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A Historical Mirror? The Saltpetre and the Lithium Eras in Chile

Master Thesis

Submitted by

Alejandra Rodríguez-Morales
al1041ro-s@student.lu.se

Abstract: The current Lithium Era of Chile shares many similarities with the Saltpetre Era that took place in the country decades ago. To understand whether there is a historical mirror between both, this paper uses a synthetic control method to carry out a regional comparison of the effect of saltpetre mining, and several forecasts to anticipate what to expect from the development of the lithium sector in Chile. Overall, results support a positive view of the effects of saltpetre in the country, with a milder impact in the region where it was developed (*Norte Grande*) than has been assumed so far. For its part, Chile's lithium production is expected to increase, but predictions also alert that it will entail negative socio-environmental externalities. Although the Lithium Era closely resembles the Saltpetre Cycle, Chile still has a chance to learn from the past.
Keywords: Energy transition, green economy, neo-extractivism, Chile, natural resources, lithium, saltpetre, synthetic control method, forecasting.

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And finally, I would like to dedicate this work to my grandmother, who would be proud of me today.

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1. Introduction

As part of the energy transition, countries worldwide are directing part of their efforts toward mobility based on electric vehicles (EVs). Moreover, with the recent conflict between Russia and Ukraine, these plans for change have been further accelerated in an attempt by Western Countries to cut their dependence on Russian natural resources. This *fever* for decarbonised mobility arises within the framework of the green economy, which has been gaining popularity lately as a fundamental part of many governments. The green economy is characterised by its aim to reduce environmental risks and ecological scarcities, as well as to achieve sustainable development without degrading the environment (Loiseau, Saikku, and Antikainen, 2016). However, while it seems to offer a perspective more in line with the environmental problems becoming increasingly severe, contradictions have also begun to appear in its implementation.

In this narrative, lithium (Li) emerges as the critical metal for the successful development of the energy transition, being one of the crucial components for the manufacture of all types of electric batteries. According to IEA (2020), lithium is expected to become the most demanded mineral in the two scenarios contemplated of the energy transition (see Appendix A). Nevertheless, this white metal is related to one of the potential problems blamed on the green economy policies of the Western Countries.

Repeatedly, in order for the more developed countries to achieve their goals of sustainable and environmentally friendly economic growth, they exploit the natural resources of developing and underdeveloped countries without considering the socio-economic and environmental impact this may have. Latin American countries are one of the traditional suppliers of raw materials to the states of the Global North, and between them, one common denominator stands out. Latin American economies are highly dependent on the world economy as natural resource-extracting countries, regardless of their economic and political structural differences. This model of dependent development has been called neo-extractivism, and its origin can be found in the colonial extractivism they suffered in the past (Merchand-Rojas, 2016). For this reason, this paper presents the Chilean case study as one of the key countries in the production of lithium and the successfulness of the energy transition.

Chile is the country with the most significant assets of this metal, owning 50.5% of the planet's lithium reserves (USGS, 2022). Nevertheless, what can be named the "Lithium Era" has recently begun, and there are many factors that could contribute to making it more or less beneficial for this developing country. Indeed, the list of critical minerals includes, by definition, those minerals that are fundamental to the economy and the improvement of a society and whose supply may be disrupted by shortages, geopolitical issues, or other events. Lithium has been added to this list by Chile, China, the United States, the European Union, Canada, and Australia. Similarly, as Jacks, O'rourke, and Williamson (2011) and Di Pace, Juvenal, and Petrella (2020) point out, the economic future of emerging economies and developing countries (EMDEs) may vary significantly depending on their commodity exports, being energy and metals exportations key in this context.

Withal, this is not the first time Chile has been gifted with such an opportunity.

As a country with a solid link to mining, in 1880, Chile owned the world's largest reserves of another critical mineral at the time: the potassium nitrate (KNO_3), most commonly known as saltpetre. It was a crucial component in the manufacture of fertilisers and explosives. From a monopolistic position, the Andean country went through what has been known as the "Saltpetre Era" or "Saltpetre Cycle". However, this era of mining splendour that seems to have fallen into oblivion came to an end in 1930, when the natural resource price collapsed. Since then, a debate has raged concerning the impact of saltpetre on the country's development. But although the literature is extensive, a consensus has not yet been reached.

All this forms the motivation for this paper to analyse the possible historical mirror between the Saltpetre Era and the Lithium Era in Chile. Given the recent nature of lithium mining in the Latin American country and the prospects of a significant increase in demand for this mineral in the coming decades, it is of paramount relevance to study what saltpetre mining meant for Chile between the late 19th and early 20th centuries. If the regional effect of saltpetre exploitation in Chile is understood, it will bring a much more accurate vision of what decisions should be taken today regarding lithium production. For as the famous quote by Mark Twain says, "History does not repeat itself, but it often rhymes", and it is well known that natural resources can be a double-edged sword for developing and underdeveloped countries. They have the power to help the economic development and growth of these societies, and at the same time, the power to cause them to incur the natural resource curse.

This paper, therefore, will address two main research questions.

Question 1 *How did the Saltpetre Era impact the Norte Grande and the rest of Chile?*

As will be later explained, the nitrate industry was developed in a concrete area in the north of Chile that has been named the *Norte Grande* (Great North in English). Apart from the mixed opinions on whether this mining sector benefited the country, there are doubts concerning if its effects were present in the whole country or just in the region where it germinated.

The second goal of this research will be to answer a question regarding the connection between both mining experiences:

Question 2 *Is the history of the Saltpetre Era repeating itself in today's Lithium Era?*

Even if this study finds an affirmative, negative, or partial answer, it would have considerable implications in responding to this question. On the one side, it would provide valuable information for Chile to consider when making decisions regarding lithium mining to have the most beneficial effect on the country. It can be either by not repeating mistakes made in the past or by drawing inspiration from successful strategies. Either way, lessons could be learned from past experiences and applied to the present and the future. On the other side, the success of this study could motivate similar research in other countries, such as Argentina or Bolivia, also part of the Lithium Triangle[1] and with an important mining tradition.

[1] The Lithium Triangle is in the extreme southwest of the Andes in South America. Its three corners are the Salar de Atacama in Chile, the *Salar del Hombre Muerto* in Argentina, and the *Salar de Uyuni* in Bolivia.

To tackle these inquiries, this paper will be structured as follows. The historical background and literature review will be explained in Section 2, dividing it between the Saltpetre and Lithium Eras. Section 3 will then cover the similarities and differences between both periods to address why the historical comparison is feasible in this case study. Sections 4 and 5 deal respectively with how data used in this research was obtained and managed, as well as the methodology that will be employed. In Section 6 the empirical analysis is displayed and interpreted. Finally, the paper will end with Section 7, where a summary of the main content of the research will be provided, the concluding remarks and some thoughts for further research.

2. Theory

2.1 The Saltpetre Era (1880-1930)

2.1.1 Historical Background

Between 1879 and 1883, the War of the Pacific or the Saltpetre War[2] ended with Chile taking control of two new territories: *Antofagasta* and *Tarapacá*. It was then that Chile started to produce potassium nitrate from the caliche[3] located in sedimentary rock strata at dry old salt lakes, marking the beginning of what has become known as the Saltpetre Era in Chile (1880-1930). Nitrate was the main exported product of the Andean country during this period. The popularity of saltpetre was initially due to its use as a fertiliser in agriculture, and with the outbreak of the First World War (WWI), as an essential component in the manufacture of explosives and weapons. These two usages of saltpetre made it highly demanded by Western Economies.

With the rise in demand of this natural resource, the government of Chile imposed an export tax of 1.6 Chilean pesos for each quintal of saltpetre exported. The fiscal revenues generated by nitrate accounted for 58% of the total tax collection, which made the State extremely dependent on foreign trade. Nevertheless, this export tax was not the only measure introduced. During the late 19th century, Chile also saw the abolition of several direct taxes (mainly inheritance and income taxes), which benefited the country's elites (Miller, 2021) (Badia-Miró and Díaz-Bahamonde, 2017). Another strategy implemented during the Saltpetre Era was that when the nitrate industry generated enough profits, these were used to emit external and internal bonds. The former was particularly important since they were used to financing public works such as the construction of railways[4]. However, as will be explained later, the effectiveness of these investments has often generated scepticism among various authors. Besides, it should also be noted that the conflicts marked the social context in which the saltpetre industry developed. In 1891, Chile suffered a Civil War that put an end to the liberal political regime of President Balmaceda (1886-1891) and ushered in a Parliamentary Regime (1891-1925) in which

[2]The War of the Pacific was a military conflict in which Chile, Bolivia, and Peru were involved. The conflict ended with the signing of the *Treaty of Ancón* in 1883. Bolivia granted Chile the province of *Antofagasta* (formerly part of *Potosí*) while Peru ceded control to Chile over the province of *Tarapacá*. Indeed, the conflict was largely initiated by Chile's interest in controlling the Bolivian-held Atacama Desert because of its valuable mineral resources (Sater, 2007).

[3]Caliche is defined as the raw material from which saltpetre is extracted, which consists of a mass of sodium nitrate mixed with other salts like chlorides and sulphates and different earthy substances (SC, n.d.).

[4]Under the government of Balmaceda, the investment in infrastructure experienced a boom. In 1884 the *Empresa de Los Ferrocarriles del Estado* (EFE, translated in English as National Company of Railroads) was founded, and the connectivity of the Andean country was improved. The country constructed railroads, roads, and bridges but also installed telephone lines (Cariola and Sunkel, 1982). However, the ownership and investments of the railroads varied across regions — private companies invested in railways in the northern territory, while the government carried out the infrastructure of the central part of the country (Hurtado, 1966).

the power of the president was limited. Social unrest was also latent between 1880 and 1920, known as the *Social Question*. It was distinguished by the Chilean workers' movement in its struggle for better working conditions and salaries, in which the saltpetre mine employees played an important role[5](Cariola and Sunkel, 1982).

Finally, WWI also had considerable effects on the development of the Latin American country. As mentioned, the Saltpetre Era ended between 1929 and 1933, coinciding with the Wall Street Crash. Nonetheless, the first signs of decline began to be observed in 1920[6]. During the WWI, a new way of production of potassium nitrate was discovered (the German synthetic nitrate) and Chilean saltpetre demand started to decrease[7]. In 1927, with state funds strangled by its dependence on saltpetre exports, the government tried to improve the situation with a system of free sales. Exportations initially increased. Unfortunately, it generated excess stocks, and ultimately prices collapsed due to overproduction and plummeting demand for Chilean nitrate during the Great Depression. The result of this chain of events was the collapse of the Chilean saltpetre industry: the value of the nitrate fell about 90%, and more than 200 mines closed (Miller, 2021).

2.1.2 Literature Review

There are mixed opinions about how the Saltpetre Era economic influx affected Chilean society. They go from the most pessimistic points of view to the optimistic ones.

One of the probably most comprehensive studies on the structural consequences of this period is the one developed by (Cariola and Sunkel, 1982). They deeply analysed the Chilean first and second economic growth cycles. Focusing on the second cycle, which had the saltpetre industry as a fundamental pillar, the authors stated that the development of the country during this period happened, but that it was *violent* and heterogeneous. By violent, they mean that it was not a gradual improvement of the economic situation, but rather brusque and with very marked periods of ups and downs. Besides, by heterogeneous, they refer to the fact that albeit the whole country experienced a population increase and a boom in urbanisation, the improvement benefited predominantly minority sectors of society made up of elites. In addition, according to them, all state efforts were focused on large cities (particularly in Santiago, the capital), while they neglected rural areas. The co-authors also point out that the primary sector was certainly highly developed. Mining improved thanks to its strategic role in the saltpetre trade. On its side, agriculture developed due to the demographic increase and new demand for food from the north of Chile. Indeed, they believe that this rising demand led to the

[5]One of the most tragic and illustrative events of the Chilean *Social Question* was the massacre at the Santa María of Iquique School in 1907. In this event, the saltpetre workers strikers were demanding better wages in the face of the peso devaluation and the rise in the price of essential commodities. However, the government's response to the dispute was to open fire on the demonstrators (Cariola and Sunkel, 1982).

[6]Even when synthetic nitrate came on the market, Chileans thought that their mineral could coexist with German synthetic nitrate and still be profitable, which was finally not the case.

[7]Although the development of German synthetic nitrate marked a turning point in the saltpetre industry, it should be noted that other strong rivals to the Chilean mineral were already present years before. For instance, between 1901 and 1913, as Couyoumdjian (1975) mentions, the use of ammonium sulphate as fertiliser had increased by 175%, compared to a 60% increase in saltpetre consumption during the same period.

modernisation of agriculture, especially in the rural provinces of *Norte Chico* and *Núcleo Central*. On the opposite, they support the vision that the industrial manufacturing sector remained underdeveloped despite attempts during the government of Balmaceda to develop technical education and promote the immigration of skilled technicians and craftsmen[8].

The latter idea was also supported in a more recent study by Ducoing and Badia-Miró (2013). By studying the evolution of Chile's Industrial Gross Domestic Product (GDP) between 1880 and 1938, they support the pessimistic view that the manufacturing industry was in decline. The explanation provided by the authors is that the country's low imports were harmful to the industry, as the necessary inputs of the sector depended on the importations.

Now, moving from this mixed interpretation of what happened during the Saltpetre Era to more extreme views, the contributions of Hurtado (1966) and Pinto (1959) to the literature need to be highlighted.

Hurtado (1966) is a reference for the positive perspective on this part of Chilean History. The author states that thanks to the profits generated by the nitrate industry, the government was able to invest in the country's connections, in addition to the interest of the private companies involved in the mining activity in building these infrastructures. Due to this improvement, mining production benefited, but so too other sectors experienced a positive spill-over effect. Agriculture and livestock farming[9], industry, and the service sector had not the opportunity to expand appropriately due to the lack of infrastructure until that moment. In turn, in his opinion, the investment in these facilities led to an increase in employment[10] and urbanisation. Concerning agriculture, he warns that many other works have merely focused on a very superficial analysis of the evolution of agriculture since, after only comparing its growth rate with those of 1855, they concluded that it was stagnant. Nonetheless, he puts forward a new analysis centred on the fact that the significant advance of agriculture was not in its growth rate but its diversification and productivity. Hurtado (1966) shows that the growth rate of wheat (one of Chile's principal crops at the time) continued to increase steadily. In contrast, agriculture was modernised by introducing new technologies and the production diversified by giving more attention to fruits, wine and legumes. Finally, focusing on the other hot-point in the Saltpetre Era, the industrial development, he shows that the railway, the increase in the domestic demand thanks to the growing population and urbanisation, and the arrival of immigrants benefited the industrial sector. Moreover, the devaluation of the Chilean peso since 1974 also helped the exportation.

Pinto (1959) work emerges in a pessimistic view of the one just discussed. For him, saltpetre was harmful rather than an opportunity for improvement. He states that due to the attraction generated by nitrate, the agricultural sector went from accounting for almost 45% of the country's exports to less than 15% during the Saltpetre Era. For him, this change in the composition of trade was the reason for the decline and stagnation of the Chilean agricultural sector. He also criticises that

[8] Cariola and Sunkel (1982) suggested that there was a true betterment in the secondary sector during the first phase of the Saltpetre Era (until the first decades of 1900) but that at the end, in comparison with other economic sectors this was left behind.

[9] Until the Saltpetre Era, agriculture and livestock farming were activities developed in areas that had traditionally transported their products by mule or ox.

[10] Hurtado (1966) estimates that around 15,000 workplaces were created in jobs directly related to the railway, to which should be added all the indirect employment that was also arisen.

the saltpetre boom displaced copper mining from the world market, again frustrating other sectors of the country's economy. His view of the development of the industry is similar too, arguing that the industry began to develop in 1850 and that it was the saltpetre boom that damaged its evolution by concentrating all economic activity and encouraging a massive opening to the foreign market. In short, for this author, nitrate was negative for the country's development because an appropriate state policy did not accompany it. On the contrary, he argues that it paralysed the other sectors of the economy by attracting all the attention of investors and politicians. Nevertheless, it should be borne in mind that contrary to the rest of the authors, the opinion of Pinto (1959) stands out for being the most supported by testimonies and previous work, rather than on a data-driven analytical view. It was also heavily influenced by political views.

So far, I have presented some of the most traditional contributions to the literature on this topic, but they were characterised by not being empirical studies.

Miller (2021) offers a more quantitative evidence-based analysis and takes a relatively optimistic view of the effect of the Saltpetre Cycle. He acknowledges that it helped population growth, urbanisation, and agriculture's modernisation and development. In industry, he does not take as much of a stand. However, the author indicates that several institutions were set up for the development of the industry[11]. What this work does pay special attention to is how Chile managed to avoid the curse of natural resources largely, also called the Dutch Disease[12]. The author analyses that this was partly due to an unorthodox monetary policy taken by Chile during WWI and the Great Depression (very lax compared to that of neighbouring countries in the same period). This attitude meant that Chile's external credit was not significantly affected, and the country was able to issue sovereign debt when the international market was favourable. Furthermore, what helped the Andean country not to suffer the ravages of the Dutch Disease was that the copper industry began to grow from the 1920 century onwards. Moreover, as the Chilean peso remained depreciated, the exchange rate protected producers in the primary sector, manufacturing industries from imports, exporters (because wages were kept below prices), and banks gained from foreign currency transactions.

Finally, Badia-Miró and Díaz-Bahamonde (2017) and Ducoing (2021) developed the most empirical research of all those presented here. The former, Badia-Miró and Díaz-Bahamonde (2017) offers an intermediate view between pessimists and positivists of the Saltpetre Cycle. They argue that the positive effects of the export-led growth model fostered by Chilean nitrate outweighed the negative ones. The mining sector helped ensure that the impact of WWI and the Great Depression on the Chilean economy was milder than in neighbouring countries. Furthermore, although many of the signs of the Dutch Disease are not evident in the case of Chile, according to them, and unlike Miller (2021) supports, Badia-Miró and Díaz-Bahamonde (2017) held that the country experienced a loss of industrial competitiveness, a symptom of the resources curse. They also support that the rising mining activity in the country's north gave way to the diversification of non-durable products. The manu-

[11] In 1888, the *Ministerio de Industria, Obra Pública y Ferrocarril* (Ministry of Industry, Public Work and Railways, in English) was created, among other state agencies and state-owned enterprises (Miller, 2021).

[12] The Dutch Disease is an economic phenomenon that happens when one sector of an economy (often natural resources) experiences a fast development while precipitating a decline in other sectors and appreciating the national currency.

facturing and agricultural sector diversified, principally driven by demand from the *Norte Grande*. The problem is that this shift was not strong enough to boost the country's economy and resulted in the loss of competitiveness in industrial terms. Thus, although the authors partly support the position of Hurtado (1966) on the improvement of the agricultural sector thanks to saltpetre mining, they are more critical of the effect of this improvement.

Last but not least, the recent article by Ducoing (2021) is worth mentioning, as it addresses through time series analysis how nitrate exports may have affected the human capital formation and productive structure investment. To this end, the author looks at the growth rates of total mining exports, nitrate exports and copper exports. Additionally, as an indicator of human capital development, he examines the growth rate in education expenditure and investment in fixed capital in machinery and non-residential construction as an indicator of investment in productive structure. His findings back up a positive view of what the Saltpetre Era entailed. Between 1850 and 1893 Ducoing (2021) finds that the growth rate of his two variables of interest was 6%, coinciding with an increase in nitrate exports of 38%. He also finds favourable growth rates for the second half of the mining cycle (from 1893 to 1927) and when the sector started to shrink. Expenditure on education grew by 4.5% and investment in fixed capital by 7.5%, even though the growth rate of nitrate exports was 1.9%. However, it is of great importance because Chile also experienced a 6.8% increase in its copper exports in the latter period. This study represents evidence contrary to the view of Pinto (1959), who states that saltpetre stagnated and damaged copper mining. On the contrary, this paper points out that the development of the copper industry might have helped Chile not to suffer further damage from the collapse of the saltpetre sector. For this reason, the author describes the legacy that saltpetre left in the Andean country as "indisputable".

