the strategies or determining factors that are hindering the mass production of this mineral in Chile, considering the perspectives of the professionals involved in the process. To address these barriers, a review of the regulatory framework is suggested, which incentivizes private investment, and in turn, this should be the driver for the incorporation of clean technologies that meet environmental, social, and community needs and restrictions.

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