LUND UNIVERSITY
School of Economics and Management

Master's Programme in Innovation and Global Sustainable Development

Powering Sustainable Growth: Investigating Energy Efficiency in Chilean Industry through Decomposition Analysis

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Abstract:

This research aims to study the energy efficiency of the Chilean industry sector using decomposition analysis methods to understand energy intensity decoupling from economic output. The study focuses on the industry sector, the biggest energy consumer, and utilises a dataset that specifies subindustries' energy consumption and economic contribution to GDP. The results suggest that, for the subset analysed, industry was in decoupling during the 2015-2020 period, with some sectors contributing highly to this decoupling, while others showed no signs of detaching their economic output from their energy intensity. The findings present a different conclusion than previous research, indicating a positive trend towards decoupling, although further research is required to validate these results. This highlights the potential for targeted policy interventions and private sector investments in energy efficiency to drive sustainable economic growth in Chile.

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1 Introduction

In the latest years, the world has stressed even further the importance of countries developing strategies that aim to tackle the climate emergency, such as net zero commitments, energy decarbonization efforts, and energy efficiency throughout their productive processes and most energy intensive sources. Among the most energy demanding sectors, industry is one of the biggest, covering a variety of processes and output products that, aggregated, represent a fair share of global energy consumption. Efforts to address this issue have been one of the top priorities of the countries that show commitment with the climate emergency, and among them, Chile has been considered a pioneer within the Latin American region by international media when it comes to energy enhancements (Conley, 2023). However, most recent available research indicates that there have not been any significant breakthroughs in this area. The primary aim of this research study is to undertake an analysis and critical discussion of energy efficiency improvements in Chile's industrial sector. The study seeks to examine the development of energy efficiency in Chile's industrial sector during the latest years, and identify potential areas for improvement.

To achieve this objective, the research utilizes a method called decomposition analysis. This method involves breaking down a system into its constituent parts and analysing how each part contributes to the overall system's performance (Ang, 2015). In the case of this study, the industrial sector in Chile is examined in detail, and the data is analysed using the decomposition analysis method. The results of this analysis is later discussed in detail and compared with those of previous studies that utilized similar methods.

To provide with the background required for the analysis and discussion of the results, this study presents a comprehensive overview of the Chilean energy context, markets, and climate change commitments. This enables readers to better understand the background against which the analysis was conducted and the implications of the study's findings for the Chilean energy sector as a whole.

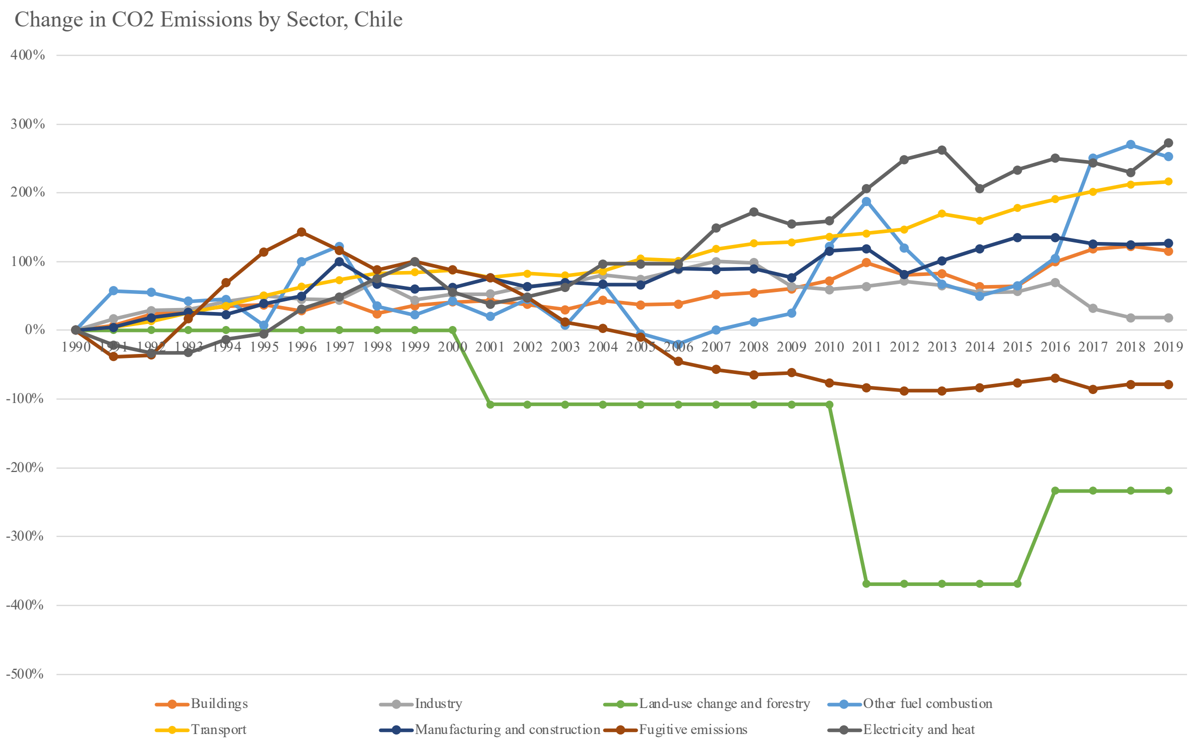
Furthermore, this research study builds on previous publications and theoretical perspectives related to energy efficiency in the industrial sector. This includes an examination of existing literature on the topic and an exploration of relevant theoretical frameworks that have been developed to understand and enhance energy efficiency in industrial settings, and the methods that have been successfully employed to analyse and discuss the subject on previous publications.

Overall, this research study aims to contribute to the ongoing discourse on energy efficiency improvements in Chile's industrial sector. By utilizing the decomposition analysis method and drawing on existing literature and theoretical perspectives, this study provides a detailed and nuanced analysis of the current state of energy efficiency in Chile's industrial sector and identify potential areas for improvement.

1.1 Research Problem

At the start of 2023, Chile was highlighted as one of the renewable energy leaders by the World Economic Forum, because of the progress made in the latest years on decarbonization of energy production and the commitments to be 70% renewable by 2030, and carbon neutral by 2050 (Conley, 2023). In the article, one of the highlighted success drivers was the private-public support for innovative green technologies, among other causes, however, not all sectors have benefited from these technologies equally (see Figure 1).

Figure 1: CO2 emissions by sector in Chile

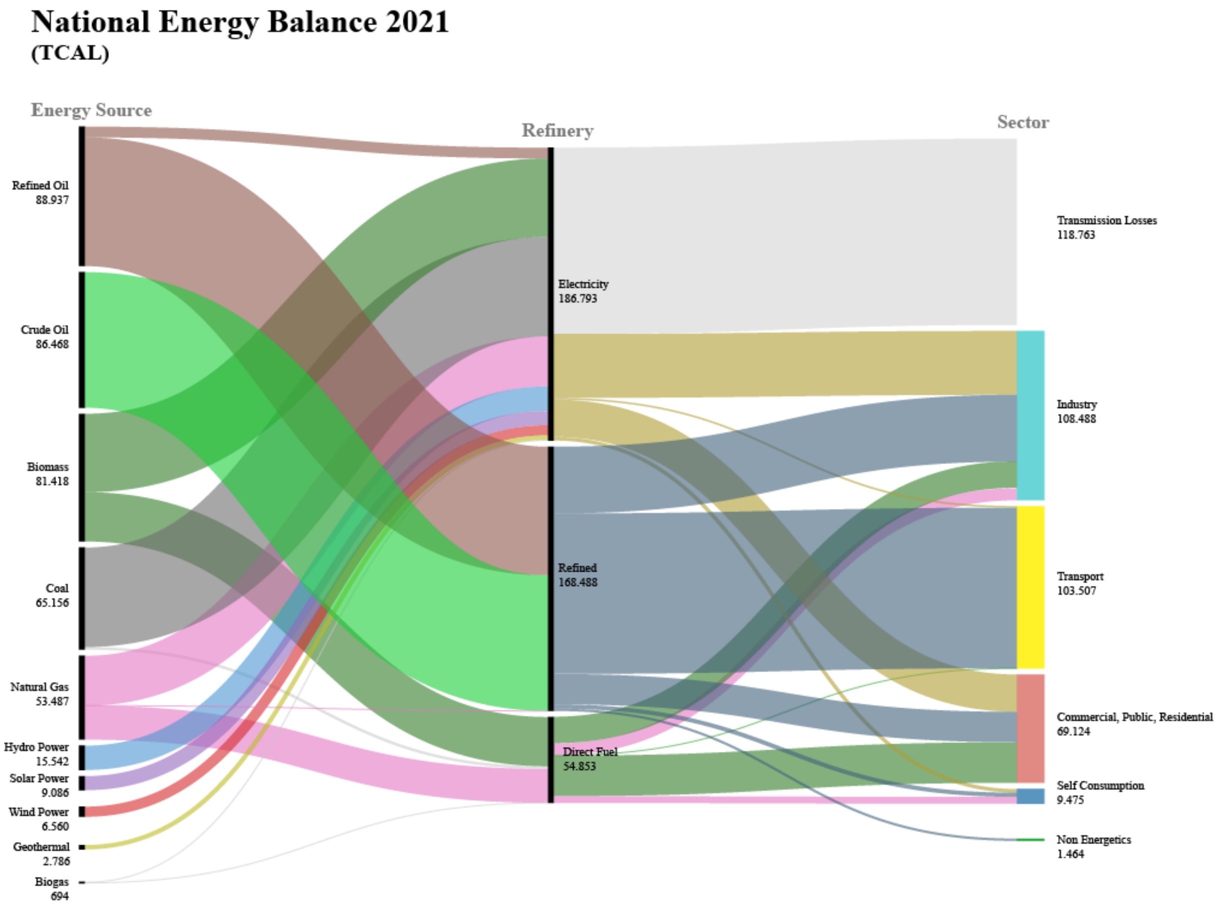


Source: Our World in Data, 2022

Figure 1 presents the change in CO2 emissions by sector, since 1990. Among the sectors shown within the figure, “Land-use change and forestry”, together with “fugitive emissions” present a different scenario, compared to the other sources, because the country is considered a natural carbon sink (Climate Action Tracker, 2022). Considering the other productive sectors, it is possible to note that almost all of them have increased or slightly decreased CO2 emissions, with the exception of industry, which has been showing a significant and constant decrease since 2016.