2.2 The Lithium Era (1995-Present)

2.2.1 Historical Background

In 1962 the North American mining company *Anaconda* was exploring the *Salar de Atacama* (Atacama Salt Flat in English) in the region of *Antofagasta* searching for water. However, they found something different: lithium. Although, at the time, not much relevance was attached to the discovery, years later, the *Salar de Atacama* was recognised as one of the most crucial lithium deposits in the world (Lagos, 2012). The intense sun, warm wind and low humidity have evaporated the water from the area's lakes to create large brine reserves, where the white mineral is found.

The so-called *white gold* was declared a resource of nuclear interest in 1976 by the Chilean Nuclear Energy Commission because it was mainly designated for the construction of nuclear reactors for its potential use in nuclear fusion and the manufacture of thermonuclear bombs. Soon, the unprecedented demand for the metal from the USA and Russia during the Cold War prompted the Chilean Government of Pinochet (1973-1990) to approve a law in 1979 declaring lithium a state mineral. In the same year, the state-owned *Corporación de Fomento de la Producción* (CORFO, translated as The Production Development Corporation in English) started to get involved in the production of lithium through its Institute of Geological Research. Hence, since the 1970s, lithium has been exploited through public-private partnerships, and CORFO has been the body in charge of granting mining licences (Jerez, Garcés, and Torres, 2021) (Graham, Rupp, and Brungard, 2021).

After numerous concessions, sales, and purchases of operating licences, in 1995, the *Sociedad Química Minera* (SQM, translated as Chemical and Mining Society in English) began its lithium production by exploiting the *Salar de Atacama*. Since then, it has become the leading producer of lithium in Chile, and until 2015, also in the World[13]. In terms of property, SQM owns more than 95% of the *Salar de Atacama* mining assets, belonging the rest to the US company Albemarle (CORFO, 2018). Moreover, according to the Environmental Rating Resolution, SQM is allowed to bomb a maximum of 1,600 litres of brine per second in the salt flat. Nevertheless, the company also has the right to use 240 litres of water per second in the same area, a privilege granted by the General Water Directorate of Chile. Thus, the role of SQM in lithium mining is decisive as the company represents about the entire Chilean production (Rodríguez-Morales, 2021).

Nonetheless, controversy has surrounded the figure of this company. On the one hand, Julio Ponce Lerou, one of SQM's principal shareholders, has been implicated in various cases of treasury fraud and because of the corrupt financing of certain politicians. Additionally, the company itself was recently accused of monopolistic practices after its agreements with some international companies (Jerez, Garcés, and Torres, 2021). These accusations are not the only ones that have made the situation in the *Salar de Atacama* complicated. Eighteen indigenous communities live near the mineral mining area and have led numerous protests to fight for their rights over the water resources in the salt flats. Taking advantage of the new Constitution that Chile is trying to approve, these groups demand that the brine from which the lithium is extracted must be classified as water and not as a strategic resource. Even though the current government of Gabriel Boric is in favour of increasing the country's lithium production, these social tensions are making it challenging (Graham, Rupp, and Brungard, 2021).

Turning now to why Chile has such a unique position in the international lithium market, several reasons can be identified. The most extensive lithium resources are found in the *Salar de Uyuni* in Bolivia, but lithium reserves (understood as the amount of mineral that is economically viable to exploit at current prices) are in Chile (USGS, 2022) (Mendez-Martín, 2019). Moreover, Chile has an advantage that goes beyond having these reserves. Chilean lithium extraction costs are lower than in other locations. Indeed, when the lithium production started in the *Salar de Atacama*, the cost difference between brine extractions and the extractions that had so far been made from the rock in the USA was more than evident (Lagos, 2012).

However, disadvantages can also be found in Chile's reserves. Unlike its biggest competitor, Australia[14], Chilean lithium is extracted from brine and not rock. Brine presents a much more delicate ecosystem than rock mining and therefore requires greater caution because of the potential externalities of pumping the brine to extract the mineral. This has been pointed to as one of the reasons why Australia has increased its production much more than Chile has (see Appendix B), but it is not

[13]Even though lithium production started in the 1970s, the beginning of the Lithium Era was established in 1995 because SQM's entry into the lithium market marked a before and after.

[14]In 2013, the production rates of Australia and Chile were at the same level after years of Chile being slightly above the Oceania country's level. In this day and age, according to the last report of the international lithium market made by Cochilco (2020) Australia has a market share in the lithium market of 48%, while the Chilean share is 29%.

the only one. The extraction of lithium from bedrocks (pegmatite mining) that characterises Australia has an average extraction time of 1 to 2 months, compared to 18-24 months[15] that it takes to extract lithium from brine in Chile (Cochilco, 2020).

Now, studying closer the case of the Andean country, the evolution of the lithium prices and its production in the country need to be analysed to have a clear picture of this particular mining sector's nature.

The lithium price trend has followed a tilted upward tendency, as could be seen in Figure 2.1. At the beginning of this century, the price of the white mineral was almost 1,500 USD free on board[16] (FOB), and it remained fluctuating around this price until 2005 when it started to increase and surpassed the 5,000 USD FOB. Due to the Global Financial Crisis the price experienced its first drop (2008-2011), which accounted for a decline of 17.9%. Nevertheless, although at first glance this drop looks pretty steep, it was very mild compared to the fall in the prices of other metals during the same period[17], which can indicate the relative resilience of lithium to periods of economic recession. Besides, between 2015 and 2017, the *white gold* price reached an unprecedented maximum at that time, increasing by 112.84% and exceeding 13,000 USD FOB per tonne. In the following year, prior to the Coronavirus-generated global crisis, lithium price fell as new lithium production projects were approved, but demand was lower than expected. The index experienced its most significant drop ever, and from 2018 to 2020, it decreased by 51.04% (BMI, 2016) (WB, 2021).

On its side, lithium production[18] grew very slowly until the end of the 20th century. From 1994 onwards, its growth accelerated thanks to increased demand for monochrome monitor manufacturing. In 1997, as a consequence of the Asian Crisis[19], there was a slight drop, from which it recovered between 2000 and 2003. Influenced again by Asia, with the entry of China into the world market in 2013, the demand for lithium increased. This event led to an increase in production until 2009 when it suffered its biggest fall (a decline of 46.31%) due to the Global Financial Crisis. This drop, however, was partly voluntary. Most lithium producers preferred to reduce production rather than lower prices. Contrary to how it behaved in the recession of 2009, with the outbreak of Covid-19 and its consequent economic recession, lithium production reached record levels, surpassing the 100,000 tonnes produced in Chile, and rising more than a 99% (see Figure 2.2) (Maxwell, 2015).

Because of the trends that have been observed in recent years in the lithium market the following question has been posed: Is lithium mining going through a

[15]Even though the production cost of the lithium extraction from the brine is relatively low (4.1 – 5.8 thousand USD/tons for the production of carbonate lithium) in comparison with its extraction from bedrocks (8.3 – 9.0 thousand USD/tons for carbonate lithium), extractions from brine are heavily dependent to the meteorological conditions due to its evaporation process at open-air ponds (Cochilco, 2020).

[16]The FOB price of exports is the market value of the goods at the customs border of the economy from which they are exported, which is a uniform valuation point (OECD, 2001).

[17]Metal prices fell on average around 50% during the Great Recession according to the WB (2021).

[18]Although Chile produces mainly carbonate lithium, about 15% of its production is also lithium hydroxide. Total production would therefore be even higher than shown in Figure 2.2.

[19]The Asian Financial Crisis began in Thailand in 1997 and spread throughout East Asia, harming the Asiatic economies and causing adverse spill-over effects in Latin America and Eastern Europe (Carson and Clark, 2013).

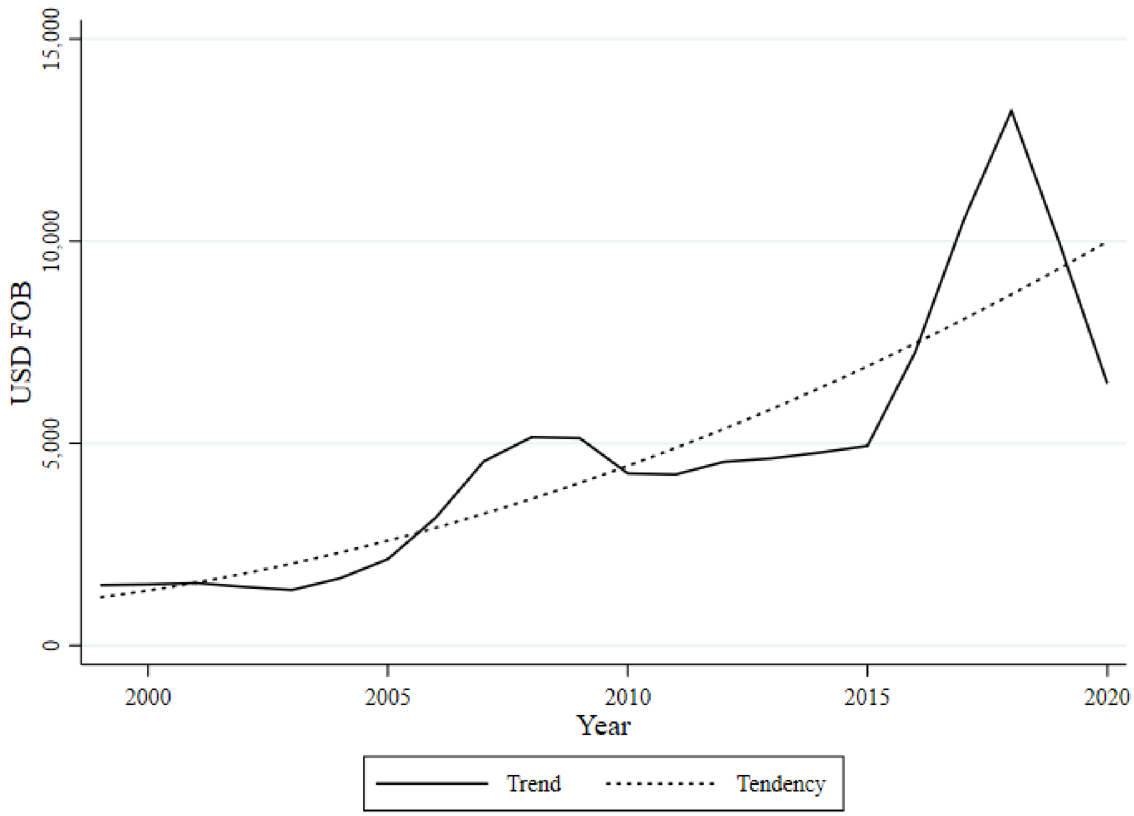

Figure 2.1: Lithium price evolution (1999-2020).

Source: Author's own elaboration based on data from BGS (1990-2021).

Note: The lithium FOB prices were measured by the market value of the metal at the Chilean customs border.

supercycle[20] ? There are more than a few who suggest that we could be witnessing one (Hume, 2022)(Economist, 2021)(Spilker, 2021). The last supercycle was observed a decade ago. In 2013, several mining sectors experienced the peak of the supercycle that has come to be known as the "China effect". China's entry into the international market led to a massive demand increase in virtually all commodities, also fuelled by the industrialisation and urbanisation of emerging nations such as India. This cycle lasted just a few years, as by 2015 almost disappeared giving way to a bear market (Kong, Goh, and Yoo, 2016). Nevertheless, what has been experienced today, if it is a supercycle, is quite different from what happened in the period just cited. The developments in the lithium sector that are happening in this age and day could be viewed as the result of a post-pandemic economic recovery, which would only have a short-term effect. Nonetheless, it can be pointed to a force that would have a long-term impact. Lithium, along with other minerals such as copper, cobalt or nickel, is indispensable for the energy transition, which is producing a structural demand effect.

[20] Heap (2007) has defined a supercycle as a prolonged decades-long increase in the trend of real commodity prices, usually driven by urbanisation and industrialisation in a major economy.

Figure 2.2: Lithium carbonate production in Chile (1984-2021).
Source: Author's own elaboration based on data from BGS (1990-2021).

2.2.2 Literature Review

The literature concerning lithium mining in Chile can be divided into two main strands. Those that examine the political and economic behaviour that lithium mining is entailing and those that focus on studying its socio-environmental implications in Chile.

In the first group of works, the contribution of Lagos (2012) stands out. The author carries out a relatively intensive historical analysis covering all aspects related to the exploitation of lithium, from the establishment of its price to the agreements between companies in the *Salar de Atacama*. With all this information, he gives a personal insight into what is to be expected from this mining industry. The author defends the state's role as the axis for the development of the lithium industry and highlights a list of requirements that it should ensure now that lithium has been included in the Chilean list of strategic minerals[21]. However, he is pessimistic about the present and future situation. The author reproaches the lack of state support for research and development in Chile since 1987[22]. He doubts that the government is currently able to provide the most conducive environment for the Lithium Era to

[21] According to Lagos (2012), if lithium is considered a critical material, the Chilean state should ensure the existence of a state body that has in-depth knowledge of all aspects of the national and international lithium market, guarantee the free entry of companies into this market, promote industrial competitiveness, and ensure that Chile uses state-of-the-art technology in lithium extraction.

[22] In 1987 the Minister of Finance withdrew funding from research institutes such as the Centro de Investigación Minera y Metalúrgica (CIMM, translated as Centre for Mining and Metallurgical Research in English) among others (Lagos, 2012).

flourish and improve Chilean economic development. Additionally, his paper opens a debate on whether lithium reserves should be exploited as much as possible now or saved. In this day and age, lithium is in high demand for the manufacture of electric batteries, but he believes there will be a boom in demand in the next century for the use of this metal in fusion reactors. He addresses this issue because he supports the idea that lithium will only generate wealth comparable to what countries with oil reserves have had so far if it can be used as a fuel. But the only way he envisages that to happen is if it is used in nuclear energy. Nevertheless, given that this usage is not expected to gain relevance until at least 2100, the author settles his view of the debate by claiming that "Chileans want to develop soon, not next century" (Lagos, 2012, p.55). He then highlights a better strategy to improve the aggregated value of lithium in the country and let new companies into the market to improve competitiveness nationally and internationally.

Another author who has looked at the way governments have approached lithium mining is Barandiarán (2019). His article focuses on the Lithium Triangle and mentions the three ways in which lithium can be understood and consequently managed. Some governments can see lithium as a commodity to be controlled entirely by the market. Some recognise it as a resource that the government must manage exclusively because of its geopolitical importance. Finally, others can understand it as a resource that can provide an opportunity for extractive countries to boost their economies through industrialisation-based development. According to the author's interpretation, the Chilean case has been characterised by its management of the mineral through a mixture of two of these positions, rejecting lithium as a geopolitical determinant. The market decides the production and price of the metal, which supports the view of lithium as a mere commodity. However, the resource has also been seen as a driver of development, and the state has invested in lithium-related industries and research. On this point, the vision of Barandiarán (2019) clashes with that offered by Lagos (2012), as the latter considers the action the government has taken so far in terms of investment to be poor and useless. Barandiarán (2019) also gives his opinion on the current debate, which mainly involves whether the benefits of lithium mining outweigh the negative consequences. He highlights that all possible effects of lithium mining have not yet been studied in-depth and takes an optimistic view. The author is confident that Chile will manage the resource the right way to encourage the proper growth of the sector, thus leading the country towards modernisation and development that does not depend exclusively on the export of raw materials.

In a stance between the literature associated with political action concerning lithium and studies linked to its socio-economic consequences emerges the work of Jerez, Garcés, and Torres (2021), which includes both perspectives.

The authors present a highly critical position on the implications of lithium mining in Chile, accusing it of reinforcing the subordination of the Latin American country as a supplier of natural resources to the Global North. They argue that the Chilean state is not preventing a return to this role and describe the exploitation of lithium as part of *green extractivism*. Through a series of interviews, they analyse the links between green electromobility, lithium extractions and water injustices, paying particular attention to how they affect the indigenous communities that inhabit the *Salar de Atacama*. The co-authors highlight how the privatisation of water during the Pinochet dictatorship and the establishment of lithium as state property remain latent today. According to them, these facts are harming the indigenous population of the region, who are seeing their land and water rights being surrendered in favour of the overexploitation[23] of lithium by international firms.

Even though the view of Jerez, Garcés, and Torres (2021) may seem the harshest so far, the truth is that almost all authors who have studied the socio-environmental consequences of lithium mining have also given a rather negative opinion.

Previously, Babidge (2016) had already spotlighted the problems concerning lithium and its extensive use of water, dating back to the Water Code created under the Pinochet Administration when water was privatised. Although in 1922, this law was modified to protect water in the aquifers of the *Salar de Atacama*, the author notes that in most cases, the private interests of the mining companies prevail to the detriment of the quality and reserves of water in the area. The Chile Human Rights Report (USDS, 2020) also highlights that there are vulnerabilities in the rights of the indigenous population of the Andean country regarding resources rights and calls for the Chilean government to safeguard these rights effectively.

Lastly, Schlosser (2020) studies the socio-ecological externalities of lithium mining in the *Salar de Atacama* too, but in a more empirical way. Her results show that some environmental implications of these extractions are the destruction of soils, the poisoning and contamination of rivers and groundwater by chemicals used to clean the brine in the ponds, and the decrease of available water in the region. The latter supposes a severe risk to indigenous inhabitants, as they often base their economic activity on agriculture or pastoralism, which further sustains the concerns identified by Jerez, Garcés, and Torres (2021) Babidge (2016) and USDS (2020). Another problem that the author refers to is that indigenous people's right to free, prior and informed consent is sometimes not respected. Frequently, information and official documents related to this issue are neither publicly accessible nor translated into languages that indigenous people can understand, violating their right to have a voice in decisions made concerning the land they have been inhabiting for centuries.

[23] Jerez, Garcés, and Torres (2021) argue that lithium is being overexploited as more lithium is being extracted than should be if water limitations and the rights of the local indigenous population are taken into account.

3. Comparison Between the Saltpetre and Lithium Eras

3.1 Similarities

The similarities betwixt the Saltpetre and Lithium Eras in Chile are numerous even when both mining industries have been relevant in very distant and contrasting periods. In Table 3.1 the main parallelisms between the two eras are presented, illustrating why the historical mirror is feasible.

Table 3.1: Similarities between the Saltpetre and Lithium Eras

Saltpetre Era (1880-1930)	**Lithium Era (1995-Present)**
The *Norte Grande*: Tarapacá and Antofagasta.	*Salar de Atacama*, commune of Antofagasta.
Two different processes were used, but both were based on open-air extraction and leaching ponds: the Shanks and Guggenheim processes.	Open-air extraction and an evaporation process that occurs in the leaching ponds where the brine is pumped.
Foreign-dominated mining sector, with England, Germany and the United States playing a major role in the development of the sector.	SQM and Albemarle are the two companies present in the *Salar de Atacama*, both heavily influenced by foreign investors.
Demand from Europe and the United States: agriculture and military equipment.	Demand from Europe, the United States and China: electric batteries.

Firstly, the geographical area in which Chilean saltpetre was extracted was in what is known as the *Norte Grande* (Great North in English), mainly comprising the communes currently called *Arica y Parinacota*, *Tarapacá* and *Antofagasta* (Miller, 2021). In the case of lithium production in Chile, it is principally located in the *Salar de Atacama*, part of the *Antofagasta* commune (SQM, 2020).

Regarding the production system, although today's lithium extraction and production use more advanced technologies, the method employed is quite similar to the one used for saltpetre mining (see Appendix C). Two nitrate extraction processes can be mentioned: the Shanks and Guggenheim. The Shanks process was introduced in the 1870s after being proposed by James Humberstone. The caliche was extracted from the salt flats and transported to the so-called saltpetre offices to be mashed in crushing machines. It was then placed in leaching tanks with high-temperature water and finally crystallized with trays (MA, n.d.). This process was the most adopted one throughout the era. On its side, the Guggenheim production system was used from 1920 onwards, proposed by Elías Cappelen, and financed by the North American brothers Guggenheim. This process was very similar to the Shanks method. However, the technology financed by the Americans optimized the production process, being possible to extract twice as much nitrate from the caliche (see Appendix D). The productivity improvement was so noticeable that the *María Elena* and *Pedro Valdivia* offices, the sole ones using the Guggenheim process, were the only survivors of the collapse of the saltpetre industry. Both continued to operate under SQM's management. Although the *Pedro Valdivia* office closed in 1996, the *María Elena* one is still in operation and is the exclusive saltpetre office running in *Antofagasta* (Semper and Michels, 1904). In the case of lithium, extraction and production are based on a multilevel process of evaporation. It consists of several tanks adjacent to each other where the caliche that has been extracted in open-air mines is pumped and cleaned. Between 18 and 24 months are needed to complete the extraction procedure and let the caliche with a minimum percentage of 6% of lithium or 35% of lithium chloride. Ultimately, the brine is transported to different plants to produce derivatives and then be distributed (see Appendix E) (SQM, 2020).

Another common characteristic of both industries is that foreign investors have heavily controlled them. In the case of saltpetre, the external domination was very noticeable and has been used over the years as one of the major criticisms of this industry. To illustrate the discontent, the words of André Gunder[24] can be quoted: "instead of developing the Chilean economy, Chile's saltpetre served to develop European agriculture" (1971 cited in Miller (2021)). Although not everyone took such a negative view of nitrate management, the fact is that in 1910 the two principal saltpetre companies in Chile were German. In the same year, albeit the third most significant producer was Chilean (*The Antofagasta Company*), 31 out of 77 companies were English-owned (Miller, 2021). In parallel, the lithium-company Albemarle has its headquarters in North Carolina (The United States). Most of its partners are also American companies, and it has another lithium-production plant in Australia where it operates with close ties to Chinese companies (Albermarle, 2022) (CORFO, 2018). For its part, SQM is owned by companies from different countries. For instance, the Chinese Lithium company *Tianqi Lithium* has a stake of 23.77% and decision-making power since 2018 (De-La-Jara, 2018) (Nasdaq, 2022).

The similarities between the two industries should also be noted regarding where their demand is targeted. Chilean nitrate was exported to the Western Economies, first as a fertilizer to support agricultural development in the USA and the Old Continent, and later as a component for the manufacture of explosives (Bastias-Saavedra, 2014). Now lithium is mainly being used to make electric batteries (Bradley and Jaskula, 2014). The leading buyer of Chilean *white gold* is Europe and, in more discrete quantities, the USA and China, as currently they can supply part of their demand with their own production, unlike in Europe (Cochilco, 2013)(Graham, Rupp, and Brungard, 2021). However, while the usages of the two minerals are very different, the two markets that demand them have two things in common. First, their consumers are mainly the USA and Europe (and China recently as an importer of lithium). Secondly, the markets to which demand is directed were and are of key importance. On the saltpetre side, the agricultural sector that demanded nitrate

[24]André Gunder Frank was a sociologist and economic historian who in 1971 developed the Dependency Theory. This theoretical approach is based on the idea that the more powerful countries dominate and exploit the less economically powerful ones due to the unequal distribution of power and resources. In other words, underdeveloped countries were underdeveloped not because of their internal barriers but because of the influence of more developed nations. Some years later, the author used this perspective to define the case of the Chilean saltpetre industry (Munro, 2018).

as fertilizer was crucial for the development and growth of the countries. At the same time, the manufacture of explosives gained abysmal value with the outbreak of WWI. By its side, lithium has also been recognized as a critical mineral essential to achieving energy transition goals (MM, 2022).

3.2 Differences

Despite the similarities already highlighted between the Saltpetre and the Lithium Eras, it is worth noticing that the differences also exist. Table 3.2 summarises the most important divergences of these mining sectors. Nevertheless, it should be taken into account that the lithium mining sector is still ongoing and changing, so there is a window of opportunity for it to behave differently[25].

Table 3.2: Differences between the Saltpetre and Lithium Eras

Saltpetre Era (1880-1930)	**Lithium Era (1995-Present)**
Nitrate prices were established by the Chilean saltpetre producer monopoly, usually above the competitive market price.	Lithium prices were imposed at the beginning of the era by the two American main producers. Currently, several companies from different countries are present in this market and Chile does not have a monopolistic position, neither is the main producer.
Cyclical demand due to the use of saltpetre in agriculture.	Non-stationary demand for lithium due to its use mainly in the development of electric batteries.
A synthetic saltpetre substitute was invented by Germany due to the country's incentives to seek an equivalent for Chilean nitrate.	There is still no mineral or technology that can replace lithium in the manufacture of electric batteries.
Largest mining export, accounting for 80% of Chile's mining exports.	Marginal percentage of Chile's mining exports, which are dominated by copper and its derivatives.

Some authors have described saltpetre production as a Chilean monopoly at the beginning of the 20th century. Companies in Chile held more than half of the market share and fixed prices above the price that would have been established in a competitive market. In more detail, how prices were set was as follows. In order to control nitrate prices, the companies operating in Chile joined together to form a combination or cartel, thus being able to control production. When the supply of nitrate grew, so did the market surplus and the price of the mineral fell. When this happened, the companies created a cartel to reduce production. Once they achieved this goal, they dissolved the cartel. With the profits generated, investment in the industry increased, again generating an increment in supply and repeating over and over again this cycle. Thus, Chilean nitrate production was based for 50

[25]Because of this, in the analysis of the two eras I have not included a comparison of the fiscal and monetary policy pursued, as the Lithium Era policy may still vary greatly.

years on cycles of overproduction, and the peaks in the growth rate of price that were generated can be seen in Figure 3.1.

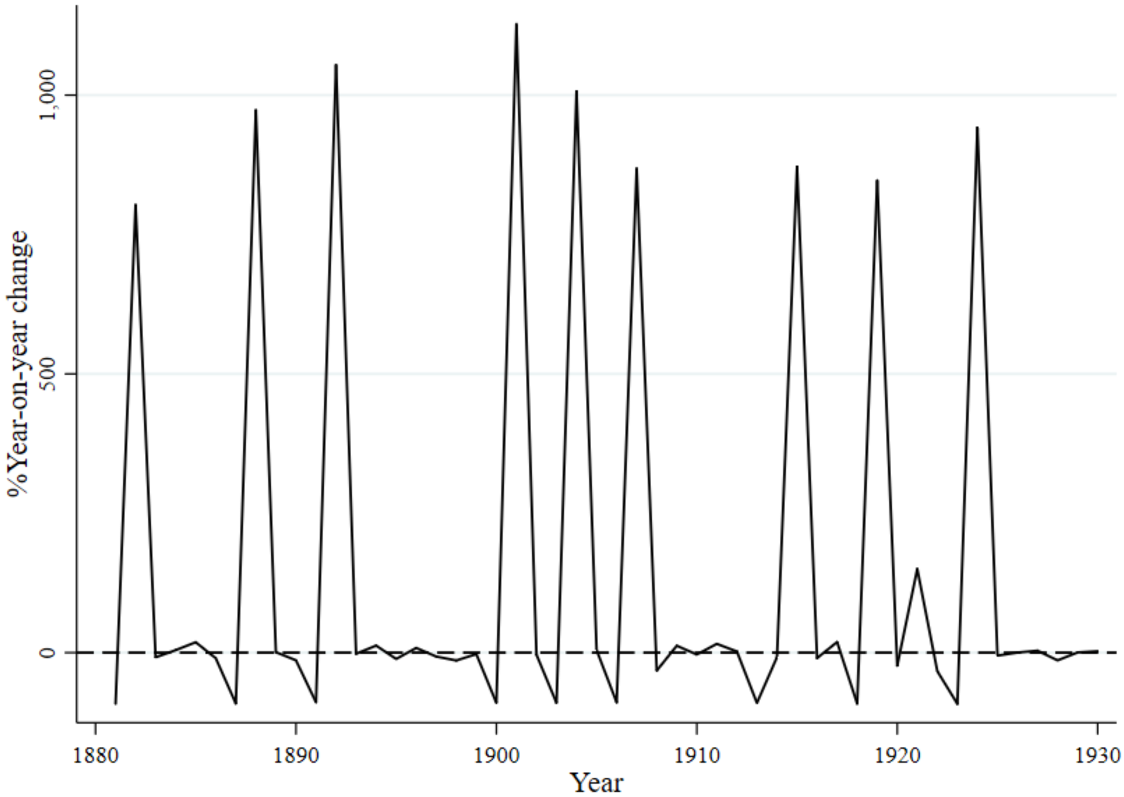

Figure 3.1: Year-to-year percentage change in saltpetre price (1880-1930).

Source: Author's own elaboration based on data from Ducoing (2021).

Besides, as can be found at Figure 3.1, the prices fluctuated during the period, with pronounced ups and downs, but with a downward tendency. In 1920, there was a maximum in saltpetre prices that almost reached 1 billion Chilean pesos per tonne. Nonetheless, from 1930 onward, the collapse of nitrate prices is notable: prices dropped to virtually zero. This manipulation of prices has been considered as one of the causes that led to the search for synthetics to replace this resource, which eventually resulted in the collapse of the Chilean nitrate sector (Lagos, 2012) (Wagner, 2005).

For its part, the way lithium price has been settled has significantly varied over the years. The reason for so much change is the number of companies that have operated in this market. From 1962 until the mid-1990s, there were only three main lithium-producing companies in the world (they owned 80% of the total production), and the price of lithium was set by these producers, as the market was a cooperative oligopoly (Lagos, 2012). However, this situation changed drastically with the entry of SQM into the lithium industry in 1995. The company revolutionized the mining sector lowering lithium production costs up to 50% by extracting it from salt flats. The market then became a non-competitive oligopoly with four majority-owned companies, which drove lithium prices down. From then until 2009, the price of the mineral was established opaquely. Due to the intense rivalry between companies, it was negotiated bilaterally between buyer and seller. In the last decade, with the entry of new firms, the production of this critical mineral has become increasingly competitive and is generally traded in terminal commodity markets (Maxwell, 2015).

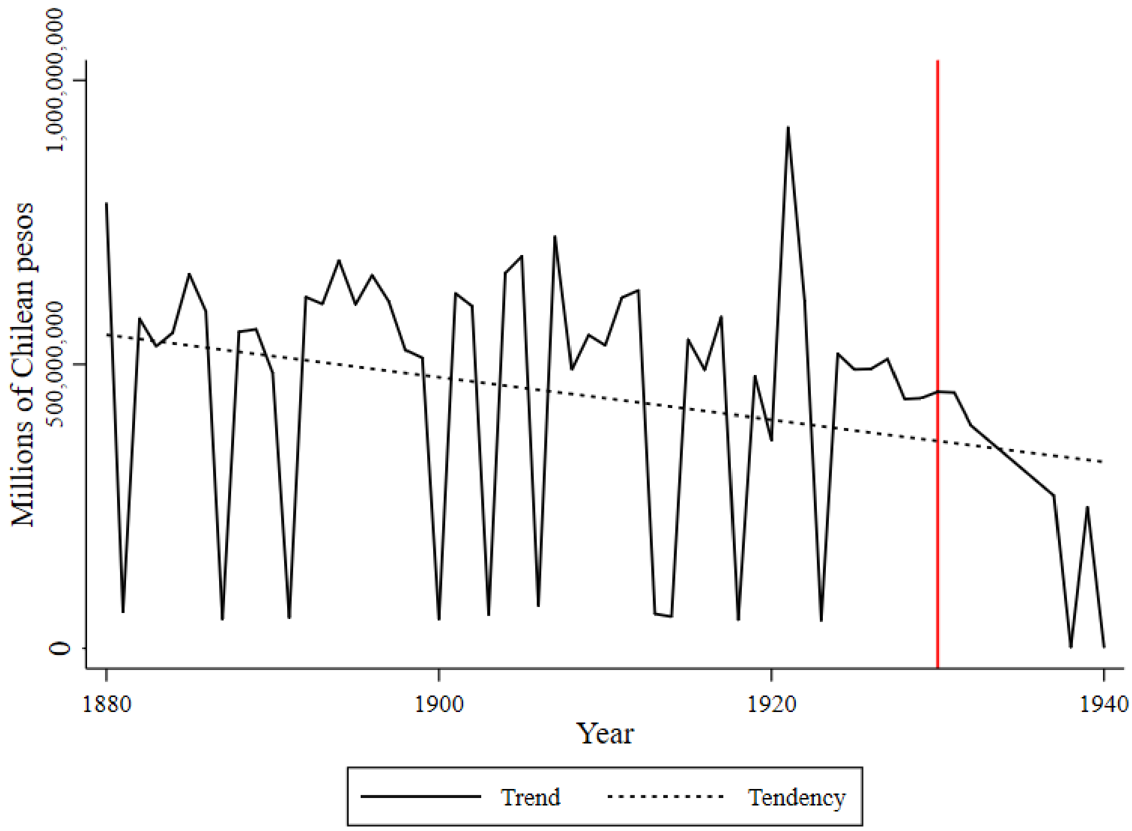

Figure 3.2: Saltpetre price per tonne evolution (1880-1940).

Source: Author's own elaboration based on data from Ducoing (2021).

Consequently, the price determination of lithium follows the intuition proposed by Radetzki (2013). This metal price is determined more opaquely in competitive oligopoly situations when rival companies aim to gain market share.

In terms of usages, the major utilizations of nitrate were its use in agriculture as a fertilizer and its use in creating explosives and military equipment. The demand from these sectors was not always constant. With the outbreak of WWI, both the demand and the supply of nitrate were modified. Although before the war, 4/5 of the Chilean nitrate traded was destined for the agricultural sector and was characterized by a cyclical demand[26]; from 1914 onwards, it was reduced to around 1/4, the remaining percentage being dedicated to the military industry. In this way, the German market became the biggest buyer and demander of Chilean nitrate until December 1914. After the Battle of the Falkland Islands, Chilean trade routes previously dominated by Germany became controlled by the British navy. With England and the USA as the new principal consumers of nitrate and its trade blockade against Germany, Germans had more incentive than ever to find a substitute for Chilean saltpetre. In 1915, Germany finally began producing synthetic saltpetre (Bastias-Saavedra, 2014). In contrast, the lithium demand is not cyclical but growing year-round. Due to the current climate change scenario, the production of EVs is snowballing, driven by large and ambitious battery manufacturing projects. This trend goes hand in

[26]The demand for nitrate was cyclical when the primary usage of the mineral was agriculture. It changed regularly over time depending on the economic time of year, in this case depending on harvesting cycles.

hand with the demand for lithium for electric batteries, which currently represents the 74% of the global market consumption (Sterba et al., 2019)(USGS, 2022), a 32% higher than in 2019. Indeed, the demand for lithium for batteries is expected to keep growing in the medium term, as there is currently no comparable substitute for this mineral. However, although lithium is in its majority destined for the production of electric batteries, other sectors also demand this mineral. The glass and ceramics sector demands around the 14%, lubricating greases and air treatments the 5%, and the remaining 7% is used in other industries like the pharmaceutical one (USGS, 2022).

To conclude, probably one of the most essential facts that differentiate the Saltpetre and the Lithium Era is their relevance to the Chilean mining sector. Nitrate came to represent approximately 80% of the country's mining exports (Ducoing, 2021). Conversely, lithium accounts for a marginal part of Chilean mining exportations (1.5% of total mining exports in 2021), currently led by copper (91% of total mining exports in 2021) (see Appendix F) (BCCh, 2021). For lithium to account for 30% of Chilean mining exports in ten years, its production would have to grow ,*ceteris paribus*, at a growth rate of 35% per year.

$$g = \left(\frac{X_{t+n}}{X_t}\right)^{1/n} - 1 \tag{1}$$

$$g = \left(\frac{0.3}{0.015}\right)^{1/10} - 1 = 0.349 \approx 0.35$$

However, going beyond, if the growth rate for lithium to reach 80% of mining exports (as saltpetre did) is calculated, the white metal production would need to grow at a growth rate of 48% during ten years, or 22% during twenty years, *ceteris paribus*.

$$g = \left(\frac{0.8}{0.015}\right)^{1/20} - 1 = 0.219 \approx 0.22$$

$$g = \left(\frac{0.8}{0.015}\right)^{1/10} - 1 = 0.488 \approx 0.5$$

4. Data

4.1 Saltpetre Era Dataset

Data availability at the regional level in Chile between 1880 and 1970 is minimal. This paper presents the first dataset created and used to analyse what happened in Chile during the Saltpetre Era regionally. Previously, the literature has shown national data to illustrate the trend of some indicators. In this context, the population growth and urbanisation of the country have been popularly used to study its development. The choice of these indicators has been partly because the data available for these ages, as I mentioned, are scarce, a problem that applies at the national level but in a milder way. Withal, the debate on how the Saltpetre Cycle affected the different regions in Chile has remained open without any study prior to this one presenting evidence on the subject.

The data regarding the Saltpetre Era have been taken from the population yearbooks that Chile began to produce in 1851 and that are the "ancestors" of the current Socio-Economic Characterisation Surveys (Spanish acronym CASEN) in Chile. Specifically, I have extracted data from the yearbooks published between 1885 and 1970[27]. Besides, I have been able to access these publications thanks to the *Biblioteca Nacional de Chile* (Chilean National Library in English) and the *Instituto Nacional de Estadística de Chile* (INE, translated into English as Chilean National Statistic Institute) since both institutions offer public access to scanned copies of these books. However, although the information provided by these serials is precious, it also presents problems and limitations to this study.

As has been already introduced in previous sections, Chile unofficially began its saltpetre operations in 1880 with its domain over *Tarapacá* and *Antofagasta*. Nevertheless, the northern part of Chile where this mining industry developed were not included in the census until 1885. Due to this limitation in the data, I tried to obtain information about both regions by searching the historical archive of Bolivia and Peru, but they did not start to provide regional data until several years after losing these territories in the War of the Pacific. Consequently, I will take 1895 as the beginning of the Saltpetre Era in my case study. Indeed, 1890 was when *Tarapacá* and *Antofagasta* officially became part of Chilean territory, and 1895 is the date of the first available census after such official incorporation.

Apart from that, despite having information by regions, Chile's territorial divisions have significantly changed over the centuries[28]. Thus, to have a constant division throughout the sample period, I will divide Chile into six zones, following the division proposed by CORFO in 1950[29] (see Figure 4.1 and, for more details, Appendix G).

[27]Data from OCES (1885), OCE (1895), CCdC (1907), DGE (1920), DGE (1930), DEC (1960), and INE (1970).

[28]As an illustrative example, in 1890, Chile was divided into 15 provinces, while in 1920, the country had 25 territorial subdivisions.

[29]The division proposed by CORFO is extremely appropriate for this research because it not only took into account the geographic characteristics of the regions to split them into groups, but also their socio-economic features (Aguirre, 2012).