This scenario for industry is accentuated when looking at the energy balance for the country, and seeing that the industrial sector is the primary energy consumer in the country (see Figure 2), accounting for 37% of energy consumption, and also representing the biggest share of direct electricity usage. This scenario means that substantial efforts in reducing CO2 emissions within the industry sector will have a higher impact due to the considerate share of energy that it demands.

Figure 2: Energy Balance for Chile



Source: Energy Department, 2021

When looking at figures 1 and 2 together, it can be interpreted that there is a decline in the change in CO2 emissions by the industry sector, but since the change has not yet reached negative numbers, according to Our World in Data, the sector is still contributing to carbon emissions. Considering that industry still represents most of the energy consumption, this scenario raises the question about the sector's energy efficiency and intensity, the effects that latest improvements leading it to reduce its contribution to CO2 have had, and the reason behind its considerate share of energy.

1.1.1 Previous Research and Research Gap

Two previous publications have addressed the issue concerning the energy consumption and economic contribution of the industry sector, the first being Duran et al. in 2015, using data from 2005 to 2009, followed by Román-Collado et al. in 2018, with data from 2008 to 2013.

For both publications, the researchers employed a method called "Decomposition Analysis". Decomposition Analysis is a tool used to disaggregate the changes in energy into contributions from several specified factors (Ang, 1995, p. 1081), which are called "effects". The effects, together with the overall energy change are analysed regarding their "coupling" or "decoupling" implications. These concepts reference the nexus between economic growth (usually measured in GDP) and change in energy use (Guo, 2021), meaning that if something is "more decoupled", the economic growth is considerably higher than the consequent energy usage, and on the contrary if the factors are "coupled" or in "expansive coupling" means they are using more energy than the economic value generated in consequence.

During this research, the energy consumption is analysed in terms of Energy Intensity, which is defined as the amount of energy consumed per unit of output (Reddy & Ray, 2011). Energy Intensity is a proxy for energy efficiency in economic terms, which is one of the main subjects of research within the Chilean industry sector. Improved energy efficiency allows industries to reduce their energy intensity, achieving the same level of output with lower costs and less pollution (Reddy & Ray, 2011).

After conducting their analysis, previous researchers concluded that the industry sector was still consuming relatively more than what it was contributing, however these researches only cover a period of data from 2005 to 2013, which does not include the relative decrease reported in CO_2 emissions from 2013 onwards (Figure 1). As was expressed by the World Economic Forum in early 2023, the most recent improvements in decarbonization and climate policies in Chile are very relevant and need to be considered, therefore this research aims to assess the accuracy of the highlighted effect of these recent changes through a decomposition analysis of the Chilean industry, with the expectation that the results may be different from previous attempts.

1.1.2 Research Questions

Following the presented temporal research gap in the current literature, this thesis aims not only to contribute to analysing a more recent period, but to give further insight into the Chilean industry's energy efficiency situation. Therefore, the main research question is as follows:

"Has the Chilean industry sector moved into decoupling?"

Further analysis into the industry subsectors will give additional insight on the reasons for coupling or decoupling, also helping answer the following sub research question:

"What subindustries are contributing to decoupling, and which to coupling?"

For answering these questions, the available data will be quantitatively analysed employing the decomposition method, and the understanding of the outcome factors will be explained.

1.2 Aim and Scope

This thesis aims to build further on the decomposition analysis previously made by Duran et al. (2015) and Roman-Collado et al. (2018), by employing a similar decomposition analysis. Previous publications concluded that the country's industry was still in expansive coupling, but moving further into decoupling. This iteration of the analysis determines if the recent changes in technologies and decarbonization have had a visible impact in the Chilean economy inside the industry sector.

The study involves analysing the latest available information spanning a six-year period, with the most recent year being 2020. A decomposition method similar to those employed in prior research is utilized for the purpose of comparability of results and conclusions.

The scope of the thesis limits itself to analyse the context of industry in Chile during the recent years, since it accounts for about 37% of energy consumption. The availability of the data limits the most recent studied year, however the research covers 6 periods of time, as it was the case for previous research as well.

Due to the mining sector's significant industry size, it will not be included in the research. Most of the data generated from the mining sector is typically treated separately, outside of the basic industry scope, because otherwise it would overshadow the remaining data in terms of the share of energy consumption, contribution to GDP and other data sources. A separate exclusive analysis of the mining sector is recommended for further researchers, conditioned to the applicability of the current methods.

By analysing the overall and specific results of the industrial sector, this document aims to evaluate whether the country's trajectory has changed course and how the industry's performance can be improved.

1.3 Outline of the Thesis

After having presented the research problem and the previous research that aimed to tackle it, the research gives some context about the country. First, the Chilean energy sector, and some of the country's geography are presented, with the aim of illustrating the different energy sources that the country has access to, but also its limitations and challenges in energy generation and distribution. The context continues with a background on Chilean economy, its position among the neighbouring countries, and main exported products, expecting to assess the internal contributors to the country's wealth, but also its position on international markets. Finally, the context presents Chile's climate change commitments, its net zero targets and the contribution to a 1.5° path, which allows for discussion of potential policies and need for investment further in the research.

The document continues by detailing previous research's contribution to the discussed subject, and the researchers' conclusions and comments, leading to the theoretical approach that this research follows for contributing to the identified gap, which connects the method that is applied to the overall aim of the thesis.

After presenting the theory, the document moves on to explain the data sources that are used for the analysis, detailing the measures that are taken to ensure a fair quality of data so that the results can rightfully represent the selected scope, but also recognizing potential shortcomings and biases that may emerge due to the available the data sources' condition and context.

The thesis then moves on to explain in depth the numerical method that is applied to the data, detailing its selection above similar alternatives, and the main features it possesses, before moving on to the analysis of the results. The analysis presents the results from most aggregated to most specific, starting by overall energy intensity rates for different time periods, and later going into the effects that are particular to the applied method.

Results are later discussed in contrast to previous research and interesting findings in the results themselves, before presenting potential policy implications and closing reflections.

2 Chilean Energy and Economic Context

The primary objective of this research is to provide a comprehensive characterization of the energy efficiency improvements that Chile has made in its industrial sector in recent years, as well as to raise awareness of the areas where the country is still lacking. These improvements are the result of both public and private measures, and as such, it is essential to consider the broader context of the Chilean energy markets, the energy matrix background, and the current situation, as well as the country's latest climate change commitments, to fully understand the context within which this research is situated.

To achieve this, a detailed review of the relevant literature is conducted, which are used to identify the key areas of progress and the remaining challenges that must be addressed. The research utilizes quantitative analysis to provide a comprehensive assessment of the current state of energy efficiency in Chile's industrial sector.

Furthermore, to fully contextualize the findings of this research, this study provides a detailed overview of the Chilean energy markets, the key players involved, and the various policies and initiatives that have been implemented to promote energy efficiency. Additionally, the research examines the country's energy matrix background, including the mix of energy sources that are currently used in Chile and the trends that are shaping the future of the country's energy landscape.

Finally, an overview of the latest climate change commitments that Chile has made, including the country's participation in international agreements and its efforts to reduce greenhouse gas emissions is presented. By considering these various factors, this research provides a holistic and nuanced analysis of the energy efficiency improvements that Chile has made in its industrial sector, while also highlighting the remaining challenges that must be addressed to ensure continued progress in this area.

2.1 The Chilean Energy Background

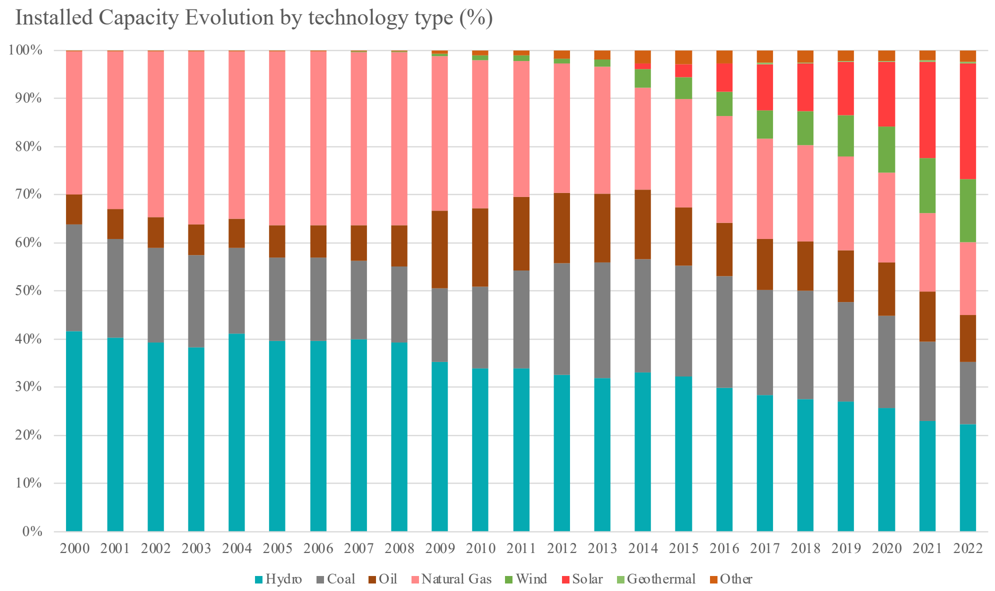
Being one of the longest countries in the world, and the longest from North to South (US Central Intelligence Agency, 2023), Chile is therefore home to several different climates and geographies that have incentivized different energy generation methods across its 4.300km of length.