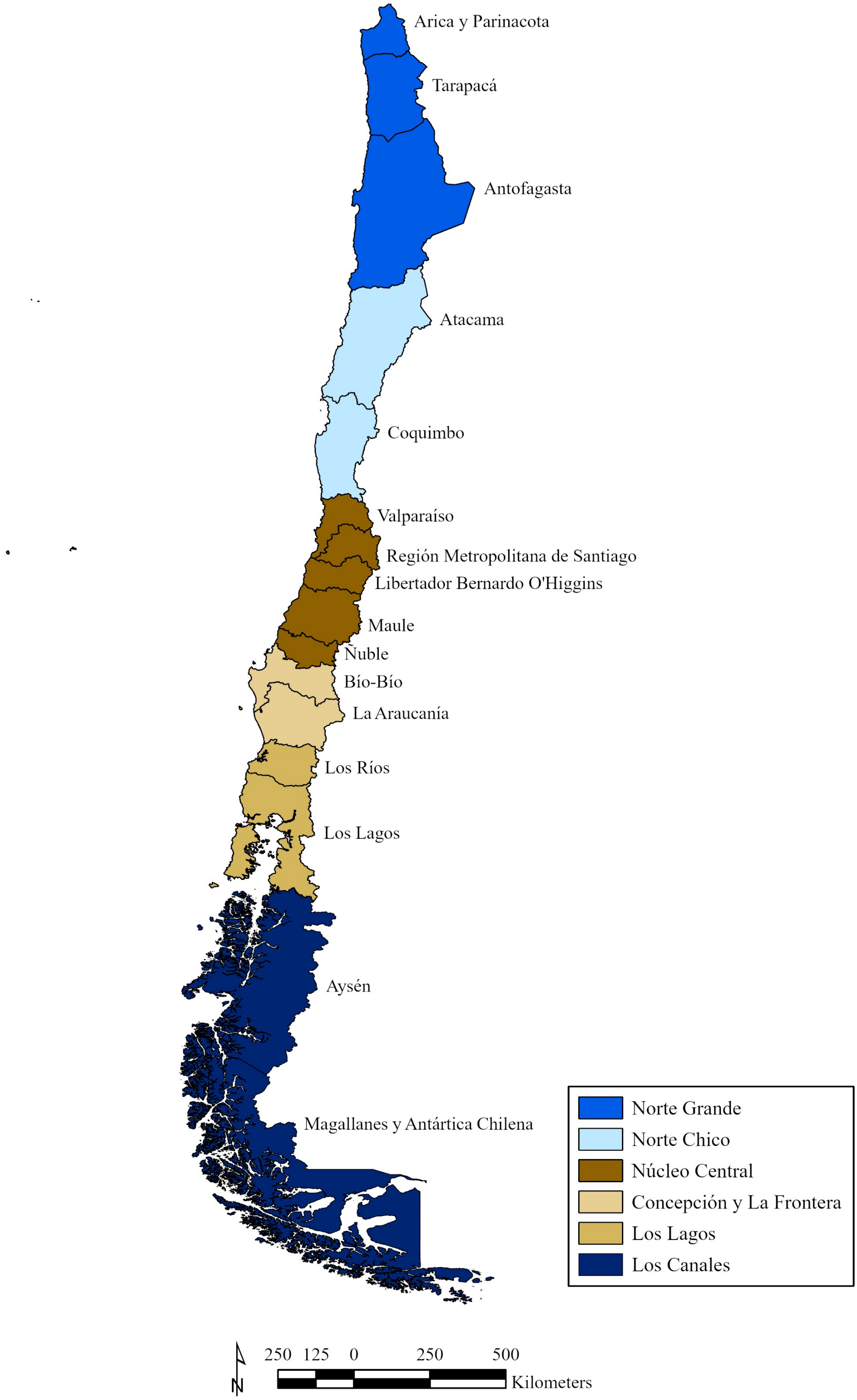

Figure 4.1: Current map of Chile with the division proposed by CORFO in 1950.

Source: Author's own elaboration.

Likewise, the surveys carried out to create these population censuses suffer from attrition, as the questions asked changed from one publication to another. Anyhow, I have managed to deal with this problem by calculating some missing variables and taking only into account indicators that were constant through the sample period. For instance, even though population data has been commonly used in national studies, due to the substantial territorial heterogeneity of Chile's regions, I have opted for using the population density to try to control these differences. However, in several yearbooks, the population density is not implicitly specified. Instead, only the number of people per region was collected. Notwithstanding, studying the text of these publications I noticed that in the introduction of the census of each Chilean region some of their geographic characteristics were described, among them, the surface of each territory in kilometres. Thanks to this detail, it was possible to calculate the population density for all the years in which it was not aggregated and, thus, have observations for the entire sample. In this context, I will also consider urbanisation, measured as the percentage of the population living in an urban area, as an alternative dependent variable because the information about it is also accessible and has been widely used in the literature.

Another problematic fact concerning attrition for this research's purpose arises in the case of the explanatory variables I plan to employ. There is information about the percentage of foreigners per region and the percentage of inhabitants working in the mining sector and in the agricultural one too. Nevertheless, the education level achieved was not collected until the last census I am working with. As has been pointed out, saltpetre could have encouraged investment in education, and consequently, it is a relevant indicator to be included (Ducoing, 2021). Then, I needed to search for another measure to control for education. Fortunately, there is information about the number of people who can read in all of them. Hence, as an alternative to having a traditional indicator of the literacy rate[30] this dataset contains a variable that represents the percentage of the population who can read, which I am confident is a very close measure of what the literacy rate would indicate.

The resulting dataset is a panel data composed of 6 regions, 9 years, 16 variables, and more than 8,000 observations (see Appendix H).

4.2 Lithium Era Dataset

To obtain data on Chilean lithium mining, I have created a dataset by extracting the production in tonnes of lithium in Chile from the "World Mineral Statistics" yearbooks produced by the British Geological Survey (BGS) using their publications from 1984 to 2021[31]. I have further obtained lithium prices from the Central Bank of Chile's (BCCh) quarterly publications on Foreign Trade Indicators from 1999 to 2020[32]. In addition, thanks to data provided by the BCCh, it was also pos-

[30]The literacy rate of a country represents traditionally the percentage of people that can read and write (UNESCO, n.d.).

[31]Data from BGS (1990), BGS (1994), BGS (1995), BGS (1998), BGS (2002), BGS (2007), BGS (2012), BGS (2017), BGS (2021).

[32]Data from BCCh (1999),BCCh (2000), BCCh (2001), BCCh (2002), BCCh (2003), BCCh (2004), BCCh (2005), BCCh (2006), BCCh (2007), BCCh (2008), BCCh (2009), BCCh (2010), BCCh (2011), BCCh (2012), BCCh (2013), BCCh (2014), BCCh (2015), BCCh (2016), BCCh (2017), BCCh (2018), BCCh (2019), BCCh (2020).

sible to access country's total mining exports and, from there, I have calculated the percentage of lithium exports out of Chile's total mining exports[33]. This indicator has valuable information to contextualise the Lithium Era, as the marginal percentage that lithium represents in total exports is one of the main differences with its analogue: saltpetre.

Due to the level of competitiveness of the white metal market, the information regarding its main features is relatively opaque and frequently the only data available is the annual average. I will therefore work with annual time series (see Table 4.1).

It is worth noting that in the case of the production, only information about the amount of carbonate lithium produced in Chile is accessible. However, the country also creates other lithium derivates like lithium hydroxide. Therefore, the results that will be obtained from this data will be underestimated. But this underestimation should not be seen as a severe one. As far as lithium carbonate accounts for more than 85% of the total production of lithium in Chile, this data is a good representation of the total production (SQM, 2020). Likewise, there is only available information until 2020. Recent changes in this market are not observed, so the results can be a bit outdated, which may cause the forecast slightly to differ from what has truly occurred in the last few months.

Table 4.1: Summary statistics: Lithium Era dataset.

Variable name	**Data**
Lithium production (tonnes)	1984-2020
Lithium price (USD FOB)	1999-2020
GDPpc (PPP, 2017 constant international $)	1990-2020
Foreign Direct Investment (net inflows as a % of GDP)	1984-2020
Civil Liberties (score)	1984-2020
People without access to safe water (number of people)	2000-2020

Source: Author's own elaboration.

Due to the awareness of these limitations and to make a more in-depth analysis of the situation in Chile regarding lithium, other indicators have been added. From the World Bank, the Gross Domestic Product per capita (GDPpc) in Chile has been included as an economic development indicator (WB, 2021). Besides knowing the strong ties of lithium mining with foreign investors, data of Foreign Direct Investment (FDI)[34], from the World Bank too, are present in this dataset (WB, 2019). To also bear into account the potential externalities of lithium mining in the country, two other indicators will be considered based on the negative connotations that Jerez, Garcés, and Torres (2021), Babidge (2016) and Schlosser (2020) highlighted. A measure of civil liberties and the number of people without access to safe water will be added. In this way, an attempt is made to include the potential negative externalities of lithium exploitation concerning water pollution and the rights of the indigenous population.

[33]Data from BCCh (2021).

[34]FDI is defined as net inflows of investment to acquire lasting participation in the management of an enterprise operating in an economy other than that of the investor. This category includes acquisitions equal to or greater than 10% of the voting shares (WB, 2019).

The former is a measure created by the Freedom House (FH), which scores each country on the basis of its civil liberties (FH, 2022). The various political rights and civil liberties, such as the rule of law, freedom of association, political pluralism and individual rights, are analysed to award a score. According to Chile's latest report, the country has problems in terms of equal opportunity and freedom of economic exploitation, guaranteeing that laws and policies ensure equal treatment of all segments of the population, and in terms of abuses and violence by state security forces. Accordingly, the lower the rating a country receives, the more liberties its population has.

Finally, from the *Joint Monitoring Programme (JMP) for Water Supply, Sanitation and Hygiene* of the World Health Organization (WHO) and the United Nations International Children's Emergency Fund (UNICEF), the number of people without access to safe water in Chile has been obtained. More precisely, this indicator represents the number of people who are unable to access water that is free of microbiological and chemical contaminants (WHO/UNICEF, 2020).

5. Methodology

5.1 Synthetic Control Method

The debate on the true impact of the saltpetre mining industry in Chile continues to have opposing opinions. Some authors consider that it did not benefit Chile and that it was an economic enclave and did not contribute economically to the rest of the territory. In contrast, others support its positive role for the entire Andean country. In this research, I will carry out a synthetic control method (SCM) to provide evidence of the real consequences of this mining sector and then be able to compare these results with what is currently happening with lithium mining.

The SCM was first introduced by Abadie and Gardeazabal (2003) and more widely developed by Abadie, Diamond, and Hainmueller (2010). It is a statistical method that makes it possible to evaluate the effect of a treatment in a comparative case. A synthetic version of the treatment group is created by giving different weights to the variables in the control group. In this way, this methodology makes it feasible to compare treatment and control groups that are a priori incomparable because they do not meet the parallel trends assumption[35] that allows a traditional difference-in-differences (DiD) method to be carried out.

For this case study, I understand the Saltpetre Era as the treatment with a start date in 1895 and an end date in 1930. The problem with my study, and the reason I cannot apply a DiD method, is that the region of Chile mainly affected by this mining was the *Norte Grande*. However, this region is not comparable with the rest of Chile, which would represent the control group. Since the parallel trend requirement is not satisfied, I have to create a synthetic *Norte Grande* by weighting the data from the rest of the Chilean regions.

To be more technical, the research presented here is based on a cross-regional comparative study. I aim to compare the effect of my event of interest, the Saltpetre Era (hereinafter referred to as "treatment"), between affected regions and unaffected ones. To do so, I will mainly rely on Abadie, Diamond, and Hainmueller (2010) SCM approach, which will be now explained.

I will work with $J + 1$ Chilean regions following the division of CORFO in 1950. As my null hypothesis is that *Norte Grande* was the only region affected positively by the impact of the nitrate industry, the remaining J regions (*Norte Chico, Núcleo Central, Concepción y La Frontera, Los Lagos,* and *Los Canales*) are potential controls.

$\mathbf{H_0}$: *Norte Grande was the only region positively affected by the Saltpeter Era.*

[35] The parallel trends assumption is a critical condition that must be met to implement the DiD method. It requires the difference between treatment and control group to be constant over time in the absence of treatment. It is tested by visual inspection, but could be violated if the pre-treatment trends of groups are different, if the visual inspection is not powerful enough to validate the assumption, or if it is thought to be a shock apart from the treatment that have cause the post-treatment difference (McKenzie, 2020).

Also, notice that T_0 is the number of years previous to the start of the treatment and $1 \leq T_0 < T$ is the pre-treatment period (from 1880 to 1895). Thus, the years between $T_0 + 1$ and T represent the treatment period (1896-1970).

With this in mind, I can state that Y_{1t}^I will be the potential population density (my main dependent variable) for the treated region i at a time t because it is believed that *Norte Grande* is exposed to the treatment and its aftermath during the treatment period. Similarly, Y_{1t}^N will represent the population density observed for control regions ($i = 1, ..., J + 1$) at a time t during the pre-treatment period.

Considering this and the assumption that the Saltpetre Era had no impact on the dependent variable in the pre-treatment period, it is possible to come to the following conclusion. The outcome for both groups is the same in the pre-treatment period, or mathematically, that for $i \in [1, \ldots, N]$ and $t \in [1, \ldots, T_0]$ Y_{1t}^I and Y_{1t}^N are the same:

$$Y_{1t}^I = Y_{1t}^N \tag{2}$$

Now, in order to study the effect of the Saltpeter Era for *Norte Grande* during the treatment period, I will have that the potential outcome for this region will be equal to the potential outcome of the untreated regions plus the treatment effect:

$$Y_{1t}^I = Y_{1t}^N + \alpha_i t * D_i t \tag{3}$$

where $D_i t$ is a dummy variable that takes value 1 if region i is affected by the treatment at time t, and 0 otherwise[36]. Besides, $\alpha_i t$ is the specific causal effect of the Saltpeter Era on population density. Therefore, as I can observe Y_{1t}^I, to find $\alpha_i t$ I only need to estimate Y_{1t}^N as follows:

$$\alpha_i t = Y_{1t}^I - Y_{1t}^N \tag{4}$$

$$\widehat{Y_{1t}^N} = \sum_{j=2}^{J+1} w_j Y_{jt} \forall t \tag{5}$$

Having a $J * 1$ vector of weights for each untreated regions ($W = w_2, ..., w_J + 1$ for $w_j \geq 0$ and $j = 2, ..., J + 1$), each value obtained by W will be a potential synthetic control created up by a concrete weighted average of the control regions[37].

[36]As only *Norte Grande* is believed to had been affected by the nitrate industry and only after 1895 (T_0):

$$D_{\text{it}} = \begin{cases} 1 if i = 1 \cap t > T_0 \\ 0 \quad otherwise \end{cases}$$

[37]According to Abadie, Diamond, and Hainmueller (2010), the perfect synthetic group will meet $\sum_{j=2}^{J+1} w_j^*$ and satisfy these three conditions:

$$\sum_{j=2}^{J+1} w_j^* Y_{j1} = Y_{1,1}$$

$$\sum_{j=2}^{J+1} w_j^* Y_{j,T0} = Y_{1,T0}$$

$$\sum_{j=2}^{J+1} w_j^* X_j = X_1$$

where X_i is a vector of variables explaining population growth. However, in practice, it is not easy to find a synthetic control that exactly meets these conditions, so I will work on the example of Cavallo et al. (2013) and use the synthetic control that comes closest to meeting it.

5.2 Forecasting

5.2.1 Autoregressive-Moving-Average Model

What will happen in the lithium market in the coming years continues to generate much uncertainty. Will the accelerated production growth of recent years continue? Will lithium prices stabilise? In order to study how the lithium market will behave in the future, I will start employing a univariate linear time series analysis. This type of time series is usually used to make forecasting when not much is known about the causal relationship between the variable to be predicted and the possible explanatory variables (Racine, 2019). In this case, the lithium market is relatively recent, and there is not much literature dedicated to forecasting it. Moreover, as explained in Chapter 2, it does not seem to follow so far the patterns present in other metals markets either.

Hence, I will first forecast the white mineral's future based on data that can be observed from the past. Then, the stochastic process[38] denoted as $Z(w,t)$ implicit in my time series will be modelled and used in the prediction. The univariate forecasting method that will be employed is an Autoregressive-Moving-Average (ARMA) model, a particular case of the Autoregressive Integrated-Moving Average (ARIMA) one. As its name highlights, the ARMA model is composed of an Autoregressive model (AR(p)) and a Moving Average one (MA(q)), where p and q are the respective order of each model.

The AR(p) can be expressed in either of the following two ways:

$$\dot{Z}_t = \Phi_1 Z_{t-1} + \cdots + \Phi_p Z_{t-p} + a_t \tag{6}$$

$$\Phi_p(B)\dot{Z}_t = a_t \tag{7}$$

where $\phi(B) = (1 - \phi_{1B} - \cdots - \phi_p B^p)$ is the autoregressive polynomial, and $\dot{Z}_t = Zt - \mu$ is always true. This model is advantageous when the aim is to describe a situation in which present values depend on preceding ones and a random walk. Meanwhile, when the goal is to describe a situation in which events generate an immediate effect but that only affect in the short run, the MA(q) fits better (Wei, 2006). The MA(q) can be stated as one of the equations below:

$$\dot{Z}_t = a_t - \theta_1 q_{t-1} - \cdots - \theta_q a_{t-q} \tag{8}$$

$$\dot{Z}_t = \theta(B)a_t \tag{9}$$

where $\theta(B) = (1 - \theta_{1B} - \cdots - \theta_q B^q)$ is the moving average polynomial. Besides, any MA(q) model is always stationary by definition because $\left(1 + \theta_1^2 + \ldots + \theta_q^2\right) < \infty$ is always fulfilled.

By joining these two models an ARMA(p,q) model is created:

[38] According to Wei (2006), a stochastic process is a family of time-indexed random variables where w belongs to a sample space and t to an index set.

$$(1 - \phi_{1B} - \cdots - \phi_p B^p)\, \dot{Z}_t = (1 - \theta_{1B} - \cdots - \theta_q B^q)\, a_t \Longrightarrow \tag{10}$$

$$\Phi_p(B)\dot{Z}_t = \theta_q(B)a_t \tag{11}$$

When using this methodology, it has to be assumed that $\phi_p(B) = 0$ and $\theta_q(B) = 0$, and that they do not share any common root. Besides, it should be taken into account that p and q are still associated with the orders of the autoregressive and moving average polynomials respectively (Wei, 2006).

To find the best ARMA(p,q) to fit each time series, I must identify whether they are stationary. This identification will be done by checking the Dickey-Fuller test[39]. Then, to determine the order of the AR(p) and MA(q) I will analyse the sample autocorrelation and partial autocorrelation functions (ACF and PACF) respectively. Thanks to this preliminary analysis, the best candidates can be highlighted, but I will choose the best of them based on the Akaike and Bayesian information criteria[40].

5.2.2 Vector Autoregression Model

Although, there is not much information on the possible causal relationships concerning the lithium market in Chile, a Vector Autoregressive (VAR(p)) model will be used to provide a more complete view of the predictions of relevant indicators in the Lithium Era. Besides, it could help to understand better the possible relationship between lithium exploitation and other indicators. This forecasting model has been used often to study time series flexibly and intuitively. As well, it is pretty helpful for forecasting because it can capture the possible interdependent relationships between different variables (Hamilton, 2020). In more detail, a VAR(p) model can be expressed as follows:

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_p y_{t-p} + CD_t + e_t \tag{12}$$

where y_t is a set of K endogenous variables ($y_t = y_{1t}, \cdots, y_{kt}, \cdots, y_{Kt}$ for $k = 1, \cdots, K$), p denotes the number of earlier periods that will be used (also called *lags*), A_i is a $K \times K$ matrix of coefficients for each $i = 1, \cdots, p$, and e_t is a K-dimensional white noise process. Besides, C and D_t can be also included, representing respectively the matrix of potential deterministic regressors, and a vector composed by a

[39]Null hypothesis (H_0) of the Dickey-Fuller test states that the process has a unit root. On the contrary, the alternative hypothesis (H_1) is that the process is stationary. As working with a process that has unit roots can cause problems when forecasting, I aim to reject H_0 and accept H_1.

[40]The Akaike information criterion (AIC) is calculates with the following formula:

$$AIC(M) = -2log-likelihood_{max}(M) + 2dim(M)$$

where M is each potential model and $dim(M)$ is the length of its parameter vector. This information criterion provides a balance between a good-in-sample fit and model complexity, because it penalizes more heavily models with a large $dim(M)$ than those with a smaller number of parameters. Shortly, the AIC tries to minimize $n \log \widehat{\sigma^2} + 2p$. In contrast, the Bayesian information criterion (BIC) is calculated by:

$$BIC(M) = -2log-likelihood_{max} + log(n)dim(M)$$

and selects the model that minimizes $n \log \widehat{\sigma^2} + log(n)p$ as the best one (Racine, 2019).

constant, a trend, or some dummy variables. As Equation 12 clearly reflects, the VAR(p) relates $k'th$ variables in y'_t vector to the past values of itself and all other variables that have been included.