Historically, the presence of lakes and rivers in the centre-south and south zones of the country, combined with the height difference introduced by the Andes mountains, have benefited Hydropower energy generation (See Figure 3). The lack of alternatives for the centre and north parts of the country derived into a historical dependence on coal and natural gas, which comes mainly from the neighbouring country of Argentina (Gasco Educa, 2023).

With the introduction of contemporary technologies that allowed for the development of Non-Conventional Renewable Energy Sources (NCRES), the country started taking advantage of the Atacama Desert, which has been shown to possess the highest continuous solar radiation on earth (Molina et al. 2017, p.1), and developed Solar Photovoltaic and Solar Concentration projects. Further investments on NCRES included Wind Projects and some Geothermal generation.

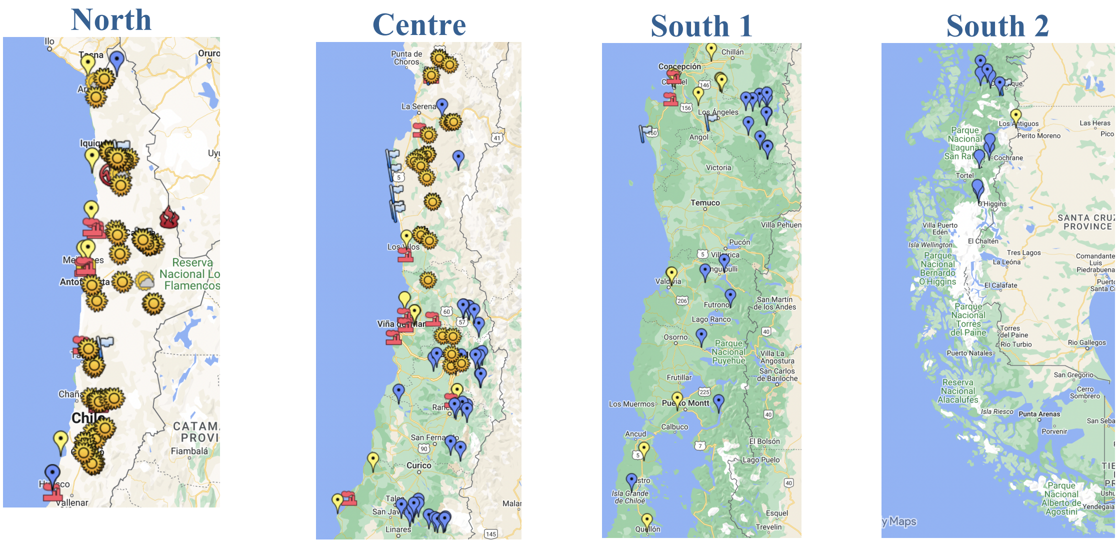
Currently, the Chilean electricity mix consists of 33.489 MW of installed capacity, of which 37,7% is thermal (coal, oil, and other non-renewables), 23,7% Solar, 22,1% is Hydropower, 13,6% Wind Power, 2,3% Biomass and 0,2% Geothermal (Generadoras de Chile, 2023). However, it is important to mention that this distribution is due to very recent changes, particularly in Solar Power, which represented only 14% of installed capacity on 2020.

Figure 3: Installed Electricity Generation Capacity 2000 - 2022



Source: Coordinador Eléctrico Nacional, 2023

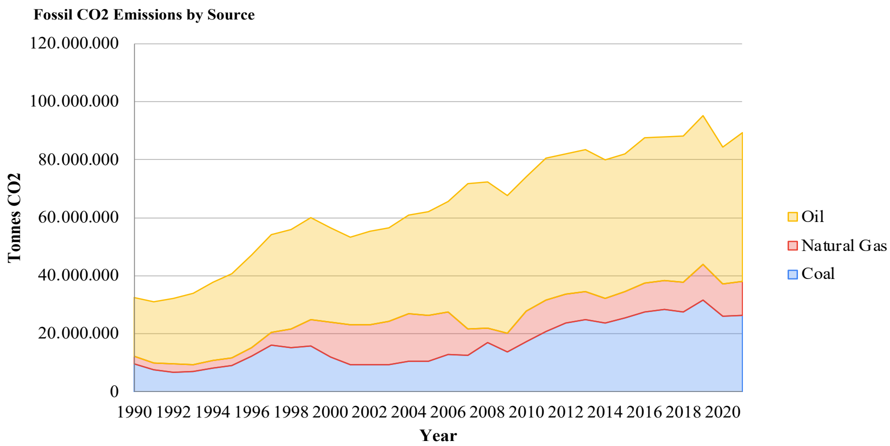
Figure 4: Distribution of energy generation through the country's length. (Suns represent Solar PV, Blue represents Hydropower, Flags represent Wind Power)



Given the current energy mix, emissions from energy generation are expected to go down as well, however, when taking into consideration the increase in energy generation, the CO2 reduction was lower than expected. Figure 5 shows the current energy emissions, until 2021, which dropped from 95,3 Mt of CO2 int 2019, to 89,3 in 2021 (IEA, 2023), and although there was a more significant drop during 2020 period, it has been argued that this effect was due mainly because of the COVID-19 pandemic, which will have to be considered during the research analysis.

Nevertheless, the emissions information still presents an upward trend, with a majority of the CO2 coming from the use of oil, and with coal in a trend that has begun to stabilize, possibly due to coal reduction policies in energy generation. 2021 presents with a positive scenario of a 6,2% reduction in overall CO2 emissions when compared to 2019, mainly attributed to the 17% reduction in coal consumption, however there is still insufficient data to affirm that this scenario will be maintained during the upcoming years.

Figure 5: CO2 Emissions by Energy Source for Chile, 1990-2021



Source: IEA, 2023

2.2 Chilean Markets and Economy

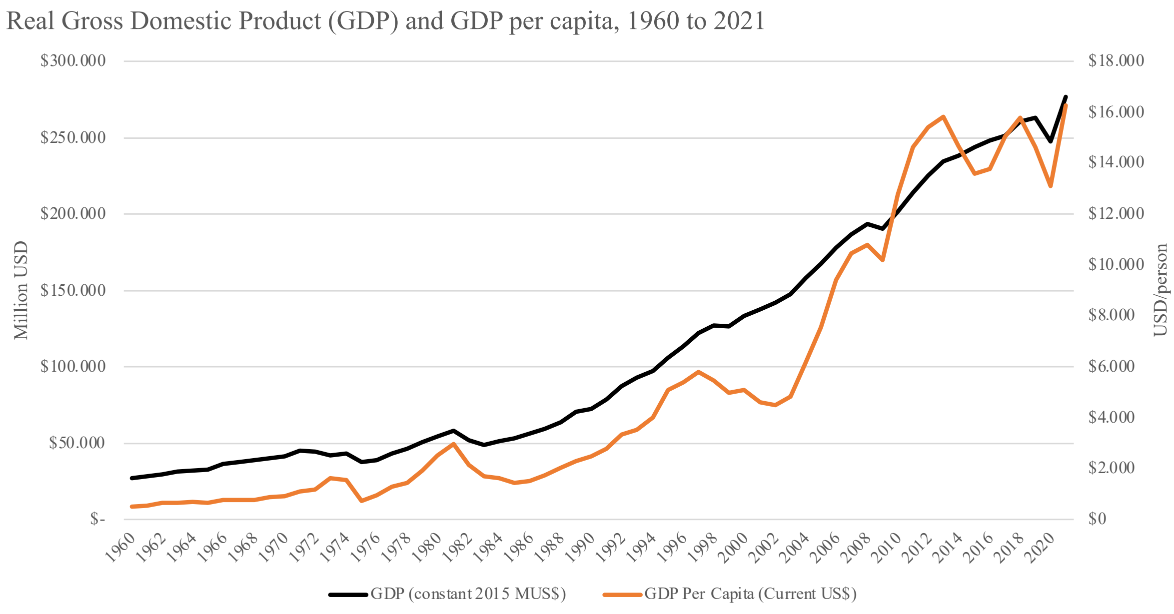
Because of this research's analysis between Energy Intensity and Economic Value, a short background of the Chilean economy is presented. The country is considered one of South America's most prosperous nations (BBC News, 2012), becoming the first Latin American country to join OECD in 2010 (OECD, 2010).

First, macroeconomic values such as GDP and GDP per capita are presented, with a comparison to neighbour economies. This is followed by context about sectoral contribution to Chile's GDP and main exported products.

2.2.1 Macroeconomic Background

As of 2021, the country presented a GDP of around $300 Billion USD (Banco Central de Chile, 2023). The country has been seeing a constant increase in GDP with the exception of periods of economic crisis, such as the COVID-19 pandemic in 2020, which was recovered during 2021. GDP per capita has been following the upwards trend to some extent, reaching an all-time high in 2021 (Note that current US$ were used to adhere to the World Bank standard)

Figure 6: GDP Growth for Chile and GDP per capita, 1960 – 2021



Source: Banco Central de Chile, 2022; World Bank, 2022

With a population of around 19 million, the country possesses one of the highest GDP per capita of the region, of around 16.000 USD/person, as of 2021. This currently makes Chile the second highest GDP per capita in Latin America, following Uruguay with a value of 17.000 USD/person (World Bank, 2022). Table 1 presents a comparison between the biggest Latin American economies (Note: Table does not include all the countries, just presents a selection of important economies for comparison).

Table 1: GDP and GDP per capita for selected Latin American economies, 2022

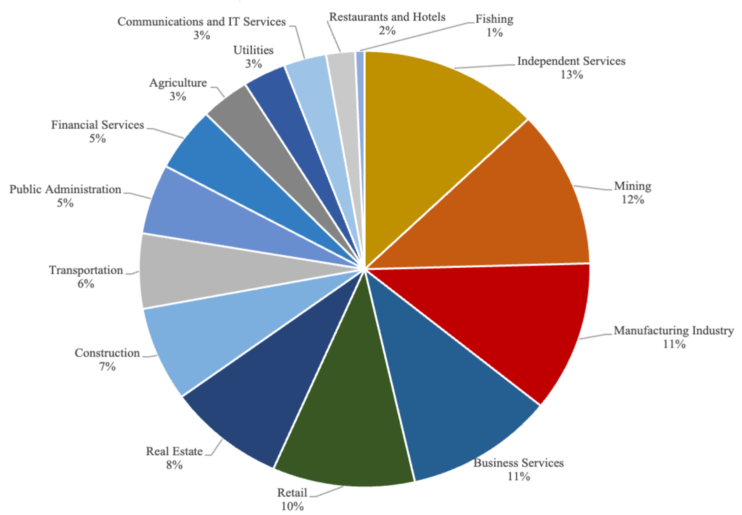
Country	GDP (current bn USD)	GDP per capita (current USD/person)
Brazil	1.608	7.507
Mexico	1.272	10.045
Argentina	487	10.636
Chile	317	16.265
Colombia	314	6.104
Peru	223	6.621
Ecuador	106	5.965
Uruguay	59	17.313

Source: World Bank, 2022

2.2.2 Sectoral Contribution and Main Exports

Chile, being a nation whose economy is primarily based on the primary sector, derives a substantial portion of its GDP from sectors heavily reliant on the extraction of natural resources. While Independent Services emerge as the largest contributor to the GDP, this sector will not be subject to further analysis due to its diverse range of activities that defy easy classification. These activities encompass Tourism, Maritime and Aeronautical Services, Engineering, Construction Services, and others. Therefore, excluding Independent Services, Mining stands as the foremost contributor to the GDP, followed by the Manufacturing Industry, which encompasses the specific sector under investigation in this research.

Figure 7: 2013 - 2022 Average GDP Contribution by Sector



Source: Banco Central de Chile, 2023

The mining sector is one of the pillars of Chilean economy, currently producing almost a third of the world's copper (World Economic Forum, 2022). In addition to copper, the country has been the world's largest producer of iodine and rhenium (United States Geological Survey, 2021). Chile is also home to the biggest Lithium reserves in the world (Government of Canada, 2021), and is currently the second biggest producer, following Australia (World Economic Forum, 2023), which has put the country in the latest debate concerning the sourcing of materials for clean technologies, such as Lithium-ion batteries, and copper wiring for electric cars.

Manufacturing Industry is comprised by several subsectors, which are the main subject of analysis in this research. It consists of the elaboration of secondary products of different natures, the biggest ones being Food Products, Beverages, Chemical Products and Paper Products (Banco Central de Chile, 2023). The contributions of these subsectors to national economy will be covered on the analysis part of this document.

In terms of exports, the country generated exportation sales for 98 bn USD in 2022, according to the Chilean Central Bank. 57% of the total exportations come from the Mining industry, 80% of it being Copper, and 14% Lithium. Given its considerable size both in GDP and in exports, Mining is usually treated separately to the rest of industry in the Chilean context, in contrast to other countries that aggregate it with other industrial sub sectors.

Manufacturing Industry accounts for 36% of total exportations, or 35 bn USD. The biggest contributor for these exports is the Food Industry (36% of Industry Exports), mostly because of Salmon exports, making Chile the second biggest exporter of Salmon, after Norway. The second contributor to Industry's exports are Chemical Products (26% of Industry Exports), which considers a wide variation of products, leaded by Molybdenum and Iodine derived products. Third in importance are Paper products and Forestry, contributing 10% and 9% of Industry exportations respectively. It is important to notice that the Forestry sector used to contribute 13% of total exports in 2005 (Amcham, 2008), and has been lowered to 3%, partially due to nature preservation and climate change policies. Chile is also the 4th biggest wine exporter globally, with sales of 1.5 bn USD in 2025, and although it only represents 4% of Industry exportations, the Wine Industry reputation has helped expand international awareness about the country, making the Beverages sector highly relevant to Public Policy and national economy.

Finally, direct Agriculture and Fishing industry does not represent a big share of exports, however the sector is highly relevant in internal economy, because it allows for the Industrial exportations of Food Products.

The biggest importer of Chilean products is China, with 40% of total exports going to the Asian country in 2022. Second in line is United States, with 14% of exports, Japan (8%), South Korea (6%) and Brazil (5%).

Due to the importance of the Chilean economy in the sectors mentioned above, not only to internal economy, but also the contribution to global economy in some critical raw materials, the subsequent emissions could be seen as international interest, and the achieving of decoupling through energy efficiency a key success in the context of the climate emergency.

2.3 Chile’s climate change commitments

As was presented in the introduction, Chile has made very substantial progress on climate action over 2022. Only two years before then, emissions were projected to rise, one year ago they appeared to be stabilising, and today, Chile’s updated emissions projections under current policies and action are beginning to decline. This leads to an upgraded Climate Action Tracking rating (CAT) of Chile’s current policies and actions to “Almost sufficient”, depending on the evaluation framework. If Chile goes ahead with the implementation of planned policies such as an early coal phase-out by 2030, it could even be on track to being 1.5° compatible (Climate Action Tracker, 2022).

2.3.1 Net Zero Targets

The current net zero target for the country is for 2050, and was presented by the president of Chile in 2020 as legislation in the Framework Law on Climate Change (President of Chile, 2020), and was later slightly modified after being published in 2022. The target is believed to cover most important elements, it covers all sectors and gases, communicates strategic goals and emissions targets per sector, and provides a detailed methodological framework. (Climate Action Tracker, 2022)

One particularly important detail for this research, is that the country underpins the sector-specific ambitions with detailed emissions pathway analysis and budgets, which could tie industry energy efficiency to Nationally Determined Contributions (NDC) in some potential policy proposals. Specifically the country has an emissions reduction target of 70% GHG for Industry by 2050, an improvement of energy intensity of large energy consumers by at least 25% below 2021 by 2050, a requirement that at least 90% of energy for heating and cooling in industry must come from sustainable sources by 2050, and a requirement that 100% of medium and large companies in Chile must implement effective and monitorable energy efficiency and/or renewable energy measures (Ministerio de Energía, 2022)

It is also important to note that the country made commitments for all GHG emissions, and plans to reach net zero through domestic actions, meaning without the removal to outside Chile’s borders (Government of Chile, 2020). Other commitments consist of reaching 58% of electric vehicles (private and commercial) by 2050, emissions peak no later than 2025, and phasing out coal-powered plants by 2040 (although it has been discussed to move it to 2030).

However, although the country’s improvements have been highlighted as positive, it has not been free of criticism. Internal criticism, coming from companies specialized in sustainability strategies country, debates whether the policy regulations towards big companies is enough, but agrees that the protection of nature, reforestation and biodiversity needs to be addressed more directly (Universidad de Chile, 2022). International media has raised concerns because of the country’s lack of evidence in implementing all its planned policies (Climate Action Tracker, 2022).

2.3.2 Latest Improvements and Global Contribution

Chile was highlighted because of the improvements in the latest update of NDC. Moreover, the updated document lowered the emissions target for 2030 by 2 $MtCO_2e$, included the goal to peak GHG emissions two years earlier than the previous draft, and promised smaller updates for COP27 (Climate Action Tracker, 2022).

The country also announced in 2020 a national strategy for Green Hydrogen (Hydrogen fuel made from clean energy), and has been considered one of the most promising countries for becoming exporters of this type of clean fuel, which is estimated that will account 12% of global energy use by 2050 (Bartlett, 2022). The country committed to producing the cheapest Green Hydrogen in the world by 2030, and be in the top three exporters by 2040, with investments that could reach $45 billion USD by 2030 (Bartlett, 2022).

Specifically to industry context, on March 3rd, 2023, the country approved a law named the "Energy Efficiency Law", which regulates the big energy consumers, most of them who belong to the industry sector. The target companies are those with energy consumption above 50 teracalories/year, which together represent a third of the country's energy consumption (Garrigues, 2023).

The companies that are considered within the addressed group will have to implement energy management systems that have to cover at least 80% of their total energy consumption, and include internal policies, goals, metrics and strategies. Companies will also have to implement energy measurement and verification technologies into their operations. Legislation also includes an auditing process of the mandatory measures, together with mandatory documents that the affected companies will have to submit, detailing their energy efficiency opportunities and measures that were taken and projected to be conducted every three years (Garrigues, 2023).

Overall, this new law expects to address, from a public policy point of view, the lack of efforts in energy efficiency that have been reported by previous research, and force private actors into taking measures in energy efficiency, the government is expecting this law to represent a reduction of 10% in energy intensity, and a 35% of GHG emissions target reduction (Ministerio de Energía, 2023).