Lastly, to select the number of lags (p) that better fits the estimations that will be performed in this paper, the information criteria will be used again. Additionally, the Granger Test[41] will be checked in order to know which variables are more relevant to predicting future values of each dependent variable (Hamilton, 2020).

[41] The Granger Causality Test is a statistical hypothesis test that helps to determine if one time series is useful for forecasting another. The null hypothesis H_0 of this test is that one variable does not *Granger-cause* other. In other words, that it cannot help to predict another. Hence, if the null hypothesis is rejected, the alternative hypothesis H_1 can be accepted and state that the studied variable helps to predict the other one, so there is *Granger causality*. However, the lack of a Granger causality relationship from one variable to another cannot necessarily be interpreted as the absence of correlation. Therefore, Granger causality need not mean anything other than predictability (Granger, 1969).

6. Empirical Analysis

6.1 Regional Impact of the Saltpetre Era in Chile

6.1.1 Visual Analysis

Until now, the literature has always emphasised population growth and the rate of urbanisation as indicators of Chile's development during the Saltpetre Era. The study presented in this paper is unprecedented since it addresses this issue from a regional comparative perspective and not a national one as it has been done so far. For this reason, the population density will be used as the variable of interest. Using this demographic indicator instead of the number of inhabitants makes the comparison between the heterogeneous parts of Chile more precise, controlling for the surface area of each division of Chilean territory.

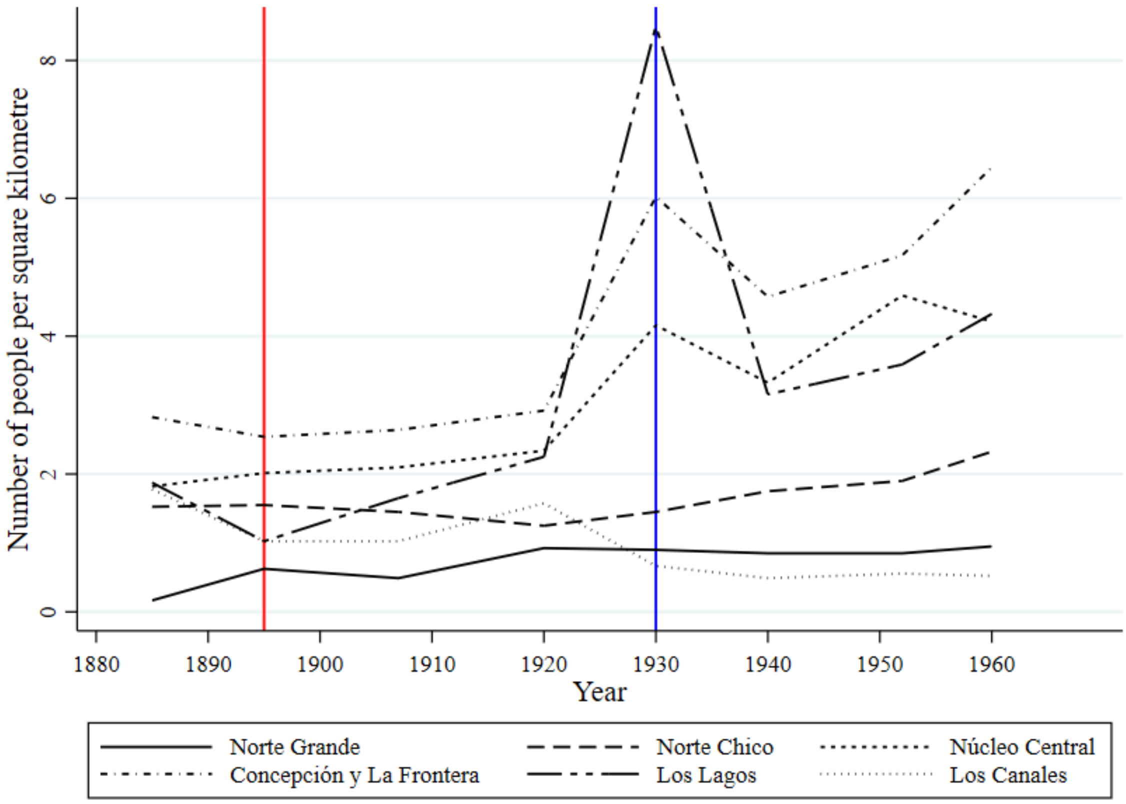

Figure 6.1: Trends in population density.

Source: Author's own elaboration.

Note: The blue line represents the beginning of the Saltpetre Era, while the red line indicates its end.

The trend of population density by region between 1885 and 1960 has significantly diverged from one region to another. Figure 6.1 shows how it is possible to sort the regions into two groups characterising them by the development of this indicator during my period of analysis.

On one side, *Norte Grande*, *Norte Chico* and *Los Canales* remain fairly constant throughout the period and stand out for their relatively lower population density. In turn, *Núcleo Central*, *Concepción y La Frontera* and *Los Lagos* had a constant population density between 1885 and 1920, ranging from 2 and 4 inhabitants per km^2. It was from 1920 onwards when their demographic denseness increased considerably, reaching a four-fold gain in the case of *Los Lagos*. However, ten years later, in 1930, the number of inhabitants per km^2 fell sharply, although it remained above pre-1920 levels and kept a slight upward trend.

The main difference between these two groups of regions regarding their population density emerges here. While the first shows no noticeable changes and remains steady even after the collapse of the saltpetre industry, the second group seem to be more influenced by the Saltpetre Cycle shocks.

Turning now to the other indicator that has been proposed as a dependent variable, I am going to analyse regional trends in urbanisation, again between 1885 and 1960 (see Figure 6.2).

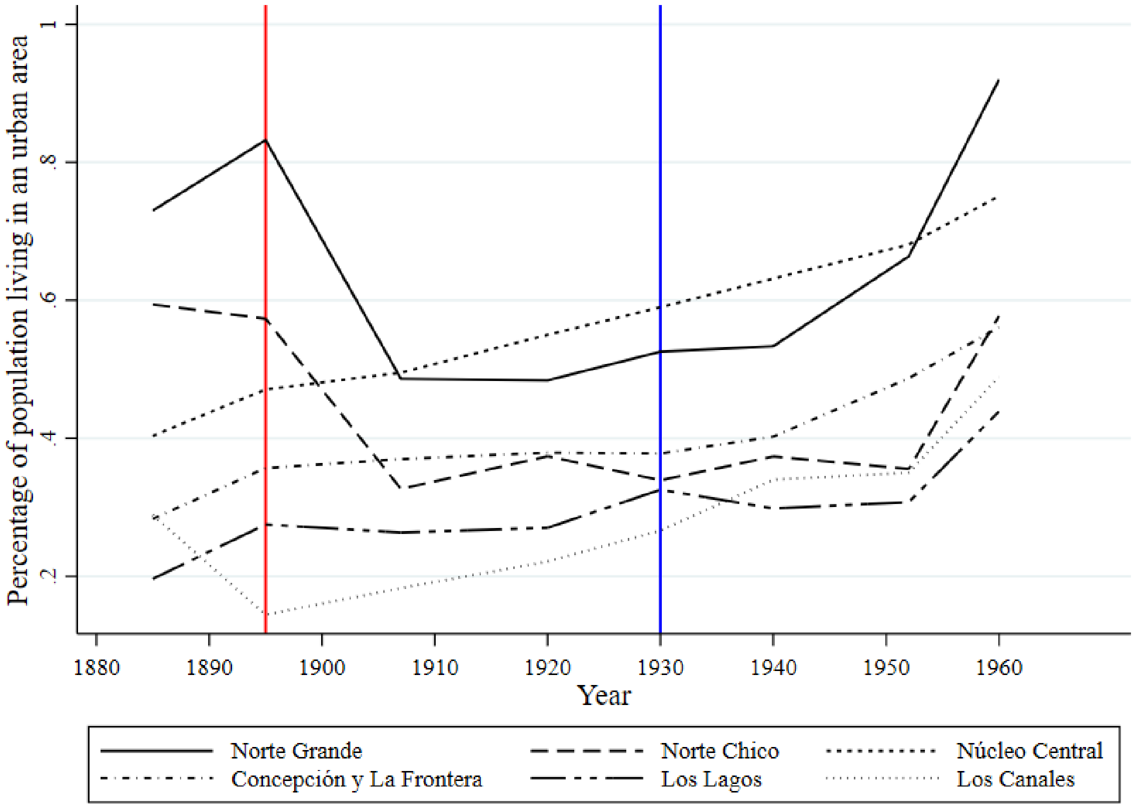

Figure 6.2: Trends in urbanization.

Source: Author's own elaboration.

Note: The blue line represents the beginning of the Saltpetre Era, while the red line indicates its end.

Norte Grande despite being the area of Chile where the nitrate industry was developed and which has frequently been pointed out as an enclave where the profits of this mining industry were directed, presents a trend that in a certain way contradicts these accusations. Before the beginning of the Saltpetre Cycle, it had the highest urbanisation rate in the country (around 75% of its population lived in urban centres). Nevertheless, in the first five years of nitrate production, its urbanisation rate dropped to about half. Only after 1910 did it remain constant at around 50%, and it was not until later on the collapse of the saltpetre industry, that it began to show a positive growth rate. In this sense, *Norte Chico* behaves in a very similar way but always remaining below the urbanisation levels of the North. Contrarily, for the rest of Chile, it can be seen how their urbanisation rates began to grow without any period of decline from the start of the saltpetre exploitation. The case of *Núcleo Central* is particularly noteworthy. Even though at the end of the 19th century only 40% of its population lived in cities, in 1910, it managed to surpass the urbanisation rate of the *Norte Grande*, reaching a 60% at the end of the Nitrate Era.

Lastly, despite the fact that it will not be used as the dependent variable, I consider it necessary to inspect the development of agriculture across regions visually. It was a frequent topic of debate in the literature, and the pessimistic interpretations have often highlighted the agricultural sector as the big victim. Using the percentage of people per region working in agriculture as an indicator, the evolution of this sector between 1885 and 1960 is presented in Figure 6.3.

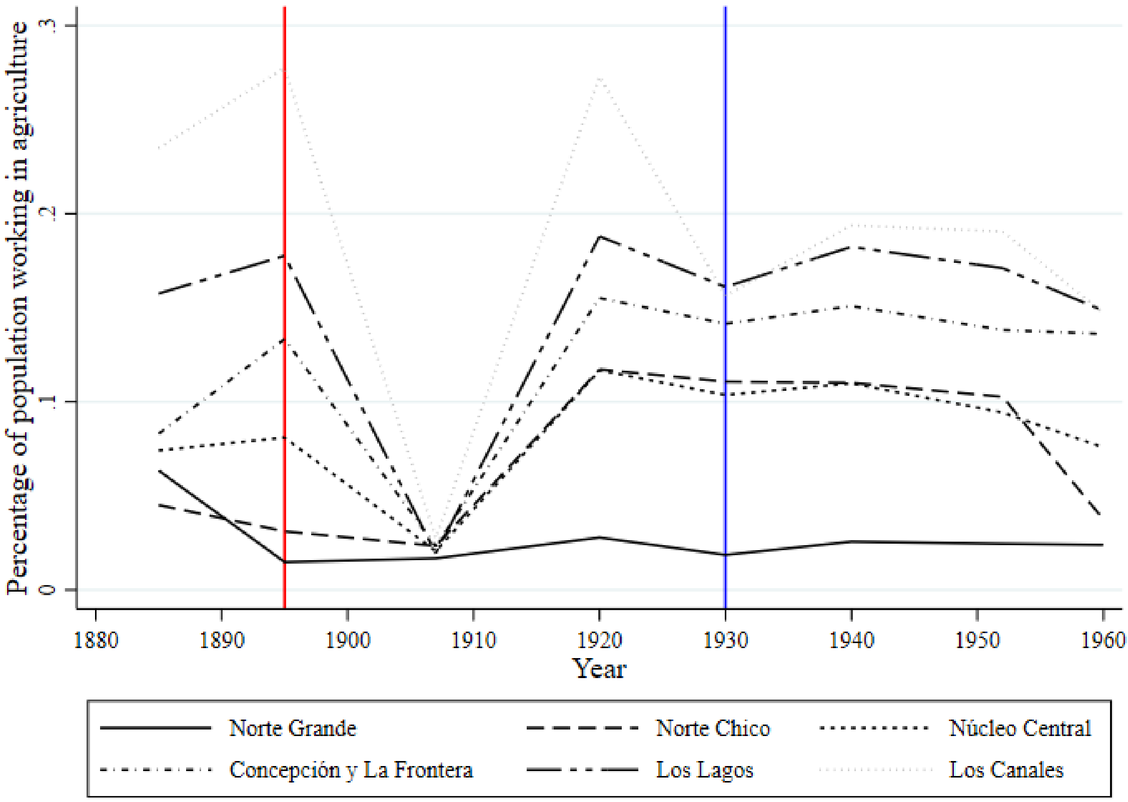

Figure 6.3: Trends in agriculture.

Source: Author's own elaboration.

Note: The blue line represents the beginning of the saltpetre Age, while the red line indicates its end.

There is a clear differentiation between the *Norte Grande* and the rest of Chile. From 1885 to 1995, the percentage of people working in agriculture in the *Norte Grande* dropped almost to zero. As has already been pointed out several times, in 1880, saltpetre was already being exploited unofficially, so this decrease might be since the few people in the *Norte Grande* who worked in agriculture probably went to work in mining. Since then, this percentage did not increase again during the sample period. On the opposite, the rest of Chile experienced an evident alteration. With an initial percentage of agricultural workers much higher than in the north of the country, from 1895 ahead this rate falls below 5%. It was in 1907 when this proportion increased again, reaching levels higher than those prior to the Saltpetre Cycle by 1920. Within this group of regions, the case of the *Norte Chico* is slightly different. Although it also underwent a boom in agriculture in 1907, it had not previously stood out as a region with a large population working in agriculture. Its percentage was much more similar to that of *Norte Grande*.

What suggests the analysis of this indicator is that apart from the early years of saltpetre Era, agriculture does not seem to have worsened. These trends would be closer to illustrating the optimistic view of Hurtado (1966), Cariola and Sunkel (1982), Miller (2021) or Badia-Miró and Díaz-Bahamonde (2017). This outcome could be a reflection of the increased demand for agricultural products generated by *Norte Grande* or the development of the sector as the country's communications improved and trade became easier. In addition, the peak in the percentage of agricultural workers also coincides with the peak of the regions' gain in population density, which could further support that population growth encouraged the rise in the number of workers to meet higher demand.

In summarising, the insight from this visual analysis of the data is a preliminary evidence that proposes a different story from what most critical views of the Saltpetre Era like Pinto (1959) have held. Besides, variations in both demographic indicators suggest that the nitrate industry did not appear to be a profits enclave. The positive impact of the revenues that the mining sector generated seems more noticeable in the other regions. For instance, in terms of population density, the more central areas showed greater increases than the more extreme parts of the country. Similarly, the rest of Chile, and not the *Norte Grande*, had a positive growth rate of urbanisation between 1880 and 1930. The *Norte Grande*, in fact, did not recover from its urban population decline until several decades after the nitrate mining industry collapsed. This fact would be consistent with the study of Cariola and Sunkel (1982). The authors indicate that government efforts to encourage urbanisation and population growth were mainly directed at large cities such as Santiago (*Núcleo Central*).

6.1.2 Results and Discussion

I will now analyse more empirically whether there are significant differences between the treatment group and the other regions that would make up the control group. Table 6.1 shows the mean of the explanatory variables for the *Norte Grande* and the rest of Chile during the pre-treatment period. It also displays the differences between the two territorial groups and indicates if they are significantly different from 0. For all variables except for the percentage of workers in agriculture and mining, I have obtained a statistically significant difference between the groups at the 99% of confidence.

This result, together with the visual analysis of Figure 6.1, motivates and justifies the SCM implementation. The figure shows that the trends in the evolution of population density were very diverse among the regions. Additionally, as seen in Table 6.1, the pre-treatment differences of the explanatory variables point to the fact that the assumption of parallel trends is not fulfilled.

Table 6.1: Differences between the Norte Grande and the rest of Chile.

	Norte Grande	**Rest of Chile**	**Difference**	**s.e.**
Population density	0.396	1.797	-1.401	(0.431)***
%Urban population	0.781	0.358	0.423	(0.112)***
%Foreign population	0.389	0.027	0.362	(0.054)***
%Literate population	0.453	0.27	0.183	(0.302)***
%Mining workers	0.058	0.019	0.039	(0.025)
%Agricultural workers	0.039	0.129	-0.09	(0.061)

Source: Author's own elaboration.
Note: Differences between the *Norte Grande* and the *Synthetic Norte Grande* significantly different from 0 are detoned as follows: *10%, **5%, ***1%.

The Saltpetre Era and Population Density

Assuming population density henceforth as the dependent variable, my first step is to stipulate what weights each of the regions within the control group should be given in order to create the best synthetic *Norte Grande*.

Following the criteria stated by Abadie, Diamond, and Hainmueller (2010), and Cavallo et al. (2013), the most appropriate weights to construct the counterfactual for the treatment group are presented in Table 6.2. From these results, it can be understood that the information offered by the *Norte Chico*, *Núcleo Central* and *Los Canales* are the most suitable for this purpose, especially those of *Los Canales*, which is consistent with my initial interpretation of the population density trends. *Norte Grande* and *Los Canales* were the regions that performed most similarly.

Table 6.2: Region weights in the synthetic Norte Grande: population density.

Region	**Weight**
Norte Chico	0.132
Núcleo Central	0.011
Concepción y La Frontera	0
Los Lagos	0
Los Canales	0.857

Source: Author's own elaboration.

After constructing the synthetic group with the weights obtained, the characteristics of my counterfactual are presented in Table 6.3. Comparing the mean of my variables for the group I have created, the original *Norte Grande*, and the mean of the rest of Chile, it can be seen that the result is broadly satisfactory. The only indicator that does not come close to matching its treatment group analogue is the proportion of foreigners. Its impossibility to be more similar may be due to the unofficial production of saltpetre by Chile before the first available record and because many foreigners would have already migrated to the *Norte Grande* intending to benefit from the mining boom. This immense outsiders influx is a phenomenon that did not occur on such a scale in any other part of the country during my study period.

Table 6.3: Population density predictors means.

Variables	Norte Grande		Average control group
	Real	Synthetic	
%Urban population	0.729	0.594	0.353
%Foreign population	0.541	0.034	0.032
%Literate population	0.416	0.303	0.247
%Mining workers	0.049	0.092	0.020
%Agricultural workers	0.063	0.045	0.118

Source: Author's own elaboration.

Figure 6.4 is the SCM's result and displays population density for *Norte Grande* and its synthetic counterpart between 1885 and 1960. The pre-treatment trends are not wholly parallel even applying this empirical method; neither the pre-assumption presented in Equation 2 is fulfilled. The reason may be the limited available data, which led to the inability to ensure that the Saltpetre Era had no impact on the dependent variable in the pre-treatment period. Indeed, the trend before 1895 is probably influenced by it. Withal, although the features that would traditionally define an SCM are not met, what the series in Figure 6.4 show fits with what I expected to find.

Figure 6.4: Trends in population density: Norte Grande versus synthetic Norte Grande.
Source: Author's own elaboration.

In the hypothetical case that earlier regional data could have been observed, it would be still tough to see that the trends of the treatment and synthetic groups coincide, as the regions of Chile have very different characteristics. However, if it is taken into account that between 1885 and 1895 the nitrate industry was already beginning to prosper, it is not surprising to see that the pre-treatment trend in the *Norte Grande* is already showing a positive inclination.