Although all these improvements have made news (Conley, 2023), and the country is considered to be a global frontrunner in climate action (Climate Action Tracker, 2022), Chile's efforts are still rated in an "Almost Sufficient" state for reaching the 1.5° scenario, stating that climate commitments need substantial improvements and announced policies need to be approved to be consistent with the Paris Agreement's 1.5°C temperature limit. Other main concern is that the country's commitments are conditioned to international support, which may hinder the effectivity of the policies in practice (Climate Action Tracker, 2022).

3 Theory and previous research

The analysis of decoupling has become a crucial tool for understanding a country's efforts in addressing the climate crisis. By examining the disconnect between greenhouse gas emissions and economic growth, researchers can identify which public and private approaches have been most effective. However, to fully understand the energy efficiency of the Chilean industry sector, it is necessary to consider previous research in related fields. Such research can provide insight into expected results and inform measures taken by industry actors. Thus, this study incorporates findings from previous research on industry energy efficiency to provide a comprehensive analysis of decoupling in the Chilean industry sector, before diving into an explanation of the approach that is taken through this work to address the scope of the research.

3.1 Previous Research

3.1.1 Decoupling and Emissions Analysis

Previous research into decomposition analysis has been done for several countries to explain how the different economic sectors have contributed to emissions and growth, and showed that energy intensity was a bigger driver than structural changes across sectors (Liu and Ang, 2007). Although the method has been very popular in recent times, it was applied for the Chilean case on two occasions, which will be discussed more in depth given their relation to the current research.

In their publication titled "*Analysis and decomposition of energy consumption in the Chilean industry*", Elisa Durán, Claudia Aravena and Renato Aguilar (2015) discuss the energy demand and CO2 emissions of the industrial sector of Chilean market. They use Logarithmic Mean Divisia Index decomposition (LMDI) to decompose energy intensity by industrial sector, and comment on the results, for a period of data between 2005 and 2009, with a year-to-year analysis. The research used the *Chilean Annual National Industrial Survey* (ENIA), which gathers information of around 5000 firms about their energy consumption, economic output and other factors, and separates industry in sub-sectors and size, among other categories.

The overall analysis concluded that although energy consumption remained stable in the last years of the study, it was explained by a lower economic output due to recession, and that it was likely that it will grow after the economy recovers. The authors also analysed data by subsector, firm size, and ownership type, and draw additional conclusions. For the subsector analysis, which was divided into 4 subsectors, they showed that all sectors except Basic Metals increased their energy intensity, with an overall positive structural effect, except for the Chemicals sector. The firm size analysis showed that the most energy intensive firms were the medium size ones, and the given explanation was that they are big enough to generate quantifiable output, but not big enough to benefit from economies of scale, these firms were also the ones with biggest structural effect (change in the mix of activities). Finally, the ownership type analysis concluded that energy intensity of foreign private owned and mixed owned firms was more stable and less dependent on economic downturns during the period, but it stated that these groups were relatively small compared to nationally private owned firms.

The study also conducted an econometric analysis of the data, which validated some of the already drawn conclusions and raised the concern about subsector homogeneity of public policy design and implementation.

The second relevant publication was by Rocío Román-Collado, Manuel Ordoñez and Luis Mundaca in 2018, titled "*Has electricity turned green or black in Chile? A structural decomposition analysis of energy consumption*". This paper leveraged a bit more on the latest increase in investment on Non-Conventional Renewable Energy Sources (NCRES), to achieve fossil fuel independence. It analysed the impact of the increase in NCRES using a similar method to LMDI, called Input-Output Tables, for a period of data between 2008 and 2013. The analysis of results divided the data into overall results, sectoral analysis, and fuel source analysis. Overall, the study concluded that the Chilean economy is far from decoupling, mainly due to the accelerated growth of the economy, it also pointed out a decrease of the energy efficiency as the economy grew. When divided by sector, the analysis pointed out that mainly copper, oil refining, transport and business sectors were responsible for the failure in decoupling, and also concluded that there was a minor technology improvement in all sectors except for transport. Finally, the fuel source analysis showed that the biggest increase in consumption was in natural gas (273%), followed by Electricity (23%) and oil (8%), it also showed that the weight of fossil fuels in energy consumption managed to decrease by 13% in the analysed period, which can be explained by a strong decrease of coal consumption, even considering an increase of oil and natural gas.

The research concluded by raising the issue of the lack of policies to promote energy efficiency, stating that there was big improvement potential. The publication did mention that there were some policies in place, but that the effects are yet to be perceived.

It is also relevant to include some of the research that was done for the Latin American country in a slightly broader context, given that the underlying objective of this research is to understand emissions behaviour in a context that concerns the climate emergency. An interesting publication that uses the concept of the Environmental Kuznets Curve (EKC), which links income growth and environmental degradation (Hwang, 2022), was presented in 2022, comparing the performance according to the EKC for Argentina, Brazil and Chile.

The research presented by Young Kyu Hwang and called "*The energy-growth nexus in 3 Latin American countries on the basis of the EKC framework: in the case of Argentina, Brazil, and Chile*" examined the period between 1978 and 2018, looking at GDP per capita, per capita CO_2 emissions, and energy consumption per capita in addition to other control variables, and confirmed the presence of the EKC for Argentina in the long run, but not for Brazil and Chile. For the Chilean case, the study found a "U-shaped" curve on the relation between economic growth and CO_2 emissions, but that the country was the only one among the three analysed in the investigation where renewable energy consumption had a significant negative impact on carbon dioxide emissions (Hwang, 2022), which led to the researcher recommending further investments in bigger renewable projects.

Overall, these three researches point to the necessity of further investment, both in energy efficiency improvements, and on bigger renewable energy projects. The newest publication highlighted the improvements that the country had in cleaner energy, which was seen on a smaller scale on Román-Collado et al (2018). The fact that the newest data used was in 2018, and that the last decomposition analysis was done using data from 2013 and before, raises the question if a newer analysis will show even better results of the Chilean investment on renewables.

3.1.2 Industry Energy Efficiency and Policy

Previous research linking the chosen subsector, industry, to energy efficiency technologies and state of the art is also important to review to build upon. Of all published documents aiming to tackle industry emissions through energy efficiency, two emerge as highly relevant for this research. The first of them is the "Study On Energy Efficiency And Energy Saving Potential In Industry And On Possible Policy Mechanisms" by Yeen Chan and Ravi Kantamaneni, which was published by the European Commission in 2015 to assess energy savings potential for the industry sector, and recommend policy options based on the results.

Chan and Kantamanemi's publication evaluates eight energy intensive industrial sector groups, and four tertiary sector groups, and models energy consumption trends, presenting final energy consumptions, and forecasting how the consumption will behave in a period from 2015 to 2050. The paper comments about each specific subsector within industry, and assesses where the biggest energy consumptions are located for each. The biggest contribution from this publication to the current research is the evaluation of the efficiency potential that the subsectors have, meaning the energy savings that could be achieved if the companies implemented Energy Saving Opportunities projects that are technically feasible (Chan & Kantamaneni, 2015, p. 6), a summary of this potentials is presented in Table 2, detailing the achievable energy efficiency potential for 2030 (from 2015) in terms of percentage derived from the reduction of energy consumption in relation to a "Business as Usual" projection of the consumption. The study also includes a forecast of potential for 2050, which is sometimes lower, because of a reduction on the baseline consumption projections. The publication then moves on to explain in depth the types of projects that could be implemented, the costs, and the strategy.

Table 2: Energy Savings potential for industry sectors

Sector	Potential for 2030	Potential for 2050
Pulp and Paper	19%	17%
Iron and Steel	24%	26%
Non-metallic mineral	19%	18%
Chemical and Pharmaceutical	25%	22%
Non-ferrous metal	22%	21%
Petroleum refineries	25%	8,3%
Food and Beverages	26%	24%
Machinery	27%	25%

Source: Chan & Kantamaneni, 2015

Overall, this document presents an assessment of the 2015 European energy efficiency scenario for industry, then moving on to focus more on explaining the possible projects to achieve the savings potential. This document sets a precedent of possible measures that could be taken, explaining that regardless of the position of the industry sector in relation to coupling or decoupling, there are several improvements that could be made to increase its energy efficiency.

The second publication of interest to the present document was published by the Chilean Energy Efficiency Agency (ACHEE), titled “Energy Management and Strategy Study: Identifying Value Opportunities”, in 2018. The publication did a similar study to the one published by Chan and Kantamaneni, but limited to Chilean industry. The research conducted several interviews to key actors in the private scene, and classified the potential measures that could be taken by Chilean companies to increase energy efficiency in the different dimensions of the company. The document presents a less numerical approach to energy efficiency than the one published by the European Commission, but still recognises that Chilean companies have an energy efficiency gap, and recommends solutions.

This document contribution to the current research is due to the reinforcing of the concept that there is also a strong efficiency potential that is yet to be achieved in the Chilean context, and although it does not cover whether the current scenario is being efficient enough when compared to the economic output, it shows that it could be more efficient than it currently is.

3.2 Theoretical Approach

The theoretical approach employed on this research draws conclusions from the resulting decoupling factors of the applied methodology, analyse similarities between the results and previous publications that used similar methods, and comment on possible implications for policy making.

As explained in the introduction to this document, decoupling theory applied to the energy context analyses the relation between energy and growth, in this case energy efficiency and contribution to GDP are used as representations of each variable. Decoupling represents the ability of contributing to growth without needing to incur in a proportional level of energy consumption. A sector that is “more decoupled” is one that is producing higher levels of output with a proportionally lower level of energy usage (Guo et al., 2021).

Furthermore, decoupling theory also connects to the necessity of a country to maintain its growth, but highlight its decarbonization efforts. Decoupling theory has been previously used as an argument of achieving a decarbonization strategy while maintaining GDP growth, although evidence has shown that applying the mentioned theory as a sole measurement for achieving sustainability is not viable (Parrique et al., 2019), and therefore needs to be complimented with policies and targets that aim to reduce emissions in an absolute (and not relative) context. However, decoupling theory is shown to be useful for analysing efficiency in a localized context, such as the industry sector within a specific country, which is the case for the present study.

The decoupling approach also assess how close or far certain areas within the analysed group are to becoming more energy efficient, by comparing them to their economic output. The use of decoupling for energy efficiency analysis also allows for comparing factors within subgroups, which could help in future policy making or to address collaborations within markets, or barriers to growth. Finally, the process allows to repeat this analysis for various time periods, which presents with the possibility to comment on trends, changes, and potential external factors.

Given the required limitations and benefits of decoupling theory, it is considered a good method to apply to the specific case of Chilean industry. Although some of the processes within the industry sector may require longer than the analysed period to show its effects, such as company strategy to reach zero emissions, most of the recommended technological improvements have a payback period of less than 6 years (Chan & Kantamaneni, 2015), and therefore the impact in energy efficiency is expected to be within the analysed period. It was also the case for previous research that a scope of 5-6 years is used.

The main identified issue that this research addresses is the lack of empirical evidence suggesting that the country’s climate policies and press success have had a real impact on energy consumption, and for the case of Industry, the energy intensity is being analysed. The link between coupling or decoupling rates and energy intensity is direct: the higher the rate, the more inefficient the energy intensity has gotten.

Among all decomposition methods, the logarithmic mean Divisia index method I (LMDI I) was the most recommended (Liu & Ang, 2007). The reasons for recommending this method are first of a technical nature, mainly the successful performance in several important tests of good index numbers which are relevant to index decomposition analysis, the possession of additive property in the logarithmic and the link to the multiplicative form, which allows the results for one version to be easily converted to those of the other, thereby making a choice between additive and multiplicative decomposition at the start of a study unnecessary, among other reasons (Liu & Ang, 2007, p. 611). Because of this technical success, the method has been adopted by official publications of New Zealand, United States and Canada, giving it further acceptance (Liu & Ang, 2007, p. 612).

4 Data

Due to the numerical nature of this research, the data section of the documents possesses special interest. Although the direct gathering of information is not a concerning issue, it is only possible to successfully conduct the research if there is enough available data for the period that concerns the discussion.

Other important issue is the quality of data, which highly influences the results and therefore the overall conclusions. Data sources employed in this type of research need to be of a primary origin, and not comprehend a mix of secondary sources, approximations, and assumptions, as some sources do.

During this section, the source material will be introduced, followed by a critical comment about potential biases, and the potential for generalization.

4.1 Source Material

The research uses two main sources of data for energy decomposition analysis, the National Annual Industry Survey (ENIA), and the National Energy Balance (BNE), in a period ranging from 2015 to 2020, the latest available year.

Overall, the source data was taken from government-conducted surveys, which help with reducing concerns about the validity of the material, while ensuring a higher level of compatibility between sources. Both data sources were downloaded from governmental websites and analysed according to the guidelines presented by the publishing departments.

4.1.1 The National Annual Industry Survey (ENIA)

This survey, gathered annually by the National Statistics Institute (INE), presents data from around 5.000 companies inside the industry sector. The more than 300 variables presented for each company include company size, industry sub-sector, ownership type, purchases, sales, number of employees, purchased and generated electricity, and value added, among others. The survey also separates companies according to their activities, so that big companies with several different operations would be represented accordingly. From the list of variables, the following were included in this research:

a) **Industry Sub-sector**: The industry sub-sector classification is done according to UN’s International Standard Industrial Classification of All Economic Activities, ISIC (United Nations, 2008), and it comprises 23 categories. See Appendix 1 for the full list of subsectors and their official names.

b) **Purchased Electricity**: Represents the amount of energy (in Kwh) purchased by every company in the list, on the said year. This variable was discontinued on the 2019 version of the survey and replaced by "Generated Electricity".
c) Generated Electricity: Represents the amount of energy (in Kwh) generated and used by the company during the surveyed year. This variable replaced the "Purchased Electricity" variable in 2019 onwards.
d) Value Added: This is a calculated variable that represents all the production value, minus the internal consumption. It is used as a proxy for the contribution from Industry to GDP.

4.1.2 National Energy Balance (BNE)

The National Energy Balance is a document published every year by the Chilean Department of Energy, detailing all the energy generated and consumed by source. As part of the energy consumption, it shows the electricity consumption, in Kwh, from the industry sector.

This data is combined with the data reported by companies in the ENIA survey, to counter for the change of variable in 2019, and the potential inaccuracies that it brings. Instead, the aggregated electricity consumption is the one reported directly by the department of energy in the Energy Balance, and the weight of each subsector is the one from the ENIA survey, thus keeping the overall consumption as it was presented during the introductory chapters of this research, but allowing for sub sectoral analysis. Note that in order to combine the information presented by the ENIA database with the National Energy Balance, the energy consumption data had to be limited to electricity consumption, as the ENIA survey does not report other energy consumptions.

4.2 Potential Biases and Generalization

4.2.1 Using a subset of the whole local market

This research chose to focus on the decoupling of the industry sector for Chile, and although the reasons for doing so were argued, it is necessary to recognize that in doing so, the conclusions will not represent the whole country situation. The analysis leaves important sectors aside such as the Mining industry, which is very influential on Chilean economy, and therefore is required to be treated separately.

4.2.2 Using electricity as energy consumption

As it was noted before, the value for energy consumption employed comes from the aggregated electricity consumption, and is divided according to generated or purchased electricity as well. In doing this, companies that use low quantities of electricity, but higher quantities of other direct types of energy, such as oil powered machines, or coal, are underrepresented on the analysis, meaning that their behaviour is probably less efficient than the one shown by the results. On the other hand, companies that rely solely on electricity are overrepresented, due to their share of total energy being lower when including the companies that use other types of sources. However, given that the method relies on weighted averages in relation to the total consumption (as it is explained on the Method section), it is not affected by the aggregated energy consumption of energy, meaning that this type of bias may affect only the effects regarding the representation of subgroups, and not the aggregated results, and given the high amount of companies included in the ENIA survey, it is safe to assume that there will be a normalised distribution of the usage of other energy sources, therefore expecting the current bias to not significantly affect the conclusions.

4.2.3 Using data reported by companies

Other potential risk of this research lies on the ENIA database, which showcases data that is reported by companies to the government, and therefore may have some inconsistencies and is susceptive to human error. This was considered when the decision to use the total energy consumption from the BNE was taken, given that the data from that publication comes from the country's energy systems and is therefore less susceptible to human involvement, but the energy weights of each sector, and the value added are susceptible to this type of error.

4.2.4 Combining different sources of data

Due to the inconsistency of the reporting of energy use in the ENIA survey, and the overall better aggregated values that the BNE presented, both sources were combined as explained before. Although this approach is considered a safe approximation, due to both sources being of a governmental nature, and both sources referring directly to the industry sector, it is still a combination of sources that may result in some mismatch with the real consumption. Aggregated values are directly taken from the BNE, but subsector values could be slightly different from the real consumption.

4.2.5 Possibility of Generalization

Applying the results of the current research to other similar contexts is a highly beneficial exercise, since it allows for conclusions that were made for a specific group to be applied to a bigger universe. In this case however, the variety of industry itself within subsectors is already high in terms of products, markets, energy use and business models, and the context of Chilean industry in relation to other neighbouring countries is also different in terms of energy consumption, energy sources available, public policies, and the contributions from each sector to the overall economy. Taking all factors into consideration, generalizing the conclusions of the current analysis to other contexts is unlikely to provide truthful insight, however, the example of Chilean industry in regard to energy efficiency can be taken as a case study to discuss other situations of global decoupling, or to further validate the use of decomposition to analyse decoupling between energy intensity and economic contribution of a selected subgroup within a country's economy.

5 Methods

5.1 The Methodological Approach

The research uses multiplicative Logarithmic Mean Divisia Index Decomposition (LMDI) to understand the efficiency and distribution of the energy consumption of the Chilean industry. The reason for choosing to use LMDI as a method for the analysis of decoupling is both of a technical nature, due to the numerical properties the method presents that allow for more comprehensive analysis, and of a reputation nature, because of the successful previous implementations, as it was mentioned during the theoretical approach section of this document.

This method was derived from the Index Decomposition Analysis (IDA) that was first used in the late 1970s, to study the impact of changes in product mix on industrial energy demand (Ang & Zhang, 2000). On 2000, Ang and Zhang coined the term IDA, and reviewed and classified 124 studies that employed variations of IDA. The research concluded that LMDI was one of the most robust methods employed at the time, and was confirmed to be the preferred approach by Ang on 2015, not only because of its extensive use, being adopted in two-thirds of the 254 IDA journal papers published over the five-year period from 2010 to 2014 (Ang, 2015, p. 234), but also because it possesses properties that make it desirable for analysing energy demand (Ang, 2015, p. 234).

LMDI methods can be divided into subcategories depending on the input data and the desired analysis, the categories are:

a) LMDI-I vs LMDI-II
b) Additive vs Multiplicative
c) Energy Consumption vs Energy Intensity

The chosen method is a Multiplicative, Energy Intensity based LMDI-I, which decomposes the ratio of change in energy intensity into two factors. This method was chosen above other combinations because it better suits the source data. The analysis of a sub-sector efficiency is better represented using an Energy Intensity based method, since it focuses more on energy productivity (Ang, 2015), and therefore it is recommended to combine with a Multiplicative approach (Ang, 2015, p. 237). The choice of LMDI-I over LMDI-II is because of its simpler formulae (Ang, 2015, p. 237).