Focusing now on the post-treatment period, during the early years of the Saltpetre Era, the synthetic control group experienced a level decline in population density (from approximately 1.5 persons per km^2 in 1895 to 1.25 in 1920). Meanwhile, *Norte Grande* between 1895 and 1910 underwent a slight downward trend in population density. Even so, the following decade the demographic indicator of the North almost doubled. It was from 1920, when the first signs of the imminent collapse were latent, that the trend in the *Norte Grande* stagnated while the synthetic region soared. Concretely, 1920 was the year when the discrepancy between the two groups was smaller.

These changes in the series appear to be consistent with the idea that saltpetre exploitation may have caused the *Norte Grande* to converge with the rest of Chile in terms of population density. Despite that, it may seem that the synthetic saw its population density worsen during the first years of treatment, but this was not necessarily the case. Migratory movements within Chile can explain the synthetic's decreasing trend between 1895 and 1920. With the birth of a new mining industry, many Chileans from other regions found new job opportunities in the country's northern part. This migratory flow has been documented mainly from *Norte Chico* and the south of the country to *Norte Grande*, regions that have shaped the synthetic North (Hernández-Román and Pavez-Ojeda, 2012). This flow would partly explain why the more the population density of the *Norte Grande* increases in the SCM, the more it decreases in the synthetic. Besides, it would also explain why, after the mining industry downturn, the density increases in the synthetic and decreases in the North. Without the source of employment generated by nitrate, there was no further incentive for workers from other areas to move to the northern part of the country. It is also worth noting that the increase in population density in the real series is greater than the decrease in its counterfactual, probably due to the additional arrival of foreigners from Europe and the USA to *Norte Grande*. Nevertheless, what appears clear is that the effect of the Saltpeter Cycle in the *Norte Grande* was milder than it has been commonly believed.

These results could also be related to another theory. Whereas the saltpetre market began to falter in 1920 and collapsed altogether a decade later, no drastic drop in population density is detected in any of the trends in Figure 6.4. Moreover, the population density of the *Norte Grande* remains reasonably constant, while the population density of its synthetic presents a notably increasing trend. This would not only support the view that nitrate was not a curse for the country but could also be related to the view of Ducoing (2021) and Miller (2021). Both authors state that in 1920 copper mining was gaining importance in Chile, which, contrary to the argument of Pinto (1959) that saltpetre frustrated any growth of the copper industry, would help to understand why the country did not suffer a decline in its population density rates after 1930. The copper industry's evolution could have helped mitigate the adverse effects of the collapse of the saltpetre mining sector in the Andean country.

To better observe the treatment effect, Figure 6.5 exhibits the difference between the population density of the *Norte Grande* and the synthetic *Norte Grande*. Thus, it represents the evolution of the gap between the two lines during the study period. As the population density of the north is always below, the gap is always negative. From this figure, two conclusions can be drawn.

Firstly, since the beginning of the nitrate industry in Chile, the difference between the groups has decreased substantially, being the moment of the lowest divergence in 1920. The second finding is based on the fact that once the northern mining industry started to deteriorate, regional differences increased again, and therefore the gap became larger. This worsening after the collapse of the saltpetre industry in 1930 could indicate that even if this mining had had positive effects, these were not sustained after it ended.

Figure 6.5: Treatment effect on the population density: difference between Norte Grande and Synthetic Norte Grande.

Source: Author's own elaboration.

Having discussed my main findings and highlighted the limitations of this examination, the next question arises. Are these estimates meaningful, or are they coincidental? To evaluate the significance of my statements, I have performed the Placebo Test. The purpose of conducting this test is to simulate the effect that the Saltpetre Era would have had on each of the regions of the control group (also called the donor pool). To perform this test, all the regions of Chile are taken into account, not only those who are part of the synthetic. Besides, for each simulation Norte Grande will be part of the donor pool, and another region will take its place as treated. In this test, *Norte Grande* behaves very differently from how the other regions would have acted if saltpetre mining had taken place there (see Appendix I.1). This outcome indicates that my results are statistically significant and that the effect I have obtained is not due to chance. Hence, it can be stated that despite the limitations of the data employed, my model shows statistically significant evidence of what happened during the Saltpetre Era in Chile.

Additionally, the study of the robust mean squared prediction error[42] (RMSPE) also reinforces that the results are indeed robust. The RMSPE measures the magnitude of the difference in the outcome of my variable of interest between each region and its synthetic counterpart. In this SCM, the RMSPE is quite small (1.36), which, together with the Placebo Test, betokens that the results have causal explanatory power.

The Saltpetre Era and Urbanisation Rate

As the literature has widely indicated that, along with population growth, the rate of urbanisation substantially improved thanks to nitrate mining, now I will examine the regional effect of the Saltpetre Era on this indicator. So far, the results have suggested that the exploitation of the white mineral had a positive effect on other regions of Chile, not only in Norte Grande. So, it could not be said to be an economic enclave for the time being.

Table 6.4: Region weights in the synthetic Norte Grande: urbanisation rate.

Region	Weight
Norte Chico	0.556
Núcleo Central	0.444
Concepción y La Frontera	0
Los Lagos	0
Los Canales	0

Source: Author's own elaboration.

To study the situation in terms of the urbanisation rate, I will follow the same strategy as when analysing population density. The table 6.4 shows the weights to be given to the regions in the control group, according to which are more convenient to construct the synthetic control of the *Great North* in this case. Again, *Norte Chico* and *Núcleo Central* offer good data to construct the contractual, in line with what I expected based on my visual analysis.

Table 6.5: Urbanisation rate predictors means.

Variables	Norte Grande		Average control group
	Real	Synthetic	
%Foreign population	0.541	0.026	0.032
%Literate population	0.416	0.290	0.247
%Mining workers	0.049	0.052	0.020
%Agricultural workers	0.063	0.045	0.058

Source: Author's own elaboration.

[42]According to Abadie, Diamond, and Hainmueller (2010), the RMSPE could be mathematically expressed as follows:

$$RMSPE=\left(\frac{1}{T_0}\sum_{t=1}^{T_0}\left(Y_{1t}-\sum_{j=2}^{J+1}w_j^*Y_{jt}\right)^2\right)^{1/2}$$

.

Using these weights, Table 6.5 has been constructed. It shows the mean of my predictors for the treatment group, its synthetic, and the mean of the control group. The means for the *Norte Grande* and the control group are evidently the same as in the previous SCM, but those for the synthetic group have changed, although it still creates a counterfactual quite akin to the treatment group. The only exception is again the percentage of foreign population. However, it is not surprisingly because the same happened when constructing the synthetic group for the population density analysis.

Figure 6.6 shows the SCM results for the urbanisation rate. As previously, the pre-assumption that before treatment the trends are the same does not hold, nor are the trends completely parallel. Nevertheless, the explanation is again the same as in the previous subsection. To check that the conclusions I will draw from interpreting these results have explanatory power and are not purely by accident, I will recheck the RMSPE and the Placebo Test. The RMSPE I have obtained is 0.220, even smaller than in the previous study, which would indicate that the outcomes are statistically significant. Likewise, the Placebo Test (see Appendix I.2) shows that the behaviour of the *Norte Grande* in terms of urbanisation rate was quite different from what would have happened if the saltpetre boom would have occurred in any other region of the country, which reinforces the explanatory power of the model.

Figure 6.6: Trends in urbanisation rate: Norte Grande versus synthetic Norte Grande.
Source: Author's own elaboration.

Having ensured that the results are statistically significant, I will now analyse them. Throughout the Saltpetre Cycle, *Norte Grande* suffers a drop in its percentage of urban population from the beginning of the treatment until 1910, when it stabilises but remains much lower than its initial levels. Concretely, from over 80%

in 1895, the urban rate fell below 50% in 1910. Until the end of the Saltpetre Era, it fluctuates around this percentage and only after the industry's collapse does it rise again. On the other side, the *Norte Grande* synthetic does not show any significant improvement in its urbanisation rate. In fact, it worsens and steadies at the same time as the mining region. Unlike in the case of population density, here both series follow a very similar trend.

Figure 6.7: Treatment effect on the urbanisation rate: difference between Norte Grande and Synthetic Norte Grande.

Source: Author's own elaboration.

From the difference between the treatment effect in the *Norte Grande* and its synthetic counterfactual, Figure 6.7 is generated. The gap is always positive this time because the northern area was all over the sample period among the most urbanised. The difference is reduced to almost zero throughout the end of the Nitrate Cycle (1910-1930). But the reason does not seem to be an improvement in urbanisation rates thanks to nitrate, but a worsening of the indicator in the *Norte Grande* and a stagnant situation in the synthetic region. The real series trend could have behaved in this way because workers in the saltpetre mines typically moved to the Atacama Desert, where they spent the night in small villages or even in the open air (Hernández-Román and Pavez-Ojeda, 2012). This mobilisation of workers to rural areas may have led to the observed decrease in the urban population.

If this is related to the literature and to Figure 6.2, it is conceivable that the increase in urbanisation that has so often been noted was not itself due to the effects of the saltpetre industry. Moreover, in order to construct this synthetic group, the *Núcleo Central* has been weighted at 44.4%, and it was an area where, according to Cariola and Sunkel (1982), the government efforts to promote urbanisation were directed. Although the visual analysis of Figure 6.2 points to the fact that there was a continuous growth in the percentage of urban population, according to the evidence presented here, it would not be a consequence of the saltpetre mining industry.

6.2 What Can Be Expected From the Lithium Era?

The lithium rush for the energy transition has raised many questions about the implications of it increasing production to meet the accelerated demand. In the case of Chile, it is vitally important to know in detail the trends that this market may follow, as it has reserves that, with the right decisions, could make it once again the largest producer of the mineral in the coming years. In order to be able to pull some conjectures about this future, I will perform predictions concerning lithium in Chile for the next 10 and 20 years.

6.2.1 The Lithium Outlook

ARMA Models Forecasting

Before carrying out the individual prediction of the production and export price of lithium in Chile, the stationarity of both annual series has been checked. The results of the Dickey-Fuller test for the two series have indicated that neither of them was stationary, so they had to be transformed.

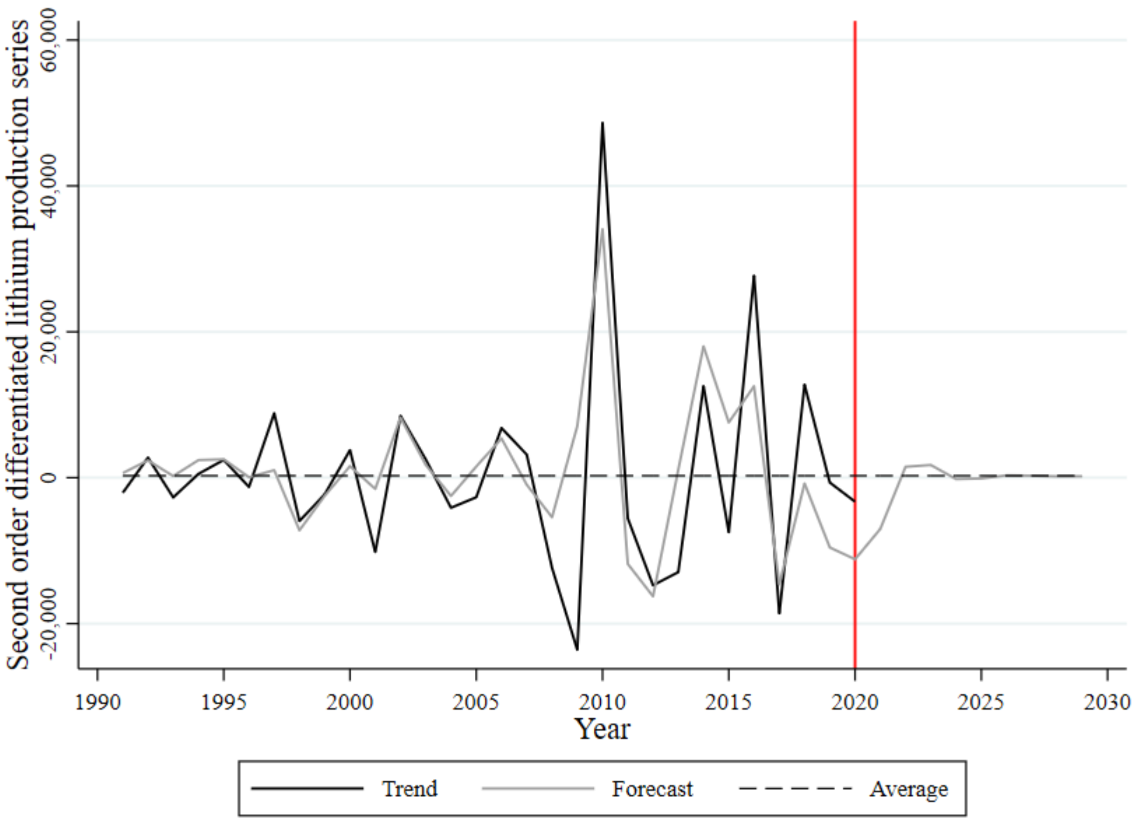

Figure 6.8: Forecast of second order differentiated lithium production series.

Source: Author's own elaboration.

To avoid problems when making the projections, their differentiated second-order series will be used (see Appendix J). Furthermore, the most appropriate order of p and q has been chosen for the ARMA(p,q) model of each indicator based on the AIC and BIC recommendations (see Appendix K).

The model that better fits the Chilean lithium production time series is an ARMA(2,1). As can be perceived in Figure 6.8, the prediction fits the actual observations quite well, and only between 2015 and 2020 the foretold fluctuations are somewhat smoother than those observed. From 2020 onwards, the forecasting shows an upward trend, which would mean that between 2020 and almost 2025, lithium production in Chile is expected to have a positive year-on-year growth rate. Then in 2025, there would be a slight downturn, and from that year ahead, it would move around the series' average.

Nevertheless, these projections do not provide much new information. The fact that this study is carried out in mid-2022, but that data is only available for lithium production in Chile up to 2020 leaves very little room for forecasting, which is already limited because it is an annual time series that started relatively recently.

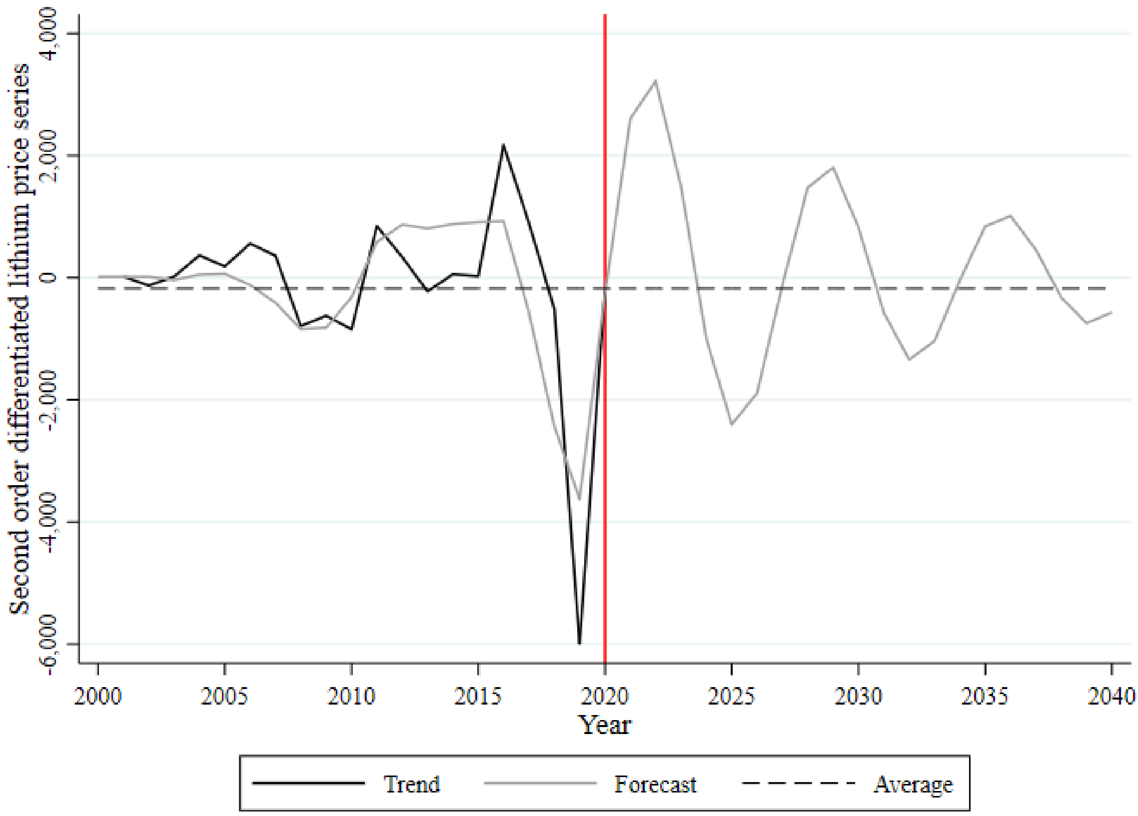

Figure 6.9: Forecast of second order differentiated lithium price series.

Source: Author's own elaboration.

By contrast, the price prediction does seem to be more illustrative. In the case of the annual time series of lithium export prices in Chile, the best fitting model according to the information criteria is an ARMA(2,2).

Figure 6.9 shows this prediction, and as the results do not tend to average as quickly as in the case of production, the forecast has been extended to 2040 (10 years longer than in the previous one). Hence, even though data for 2021 and 2022 cannot be included, interesting conclusions can be traced for the coming years.

Predictions previous to 2020 of this ARMA model also match the actual data quite well. As can be found for 2019, the fall in lithium prices as a reaction to the economic crisis generated by the Covid-19 is predicted faithfully. Additionally, the forecast indicates a significant increase in the year-on-year growth rate of prices between 2020 and 2022, which has indeed happened (Dizard, 2022). These matches, therefore, lend credibility to my estimates. What is not yet known but is suggested by the results is that between 2023 and 2025, prices will fall markedly. After that year, prices will enter, according to these predictions, a cyclical trend of rising and falling every 2 or 3 years but becoming progressively less volatile.

VAR Model Forecasting

Thanks to the implementation of the VAR(p) model, future trends can be analysed by controlling for more variables and not only based on past observations. In fact, these controls allow more realistic predictions of the future outlook for lithium in Chile than with an ARMA(p,q) framework.

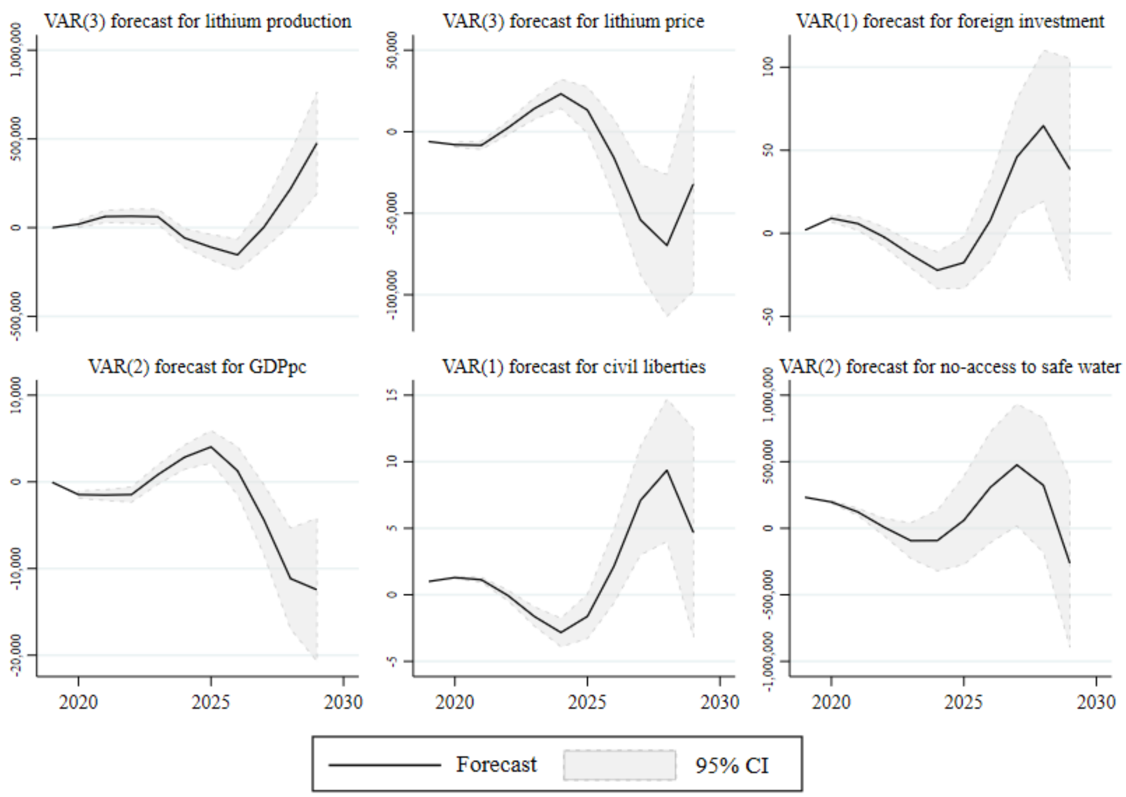

Figure 6.10: VAR model forecasts.