The two factors from the decomposition are called effects in the theory of the LMDI method, and are used to explain the drivers of the changes on energy intensity between two periods of time. These effects are:

i. **The structure effect**. This effect considers changes in the mix of activities. These changes have an impact on energy intensity because each activity has different energy intensiveness; for example, energy intensity will grow if a high intensity industry (e.g., oil extraction) increases its output share within the economy (Rue du Can et al., 2012).

ii. **The intensity effect.** This effect considers the impact of the sectoral weight of energy intensity in energy intensity itself. This is considered a good proxy of energy efficiency changes. Energy intensity reductions occur either because of more efficient technology or better processes, which can include substitution of factor inputs, e.g., substitution of renewable energy for fossil fuels in the production process (Sun, 1998).

The formulas are as follows:

Structure Effect:

$$\exp\left(\sum_i \frac{L\left(E_i^T/Q^T, E_i^0/Q^0\right)}{L\left(V^T, V^0\right)} \ln\left(\frac{S_i^T}{S_i^0}\right)\right)$$

Intensity Effect:

$$\exp\left(\sum_i \frac{L\left(E_i^T/Q^T, E_i^0/Q^0\right)}{L\left(V^T, V^0\right)} \ln\left(\frac{I_i^T}{I_i^0}\right)\right)$$

With L(x,y) being the logarithmic average of two positive numbers. For these formulas the letters represent the following:

- E_i^T: Energy consumption for subsector "i" in time period "T"
- Q^T: Total Value Added by the Industry in time period "T"
- V^T: Aggregated Energy Intensity (E/Q) in time period "T"
- S_i^T: Share of Value Added by subsector "i" in time period "T"
- I_i^T: Share of Energy Intensity by subsector "i" in time period "T"

Finally, the overall energy intensity change is calculated as:

$$U_{tot} = V^T/V^0 = U_{str}U_{int}.$$

With U_{tot} being the overall Energy Intensity ratio, U_{str} being the Structure Effect and U_{int} being the Intensity Effect

5.2 Interpretation of the Model

After the method is applied to the data, the results are coefficients for the Structure and Intensity Effects, and the final Energy Intensity ratio. These coefficients are numbers close to 1, and represent the level of decoupling. If the number is higher than 1 it means that the corresponding effect from the final year is higher, and therefore that the coefficient shows coupling, on the opposite if the number is lower than 1 it means that the effect from the final year is lower, which shows decoupling.

Decomposition analysis allows for the Energy Intensity coefficient to be separated into Structure Effect and Intensity Effect, which multiplied are equal to the Energy Intensity coefficient. These decomposition coefficients come in use when interpreting the reasons behind Energy Intensity coupling or decoupling. If for example one period of time shows an U_{tot} above 1, but U_{int} is below 1, it means that although technological change and energy efficiency is pushing emissions down, the country increase its energy intensity because of structural reasons.

It is important to note that the Structure Effect represents "between sector changes", meaning changes in the contribution or weights from each subsector inside the group, and therefore to see the real effect, the coefficient should be analysed in an aggregated way. The Intensity Effect on the other hand represents "within sector changes", meaning changes in the energy efficiency inside each subsector, and although the aggregated contribution is relevant to discuss, this effect is better analysed by subsector, to understand which contributed to decoupling and which ones did not.

These two effects are also susceptible to the analysed period of data. For the case of industry, the Intensity Effect, also called Technology Effect by some authors, represents the improvements that each subsector achieves in developing energy efficiency projects, which could encompass machine upgrade, strategy implementation, energy savings software or hardware, among others. Most of these projects are approved based on a 5-year payback period (Chan & Kantamaneni, 2015), and usually have a short implementation period, meaning that the effect of this type of upgrades will show on a 6-year period of analysis.

The structure effect, influenced by the shifting weights of economic contributions from each subsector, exhibits a distinct pattern within the industry. It is characterized by abrupt fluctuations in production as a response to short-term economic product demand while also indicating longer-term, definitive changes. Thus, it is plausible for a particular subsector to contribute more to the value added during a specific period without implying a sustained trend over an extended duration. Consequently, a more comprehensive analysis of the structure effect necessitates longer time periods to enable a definitive assessment of the sector's structural transformation.

6 Empirical Analysis

6.1 Results

6.1.1 Energy Intensity Rates

For the analysed years, the overall industry Energy Intensity rates were calculated, showing an Energy Intensity ratio of 0,83 for the years 2015-2020, this result presents with empirical evidence to think that the industry sector is decoupling from emissions overall. The LMDI method allows to decompose this factor into Structural and Intensity, which help explain the decoupling reasons. Factors are as follows:

Table 3: Energy Intensity Decomposition for 2015 - 2020

Energy Intensity Rate	0,83
Structure Effect	1,00
Intensity Effect	0,83

These results suggest that the decoupling is attributed entirely to the intensity effect, that represents changes *within* industries, which could mean that better technologies were implemented on several subindustries that led to an overall decoupling.

The results also imply that the energy intensity mix remained constant over the period, therefore there is no change on the Structure effect. This could be due to a stagnation on the industry subsectors, in which none of the subsectors grew considerably more than the others, or it could be explained by the growth of some sectors with an average energy intensity factor. As it was mentioned before, the Structure Effect is a period susceptible to production demands, and requires a long analysis period to show definitive changes in the product mix.

To rule out a potential effect of the COVID-19 pandemic on the data, the analysis was repeated for a shorter period, between 2015 and 2019. The results shown in table 4 present a slightly increased decoupling, explained again by the Intensity effect.

Table 4: Energy Intensity Decomposition for 2015 - 2019

Energy Intensity Rate	0,76
Structure Effect	1,01
Intensity Effect	0,75

This is in line to what has been seen before for periods of economic downturn (Rue du Can, 2012), which are characterized by a lower level of output.

It is also relevant to look at the year-to-year Energy Intensity rates, in order to better understand the impact that each year had on the industry subsectors decoupling. Upon seeing the rates for each year, it is possible to notice that the period contributing the most to decoupling is 2016-2017. This period does not coincide with any national or global uncommon event, and therefore it could be argued that the decoupling from the year is representative of the industry's efficiency efforts. Other interesting period is the most coupled one, 2018-2019, which also does not coincide with any special events.

Table 5: Yearly Energy Intensity Rates

Year Period	Energy Intensity Rate
2015 - 2016	1,08
2016 - 2017	0,57
2017 - 2018	0,94
2018 - 2019	1,32
2019 - 2020	1,09
2015 - 2020	**0,83**
2015 - 2019	**0,76**

This analysis reflects the fact that the Industry Sector is highly susceptible to yearly changes, and that one year of decoupling does not mean a future decoupling trend. However, this year-to-year variation is possible to overcome by looking at aggregated periods.

6.1.2 Aggregated Structure Effect

As mentioned before, the Structure Effect represents the change in the mix of activities, and therefore it is required to be analysed as aggregated data and not by subsector. The Structure effect will provide insight into one potential reason for the behaviour of the Energy Intensity rate.

Table 6: Yearly Structure Effect

Year Period	Structure Effect
2015 - 2016	1,02
2016 - 2017	0,95
2017 - 2018	1,10
2018 - 2019	0,97
2019 - 2020	1,02
2015 - 2020	1,00
2015 - 2019	1,01

The yearly structure effect ranges from a 0,95 decoupling to 1,10 coupling. Neither of them represents a very strong effect, which indicates that the industry product mix has not changed too much on the selected years, and that the year-to-year changes reflect the above mentioned changes in product demand, instead of a constant change of the sub sectoral weight in the economy. It is relevant to note that while the overall Energy Intensity rate for the 2018-2019 period was the highest, the Structure Effect was one of the lowest, representing a temporary product mix shift to less energy intensive subindustries. Across the whole period, the Structure Effect had no impact on the Energy Intensity rate.

6.1.3 Sub sectoral Analysis

After having commented on the overall Energy Intensity ratios, and the aggregated Structure Effect, it becomes relevant to disaggregate the data into the subsectors that integrate it. The representative factor from which to look at on a disaggregated way is the Intensity Effect, because it reflects within sector changes, meaning the technological advancements that are diving each sector's energy efficiency up or down.

From the 21 analysed subsectors, the biggest ones in terms of monetary Value Added are the Manufacture of Food Products, which represent around 33% of Value Added each year, and the Manufacture of Chemicals and Chemical Products, which represent around 14% of Value Added. In terms of energy consumption, the Manufacture of Food Products represents around 30% of consumption, followed by the Manufacture of Wood and Wood Products, which take up around 14% of the total energy.

A summary of the average Value Added weigh is presented on Table 7. On this table is possible to note that some subsectors represent most of the industry production, the main five being Food Products, Chemicals and Chemical Products, Beverages, Paper and Paper Products and Wood Products, covering almost 70% of the market. This leaves the other subsectors with a diminished relevance on the overall decomposition analysis.

Table 7: Industry Subsector Value Added Weight

Industry Subsector	**Value Added Weight (%)**
Food Products	32,62%
Beverages	8,75%
Textiles	0,63%
Wearing Apparel	0,89%
Leather and Related Products	0,61%
Wood and Wood Products	5,37%
Paper and Paper Products	8,45%
Printing and Reproduction of Recordings	1,02%
Chemicals and Chemical Products	13,71%
Pharmaceuticals	2,54%
Rubber and Plastics	4,16%

Industry Subsector	**Value Added Weight (%)**
Non-Metallic Mineral Products	4,20%
Basic Metals	1,44%
Electrical Equipment	1,11%
Machinery and Equipment	2,52%
Motor Vehicles	0,17%
Other Transport Equipment	0,17%
Furniture	0,97%
Other Manufacturing	0,14%
Repair and Installation of Machinery and Equipment	3,78%
Other Manufacturing Industries	6,75%

Because of their high participation in the Value Added and Energy Consumption, these five sectors are the ones that mostly drive the average Energy Intensity and Structure Effect. However, the analysis of the Intensity Effect in all sectors can give guidelines on which sectors are most decoupled regardless of the activity size, which could be interesting when looking at which subindustries to incentivize for the future of industry.