Source: Author's own elaboration.

In this model, the time series of lithium production, price, FDI, GDP per capita, civil liberties score, and the number of people without access to safe water has been added. All of these are mentioned in the literature as influencing, or being affected by lithium production to some extent. To ensure that all the variables included are relevant, the Granger Test has been performed. It indicates that the price of lithium and FDI help explain Chilean lithium production with 95% confidence in the first case and 99% confidence in the second. As for the lithium price, there is evidence that changes in production explain it only at a 90% of statistical confidence. Besides, FDI, GDP per capita and the number of people without access to safe water are also relevant. For the rest of the indicators, Appendix L also shows which variables would help predict their evolution. Nevertheless, probably some of the most surprising results are that all the variables included would be relevant for predicting the number of people without access to safe water and the civil liberties score.

Taking into account the Granger Test indications, the projections shown in Figure 6.10 have been constructed by including per each variable endogenous only the relevant explanatory variables and using the number of lags that the information criteria suggest as the most appropriate.

The predictions for the lithium price over the next ten years are in line with those found using the ARMA model, which thence points to the fact that the forecasting could be on the right track. In the case of lithium production, the previsions created from the VAR indicate that it will remain essentially unchanged until about 2025, and between then and 2030, it will grow strongly. This projection can be related to FDI, which would follow a trend similar to production, with a slight decreasing rate between 2022 and 2025 and then a substantial increase. Future projections for the other three indicators are not as encouraging.

GDP per capita is projected to remain flat year-on-year, rising slightly in 2025 and then falling sharply. The predicted future for civil liberties is not promising either. Knowing that the lower the score, the better the freedoms of the population (in terms of freedom of expression, association, personal autonomy and the rule of law), the evidence shows an improvement at the same time as an improvement is observed in the GDP per capita forecast. Then, a very steep growth rate, which would translate into a sharp deterioration in these freedoms.

Last but not least, the number of people without access to safe water is predicted to increase between 2025 and 2030, which coincides with the period when lithium production is foretold to rise. What should also be noticed is that for each forecast, the 95% confidence interval is displayed. Until 2025 all the intervals remain very close to the prediction line, which supports the robustness of the forecast.

6.2.2 Discussion

According to the possible directions that the different lithium-related indicators may take according to my results, various conclusions can be drawn with regard to the management of the lithium mining in Chile.

Everything suggests that production in Chile will increase over the next ten years. If this scenario comes true, it would confirm the expectations of Barandiarán (2019). The author, taking a very optimistic view, was confident in Chile's capacity to increase its production, unlike Lagos (2012), who expressed his doubts. What does not seem to be so in line with the former author's intuition is that the rapid development of lithium will lead to a consequent economic development. According to my estimates, at the same time as lithium production would increase (probably thanks to the injection of foreign capital because the forecasted trends coincide), the country's GDP per capita would fall. While it is true that in predicting the future trend of this economic indicator, I may be missing to include some controls, the Granger Test suggests that lithium production would indeed be causing part of this decline. Furthermore, both the worsening of Chilean citizens' freedoms and the increase in the number of Chileans without access to clean water support the pessimistic view of Jerez, Garcés, and Torres (2021), Babidge (2016), Schlosser (2020), and the USDS (2020). They all support that the Chilean lithium industry is generating negative socio-environmental externalities.

7. A Historical Mirror?

Having studied in depth both the regional consequences of the Saltpetre Era and the possible implications of the Lithium one, the second question that this study aimed to address can be answered. ¿Is the Lithium Era a historical mirror of the Saltpetre Era? Certainly, the similarities between the two mining cycles are indisputable, but the Lithium Era still has a chance to not repeat the same errors as in the past.

Neither in the database I have created nor even in the latest energy transition scenarios envisaged by IEA (2020) has a huge external shock been taken into account and that could have important implications for the lithium market: the Russia-Ukraine War. Since the beginning of the conflict, governments have expressed concern about the "dangerous overdependence on Russian fossil fuels" (EU, 2022). Such is the concern of Western economies that plans for energy transition have been speeded up. In the case of the European Union, although the so-called *European Green Deal*[43] was already underway, a new route map with more imminent targets and more effective actions for energy transition has come into force in May 2022: the *REPowerEU Plan*. Specifically, with this new program, the EU countries expect to be independent of Russian fuel resources by 2027. They will accelerate all clean energy permitting from the plan entry into force (EU, 2022). However, not only Europe is committed to a rapid transition. The USA has also implemented numerous laws and monetary incentives[44] in recent years for clean energy, with a particular emphasis on the transport sector. This change of speed in the energy transition focuses even more on lithium mining countries and producers of its derivatives, as it is up to them to supply the massive demand for this crucial component for electric batteries. In this regard, Chile could once again become the leading producer of this mineral.

Furthermore, although it is not expected to take on a monopoly role, as it did during the Saltpetre Era, the percentage of lithium exported as a percentage of the country's total mining exports could increase and become similar to what nitrate supposed in the days of yore. The Lithium Era can be an opportunity for the country to boost economic growth and development. However, it can also be dangerous because it could become even more dependent on its mining exports. In 1927 the Chilean state's accounts were extremely stifled because it was so dependent on saltpetre exports, which had fallen dramatically. In 1927 the Chilean state's accounts were extremely stifled because it was so dependent on saltpetre exports. Today, Chile's economy is still mainly based on agriculture and the copper trade (AoEC., 2019). The potential increase in the weight of lithium in their exports should, for instance, be invested in the country's industrial development, as proposed by Barandiarán (2019), and avoid making the same mistake as in 1927.

Likewise, albeit the demand for lithium is not likely to decline in the coming

[43] The European Green Deal is still in force and its targets include, among others, achieving zero emissions or decoupling economic growth from natural resources (EU, 2019).

[44] Examples of these initiatives include the *Advanced Research Project Agency-Energy* (ARPA-E), the *Alternative Fuel Corridor (AFC) Grants*, or the *National Electric Vehicle Infrastructure (NEVI) Formula Program* (AFDC, 2022).

decades, a concern from the past emerges. The Chilean saltpetre sector did not die because demand for the resource ceased but because a substitute was found that offered greater advantages. The lithium market and its recent high prices encourage the search for new ways to make batteries with the same or better advantages than lithium batteries provide. Recently, viability tests have been carried out on sodium batteries in EVs. At least in short to medium term, sodium batteries are not expected to threaten the market. Mainly because lithium has a much higher energy density than sodium, making it possible for the batteries to be smaller and lighter[45](Abraham, 2020). However, the fact that no known material or technology can replace lithium in short to medium term does not mean that it will not be found in the future.

That is why how Chile manages its lithium reserves today is of crucial importance. One of the errors made during the Saltpetre Cycle seems to be that the positive spill-over effects of nitrate profits were not managed well enough for their effect to last over time. As far as population density is concerned, my results point to a convergence between the *Norte Grande* and the rest of Chile. Nevertheless, the difference between both parts of the country increased immediately after the collapse of the saltpetre mining, and in the case of the rate of urbanisation, it does not seem so clear that its improvement is due to the positive externalities of nitrate. Moreover, I suspect that if there was no worsening after 1930 in both demographic indicators, it could be largely because copper was beginning to gain importance as a mining sector. Thus, copper mining would have alleviated the negative consequences of the collapse of the nitrate industry. On its side, lithium production is also concentrated in the *Norte Grande* region, specifically in the salt flats of the Atacama Desert. In the Saltpetre Era, it was feared that the country's northern region would become an enclave and that the benefits of its mining would be distributed heterogeneously in response to political interests. Today, the concern is that the localisation of lithium will worsen the economic equality and rights of the indigenous population of the Atacama Desert. The evidence offered by my results suggests that the saltpetre production did not exclusively benefit the *Norte Grande*, but what they do indicate is that the lithium industry is causing a negative impact on the region where it is extracted. These externalities appear to be the result of unequal management of the benefits of mining, in which the interests of foreign investors and companies repeatedly take precedence over those of the Chilean population itself. And this, in short, evokes one of the main criticisms of the Saltpetre Era that has often been pointed out.

[45]Energy density is the measure of the amount of energy contained in a battery proportionate to its weight. This measure is usually presented in Watt-hours per kilogram (Wh/kg). The energy density of lithium is between 126Wh/kg and 285Wh/kg, depending on the battery type, while that of sodium batteries ranges between 75 and 150 Wh/kg (Abraham, 2020).

8. Concluding Remarks

This study aimed to approach the Chilean Saltpetre Era from a regional comparative perspective, something that had never been studied before. Although the literature had indicated the inefficient and unequal management of the opportunity provided by saltpetre, the subject had always been studied from a national view. Moreover, the importance of studying this period in Chilean history arises from the country's current role as the central reserve of lithium, a strategic resource for the energy transition. Given the many similarities between the two mining industries, understanding whether there is a historical mirror between them would help make decisions regarding the future of the Lithium Era.

Despite the limitations of the data between 1880 and 1930 in Chile, it has been possible to carry out a synthetic control method to analyse the regional effects of nitrate production in terms of population density and urbanisation rate. Being able to obtain statistically significant results, I rejected my null hypotheses and concluded that saltpetre production had a generally positive effect on the convergence of the population density of the Chilean regions. This result can be explained due to the arrival of European and North American immigrants and migratory movements within the country. Moreover, although urbanisation rates improved during the whole period of the Saltpetre Era, I have not found evidence that it was a consequence of the mining cycle. On the other hand, from both results, it can also be noted that the Nitrate Era was not characterised by more significant development in the *Norte Grande*. Contrarily, the evidence presented in this paper shows that the improvement in population density in the north of Chile was very modest, and the rate of urbanisation even negative. What is more, the effects of saltpetre at the end of its cycle seem to be accompanied by the effects that copper mining may have begun to cause after 1920.

For the forecasts for the future of lithium it can be stated that this young mining sector may have several opportunities to escape the abrupt end of its previous analogue and avoid incurring the same mistakes. The predictions presented in this study suggest that lithium production will increase over the next ten years thanks in part to the injection of FDI and in parallel to a decline in its price. In that context, the Lithium Era follows the same steps as the beginning of the Saltpetre one, increasing its production and growth perspective. However, the prognosis of potential negative socio-environmental externalities is worrying. The country seems to fall back into a model of neo-extractivism, this time driven by the green policies of Western Economies. Again, the country appears to be making the error of focusing more on the interests of foreign-influenced companies than on ensuring the welfare of its own population.

Chile should work to safeguard the rights of its indigenous population, which is suffering the brunt of the exploitation of the *white gold*. The country should indeed concentrate its efforts on implementing a development model that is not heavily dependent on natural resources exports and escape from its role as an extractivist country that seeks to satisfy the needs of the Global North even before those of the Chileans.

8.1 Future Research

This paper opens up new lines of research that focus more on a regional interpretation of the effects of the mining sector in Chile. In the case of nitrate between 1880 and 1930, it is clear that a regional study, although more complicated to carry out, has many more advantages than a national one. Besides, the regional analysis of the consequences in the agricultural or industrial sector has only been lightly addressed in the present research, as there are too many aspects to examine in a single study. The consequences on both sectors of the economy are still under debate, and future research with a more precise focus on these issues would be relevant. On the other hand, as the effects of lithium seem to be much more concentrated in Antofagasta, a comparative study of the effects in the communes that make up the region could also be very interesting.

In addition, data limitations as well provide an incentive to expand the results presented here. More recent data in the case of the lithium dataset can be added in the future. Alternatively, other variables that could not be included in this paper can be considered to achieve better estimations for both mining sectors.

Furthermore, although lithium carbonate production is currently the main lithium output in Chile and lithium hydroxide only accounts for a marginal part of the production, it will be essential to consider all lithium derivatives in the future. New projects can be developed in Chile to diversify its mining industry, and also market demands for lithium derivatives are likely to change.

Finally, this paper can be an inspiration for other extractive countries. Concretely, similar research should be carried out for the case of Argentina and Bolivia. Both are Latin American countries with a historical past closely linked to the extraction of natural resources to satisfy the demand of other countries, which today are part of the Lithium Triangle. Moreover, they are recent players in the lithium market, and knowing its full implications could help them make more informed decisions in this respect.

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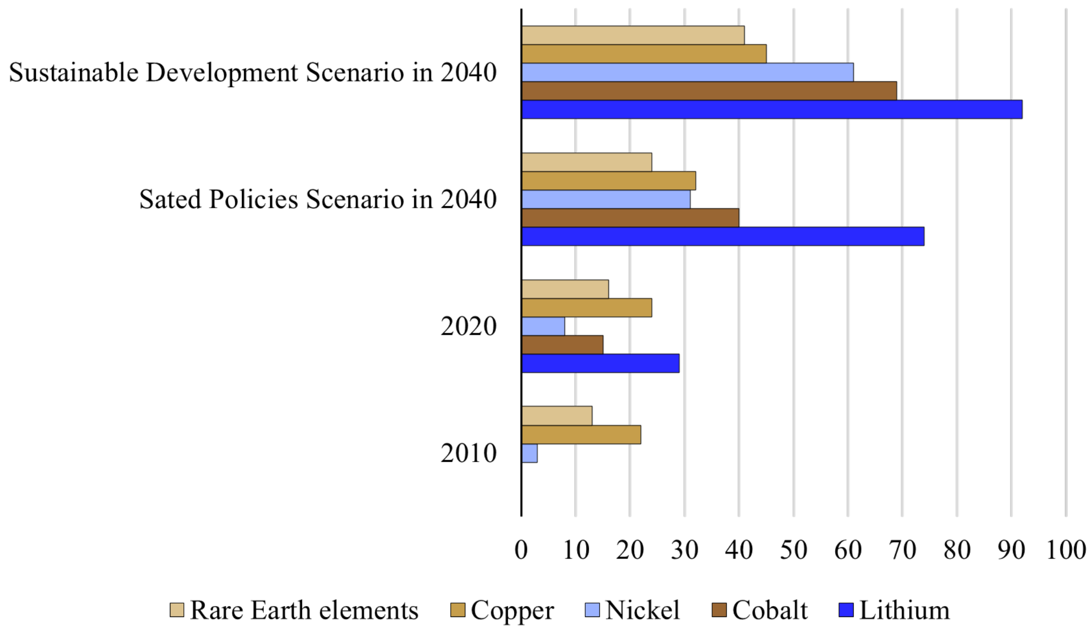
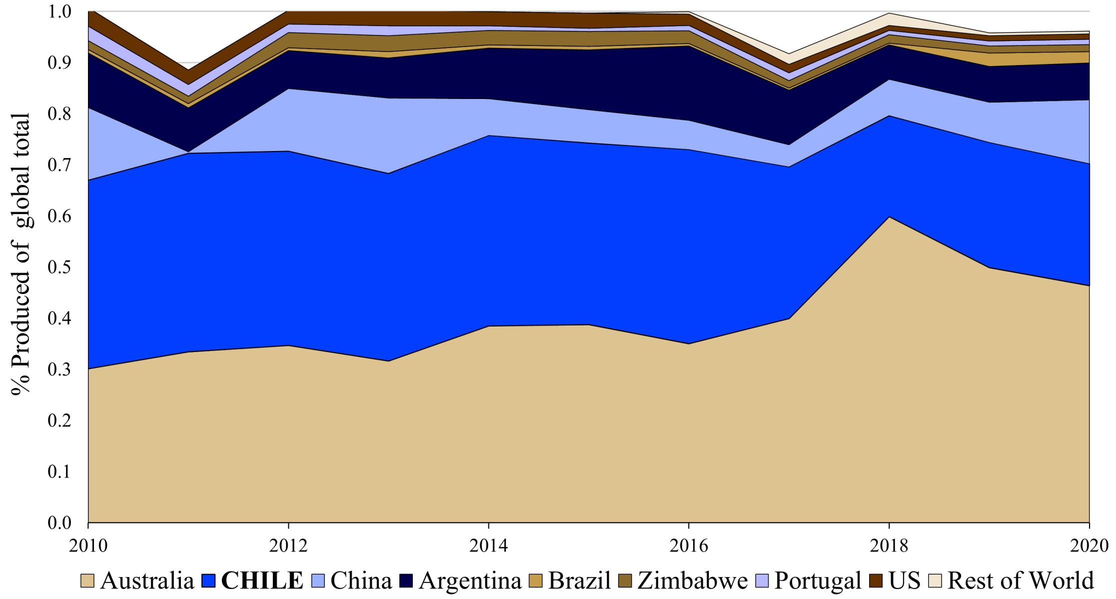
Appendices

A Share of clean energy technologies in total demand for selected minerals by scenario, 2010-2040.



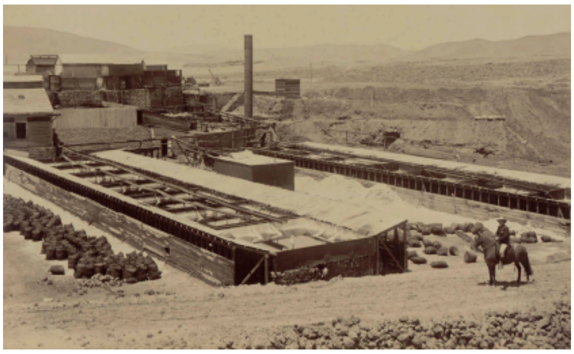
Source: Author's own elaboration based on data from (IEA, 2020).
Note: The Stated Policy Scenario refers to what would be required based on an analysis of current policies and policy announcements, while the Sustainable Development Scenario refers to what would be required on a trajectory consistent with meeting the goals of the Paris Agreement.

B Percentage of lithium produced per country of the global total.



Source: Author's own elaboration based on data from (IEA, 2020).

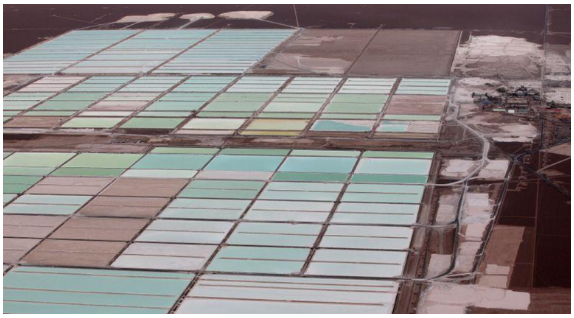
C Comparison of the saltpetre and lithium industries in Chile.



Esmeralda's Saltpetre Office

SQM's Lithium Office

Leaching tanks at Democracia's Office



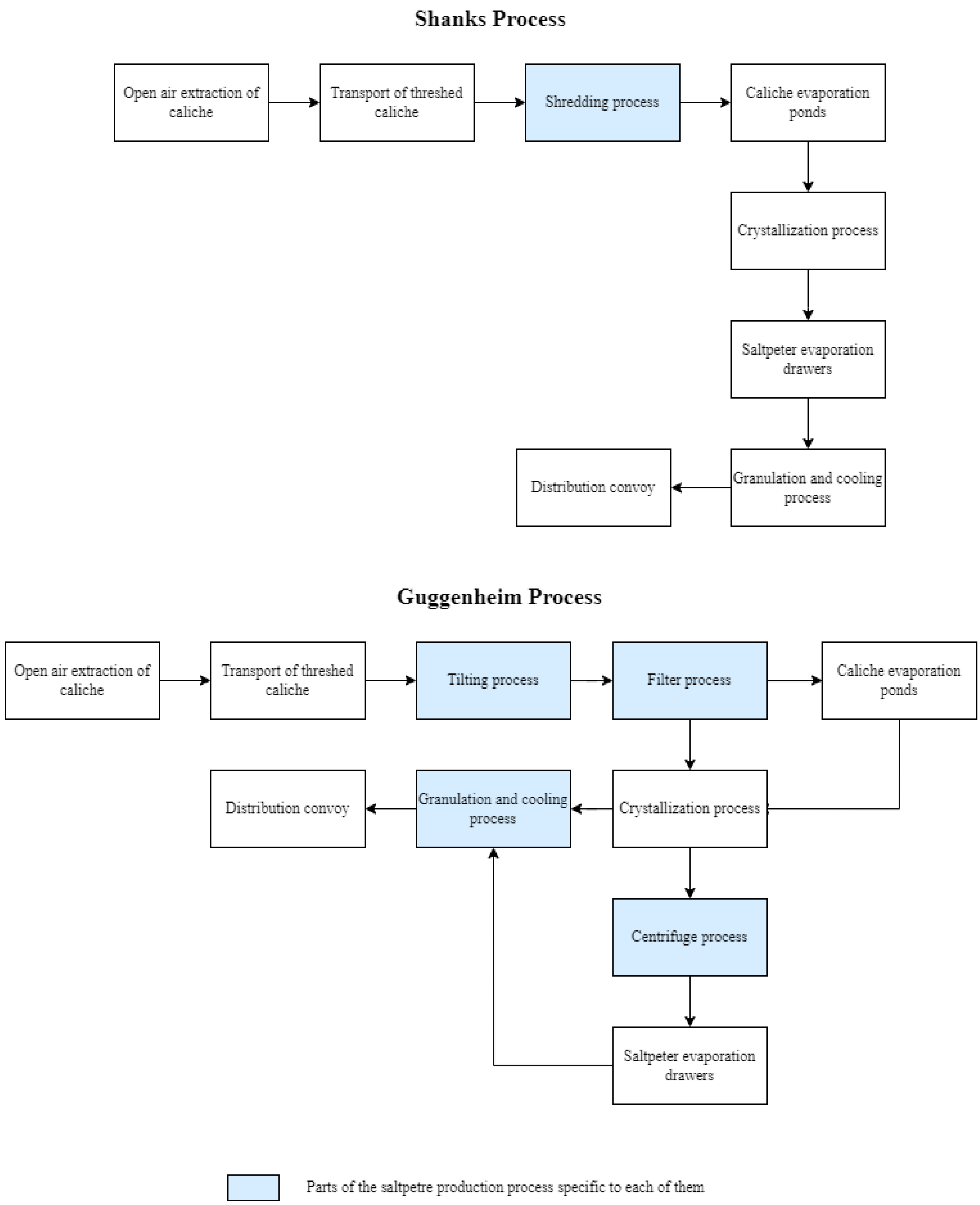
Leaching tanks at SQM's Office

Saltpetre mounds in the Amelia's Office

Lithium mounds in SQM's Office

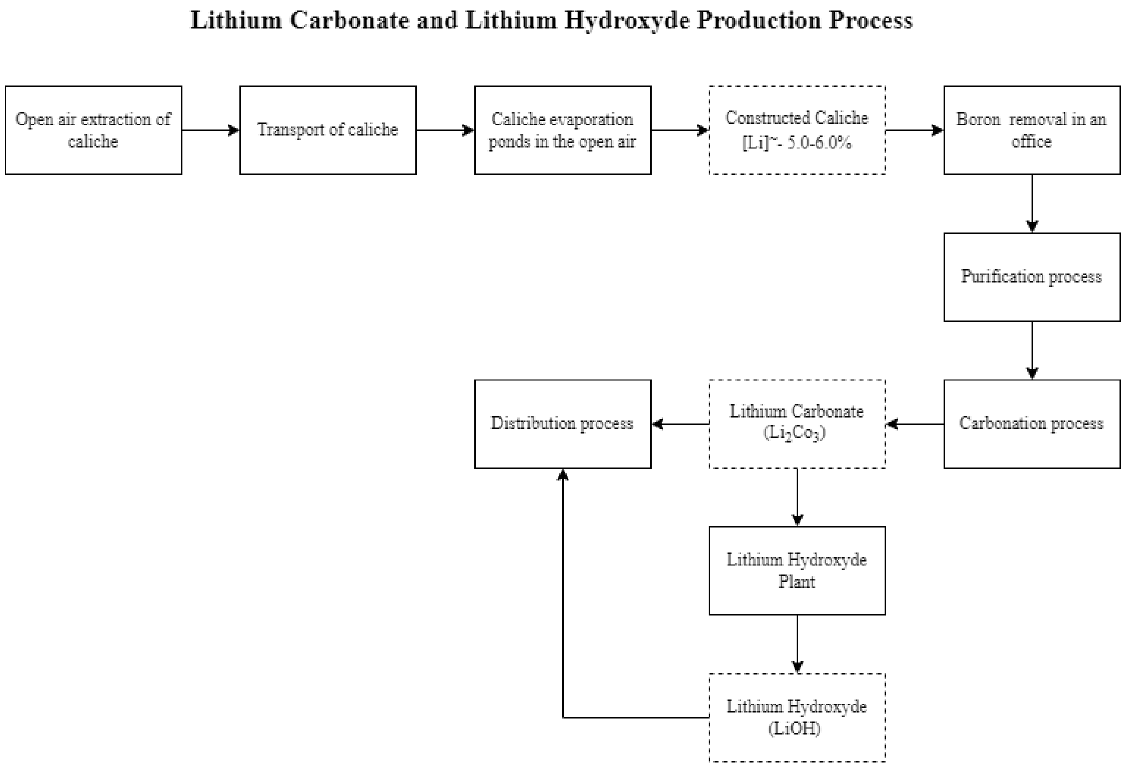
Source: Author's own elaboration with pictures from (Boudat, 1889).

D Stages of the Shanks process and the Guggenheim process.



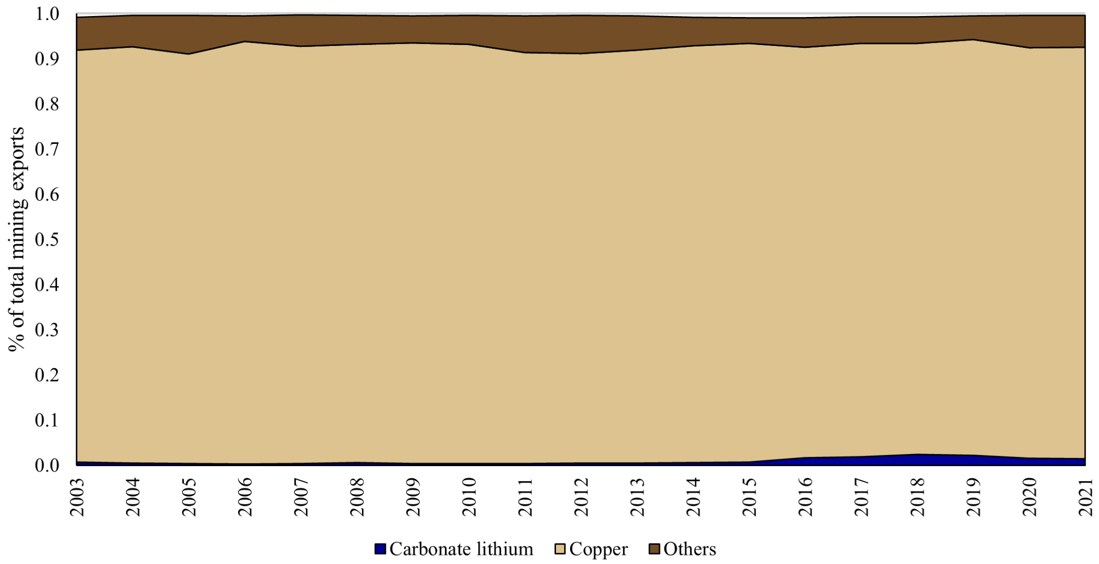
Source: Author's own elaboration.

E Stages of lithium production process.



Source: Author's own elaboration.

F Weight of exports of different minerals in Chile's total mining exports



Source: Author's own elaboration based on data from(BCCh, 2021).

Note: The "others" category includes exports of iron, silver, gold, and molybdenum.

G Division of the regions

Group name	Code	Regions included (1885-Present)
Norte Grande	I	Antofagasta
		Arica y Parinacota
		Tacna
		Tarapacá
Norte Chico	II	Atacama
		Coquimbo
Núcleo Central	III	Aconcagua
		Araucana
		Colchagua
		Curicó
		Linares
		Maule
		Metropolitana de Santiago
		Ñuble
		O'Higgins
		Talca
		Valparaíso
Concepción y La Frontera	IV	Araucanía
		Arauco
		Biobío
		Cautín
		Concepción
		Malleco
Los Lagos	V	Llanquihue
		Los Lagos
		Los Ríos
		Osorno
		Valdivia
Los Canales	VI	Aysén
		Chiloé
		General Carlos Ibañez del Campo
		Magallanes y la Antártida Chilena
		Territorio de Magallanes

Source: Author's own elaboration.

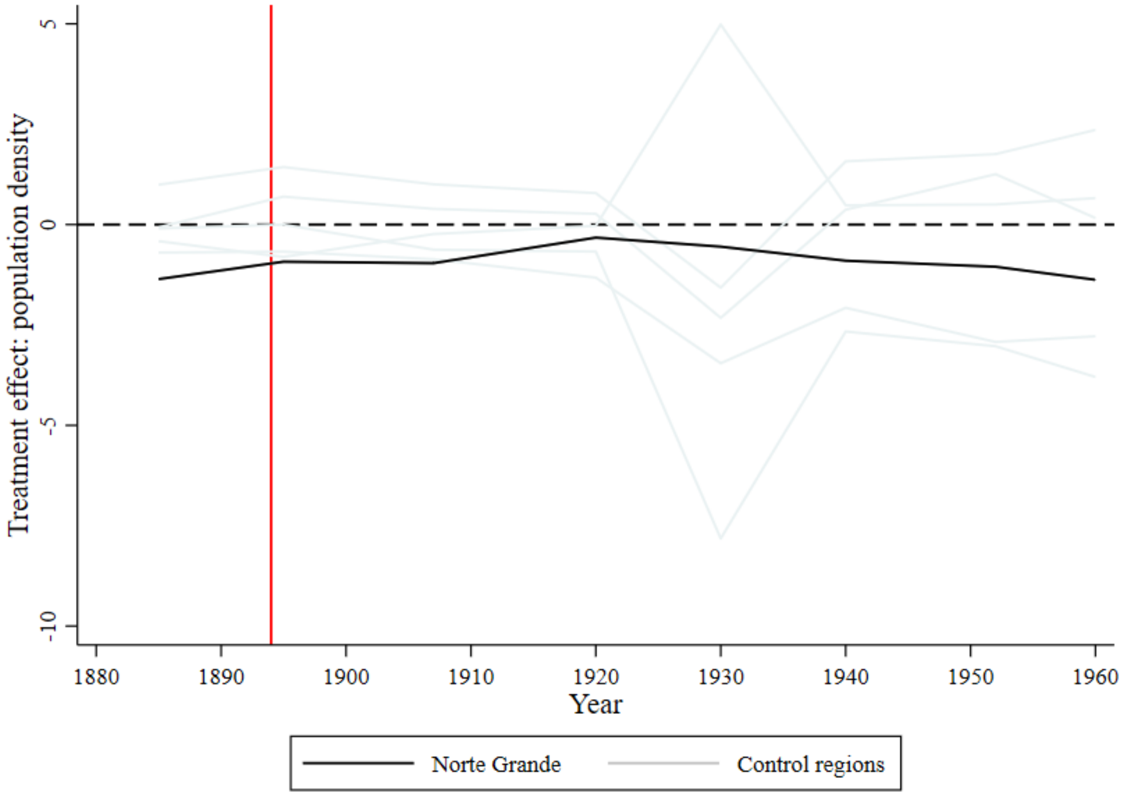
H Summary of variables

Variable name	Description
Year	1885, 1895, 1907, 1920, 1930, 1940, 1952, 1960, 1970.
Sector	Regional divisions.
Population	Average number of inhabitants per region in each sector.
Urban	Average number of inhabitants living in an urban area per region in each sector.
Rural	Average number of inhabitants living in a rural area per region in each sector.
Foreign	Average number of foreigners per region in each sector.
Read	Average number of literate people per region in each sector.
Mining	Average number of workers in the mining sector per region in each sector.
Agriculture	Average number of workers in the primary sector per region in each sector.
Population density	Average number of people living in one square kilometre per region in each sector.
%Urban	Average percentage of inhabitants living in an urban area per region in each sector.
%Rural	Average percentage of inhabitants living in a rural area per region in each sector.
%Foreign	Average percentage of foreigners per region in each sector.
%Read	Average percentage of literate people per region in each sector.
%Mining	Average percentage of workers in the mining sector per region in each sector.
%Agriculture	Average percentage of workers in the primary sector per region in each sector.

Source: Author's own elaboration.

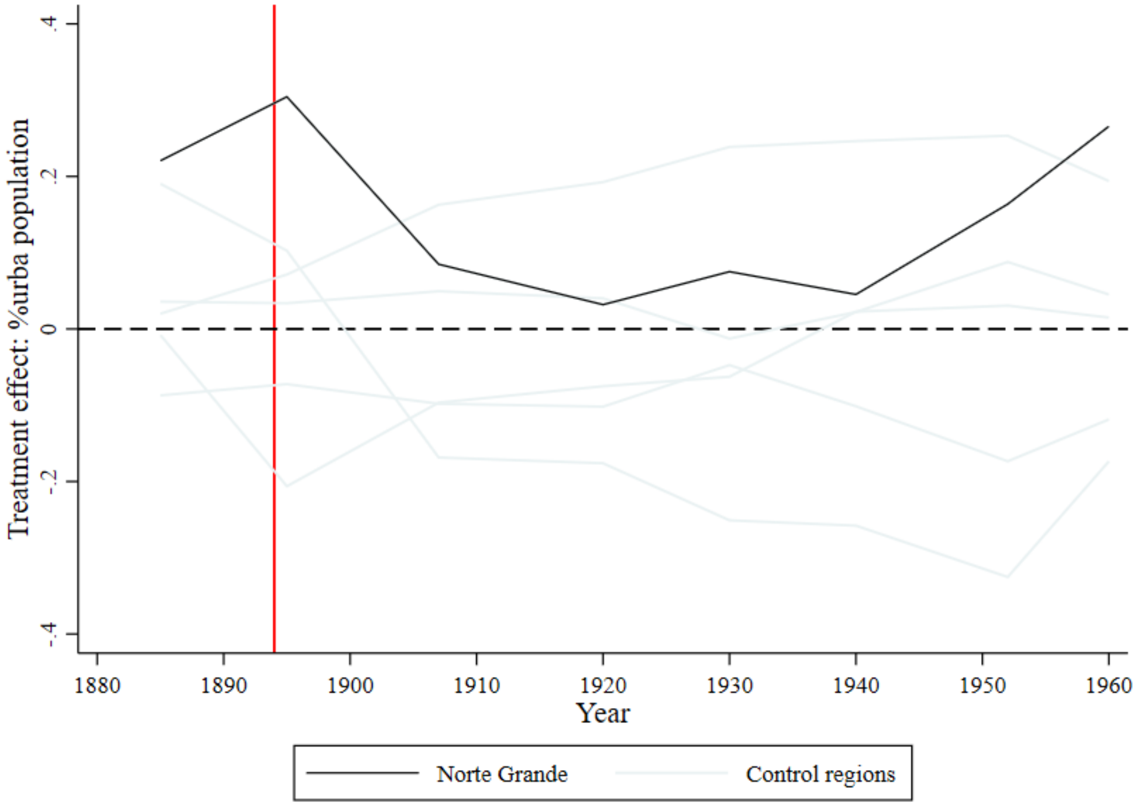
I Placebo Tests

I.1 Population density differences in *Norte Grande* and placebo differences in 5 control regions



Source: Author's own elaboration.

I.2 Urbanisation rate differences in *Norte Grande* and placebo differences in 5 control regions



Source: Author's own elaboration.

J Dickey-Fuller Tests

J.1 Lithium production

		Interpolated Dickey-Fuller		
	Test Statistic	**1% Critical Value**	**5% Critical Value**	**10% Critical Value**
Z(t)	-0.036	-3.750	-3.000	-2.630
MacKinnon approximate p-value for Z(t)=			0.9555	

Source: Author's own elaboration.

J.2 Second order differentiated lithium production

		Interpolated Dickey-Fuller		
	Test Statistic	**1% Critical Value**	**5% Critical Value**	**10% Critical Value**
Z(t)	-6.333	-3.750	-3.000	-2.630
MacKinnon approximate p-value for Z(t)=			0.000	

Source: Author's own elaboration.

J.3 Lithium price

		Interpolated Dickey-Fuller		
	Test Statistic	**1% Critical Value**	**5% Critical Value**	**10% Critical Value**
Z(t)	-1.270	-3.750	-3.000	-2.630
MacKinnon approximate p-value for Z(t)=			0.6429	

Source: Author's own elaboration.

J.4 Second order differentiated lithium price

		Interpolated Dickey-Fuller		
	Test Statistic	**1% Critical Value**	**5% Critical Value**	**10% Critical Value**
Z(t)	-3.611	-3.750	-3.000	-2.630
MacKinnon approximate p-value for Z(t)=			0.0056	

Source: Author's own elaboration.

K Information criteria

K.1 Second order lithium production series

ARMA(p,q)	AIC	BIC
(2,1)	418.247	423.150
(3,1)	419.801	424.523
(4,1)	420.427	426.094
(2,2)	421.200	427.811
(2,0)	421.820	426.542

Source: Author's own elaboration.

K.2 Second order lithium price series

ARMA(p,q)	AIC	BIC
(2,2)	346.665	351.643
(2,1)	347.316	351.299
(3,1)	348.496	353.475
(3,2)	349.478	355.452
(3,3)	349.546	356.516

Source: Author's own elaboration.

L Granger Tests

Y	X	chi^2
Lithium production	Lithium price	11.98**
	Foreign investment	16.95***
	GDPpc	4.66
	Civil liberties	4.26
	Safe water	2.76
	All	51.10***
Lithium price	Lithium production	5.36*
	Foreign investment	10.50**
	GDPpc	6.41**
	Civil liberties	4.88
	Safe water	45.78***
	All	73.56***
Foreign investment	Lithium production	3.72
	Lithium price	13.26***
	GDPpc	12.15***
	Civil liberties	1.89
	Safe water	12.3***
	All	467.00***
GDPpc	Lithium production	8.37***
	Lithium price	5.83*
	Foreign investment	9.16***
	Civil liberties	2.54
	Safe water	11.91***
	All	27.82***
Civil liberties	Lithium production	43.61***
	Lithium price	194.21***
	Foreign investment	57.48***
	GDPpc	163.95***
	Safe water	901.17***
	All	1548.3***
Safe water	Lithium production	7.03***
	Lithium price	9.75***
	Foreign investment	10.39***
	GDPpc	13.74***
	Civil liberties	6.31***
	All	71.89***

Source: Author's own elaboration.

Note: Variables X that are statistically relevant to predict variables Y are denote as follows: *10%, **5%, ***1%.