Table 8: Intensity Effect by Industry Subsector

	2015 - 2016	2016 - 2017	2017 - 2018	2018 - 2019	2019 - 2020	2015 - 2020	2015 - 2019
Food Products	**1,00**	**0,81**	**1,03**	**0,97**	**1,05**	**0,86**	**0,81**
Beverages	**1,01**	**0,93**	**1,03**	**1,03**	**0,99**	**0,98**	**0,99**
Textiles	1,00	0,99	1,00	1,00	1,00	1,00	1,00
Wearing Apparel	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Leather and Related Products	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Wood and Wood Products	**0,82**	**1,01**	**0,91**	**1,02**	**1,02**	**0,78**	**0,75**
Paper and Paper Products	**1,03**	**0,98**	**0,99**	**1,13**	**1,00**	**1,09**	**1,10**
Printing and Reproduction of Recordings	1,01	1,00	1,00	1,00	1,00	1,00	1,00
Chemicals and Chemical Products	**1,04**	**0,97**	**0,98**	**1,09**	**1,02**	**1,09**	**1,07**
Pharmaceuticals	1,01	1,06	0,93	0,99	1,00	1,00	1,00
Rubber and Plastics	1,03	0,93	1,04	1,02	0,99	1,02	1,03
Non-Metallic Mineral Products	1,03	0,96	0,99	0,98	0,99	0,97	0,98
Basic Metals	1,01	1,04	0,95	1,07	0,98	1,05	1,05
Electrical Equipment	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Machinery and Equipment	1,04	0,96	1,00	1,00	1,00	1,01	1,01
Motor Vehicles	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Other Transport Equipment	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Furniture	0,98	1,00	1,00	1,00	1,00	0,98	0,98
Other Manufacturing	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Repair and Installation of Machinery and Equipment	1,00	1,00	1,00	1,00	1,02	1,03	1,01
Other Manufacturing Industries	1,06	0,90	1,00	1,01	1,02	1,02	1,01
Overall Technological Decoupling	**1,06**	**0,60**	**0,86**	**1,36**	**1,07**	**0,83**	**0,75**

The Intensity Effect table shows that the highly coupled subsectors correspond to Paper and Paper Products, Chemicals and Chemical Products, and Basic Metals. This situation is especially relevant for the Chemicals subsector, given its high contribution to the Value Added by industry. Works on decoupling this subsector could be highly convenient from an efficiency point of view, especially considering the implications it will have on overall decoupling of the industry, however this means it could also potentially risk reducing the economic output of one of the most contributing subsectors. The Chemicals subsector already managed to show a decoupled Intensity Effect during 2016-2017 and 2017-2018, suggesting that future decoupling could be achieved.

Food Products on the other hand, is one of the most decoupled subsectors overall, while also being one of the biggest ones. With the exception of two periods (2017-2018 and 2019-2020), it has been actively decoupling, and being the biggest one in economic terms, it sets a positive precedent for Industry overall. The Chilean economy has also been historically exporter of Food Products, which means that this energy efficiency has also been beneficial to countries that import products from Chilean origins.

Wood and Wood Products is historically the most decoupled sector among all, although it only represents 5,4% of the Value Added. This subsector, as the opposite of Chemicals, is one subsector that could benefit the industry if it grows to take more of the product mix while maintaining the same energy efficiency, which could drive down Energy Intensity rates.

The Paper and Paper Products sector is also relevant for commenting. This subsector is tightly connected to the Forestry sector of the Chilean economy, which is outside of the industry scope, however, is very influential on the country's GDP. When compared to the rest of industry, this sector is in expansive coupling, which raises concerns that should alert policy makers. The sector is also attributed the overall Intensity Effect coupling on the 2018-2019 period, together with the Chemicals and Chemical Products sector.

The Paper subsector, together with the Wood Products sector also raise another important issue, that is not covered by the decomposition analysis, which is the industry's threat to biodiversity. Although is not in the scope of this research to analyse the industry's impact on forests and wildlife, it is relevant to pay attention to the decoupling results of these areas of Chilean industry given their potential threat to known external consequences. This is also in line with some of the critiques that the Chilean NDCs have received, of not including enough protection of biodiversity and forestry.

Finally, the Beverages sector presents an overall slightly decoupled Intensity Effect. This effect is relevant especially considering that the subsector is the third biggest contributor to Value Added. The sector has been pivoting between coupling and decoupling in the analysed period, which could call for more investments on Energy Efficiency technology to set the industry in a clear decoupling path.

The sub sectoral analysis also considers other industries that have not had a significant change during the 2015-2020 period. This effect is mostly due to the disparity of the Value Added, with the already commented subsectors taking up most of the market.

Overall, it is possible to see that there is a strong disparity between the most relevant subsectors, with some of them being highly decoupled and others in expansive coupling. This scenario raises thoughts about the disparity in investments in Energy Efficiency Technology, and the share of good efficiency practices among sub industrial processes, which seem to have impacted some sectors more than others, according to the obtained Intensity Effect.

6.2 Discussion

After presenting the results, the implications of some key findings are worthy of further comments, because of their impact on the analysis, and on future conclusions and policies that may emerge from the numerical output.

6.2.1 Sectoral Effects and Implications

As it was shown before, the structure effect from the 2015-2020 period was constant, meaning that the increase in production from the industry sector carried an equal increase of energy intensity, without changing the product mix. This is in line to findings by Duran et al. in 2015, that commented that energy consumption was explained by the level of output, and not by improvements in energy efficiency. The result of this effect presents a scenario that reflects that industry wide efforts to shift towards less energy intensive products have had no significant impact on energy efficiency on the analysed period, however, it might not be advisable to address the industry sector as a whole, because of the specific behaviour of firms in different subsectors (Duran et al., 2015). Nevertheless, a reduction on the structural effect will be very beneficial for decoupling overall industry emissions from economic growth.

The scenario reflected by the structural effect is almost opposite to the numbers presented when looking at the disaggregated data of the intensity effect for every subsector. While some sectors have maintained a trend of expansive coupling, others have been strongly contributing to decoupling. The disparity between the situation of different subsectors could be interpreted as a reflection of the different challenges and limitations that the areas have, but it could also be due to the efforts that some companies have put into energy efficiency, using more modern technology, electrifying production, and other measures. According to the Chilean Energy Efficiency Agency, these types of measures are strong contributions to higher energy efficiency (Hidalgo et al., 2018), and several companies have conducted work with the agency on these same subjects, therefore they may have implemented energy efficiency measures that resulted in sub sectoral decoupling, which is shown by the resulting analysis, although direct evidence of the implementation of energy efficiency measures was not analysed in the context of this research, and would have to be confirmed in further publications.

On the other hand, some subsectors are showing no relevant signs of moving into decoupling area. According to Hidalgo et al. (2018), the challenges that these companies are facing are of a technical, but also organizational nature. Better technologies are available, and according to the European Commission, some of these sectors have strong potential for energy efficiency, especially the ones that are most coupled in Chilean industry, with Paper and Paper Products having unachieved efficiency potentials of 19% and Chemical Products having potentials of

25% (Chan & Kantamaneni, 2015). These potentials show not only that it is possible for these sectors to decouple, and that there are not significant technical limitations, but also that the subindustries are facing challenges of another nature preventing them from decoupling. These limitations are likely to originate from corporate government issues, with most of companies in industry not having energy efficiency incorporated into their company strategy, or doing the necessary check-ups that their projects are following future-proof energy efficiency standards (Hidalgo et al., 2018). These lack of decoupling signs for the mentioned subindustries may also come from a lack of innovation projects, defined as investments that introduce new technologies to the company, with only 10% of the whole industry sector having developed innovation projects on the 2019-2020 period (Observa, 2020)

6.2.2 COVID-19 Impact on data and decoupling efforts

It was stated before that the results from the 2020 period may not be representative of the sector's efforts, because of the economic stagnation due to the COVID-19 pandemic, but although there was a visible effect of the pandemic in the country's GDP and overall CO2 emissions, as shown by Figures 5 and 6, industry decoupling factors did not really show any considerable changes when excluding 2020 from the analysis. This scenario can be explained by two factors: firstly, the nature of technology improvement and energy efficiency projects in an industrial context is of a longer term, so the potential effects of the pandemic in investment would not show when analysis data from 2020, but in later years.

Secondly, the choosing of the multiplicative LMDI-I method sets energy intensity as the analysed rate, which means that the method is less susceptible to energy consumption increases and decreases, and more to energy efficiency ones. Since industry production and consumption are strongly tied, because of the nature of industry, a diminishing of production output will also come with a diminishing of energy consumption, thus maintaining energy efficiency at similar levels than non-pandemic years in the short run. On the long run there is a possibility for some firms to close down some areas due to low production outputs, which may lead to a difference in the decoupling factors.

6.2.3 Past and future Public Policy implications

Although the empirical analysis presented favourable results in terms of decoupling and energy efficiency overall, and for most of the important industry subsectors, there has not been a strong public policy directly addressing industry's energy consumption until the NDC update in 2022. Previous efforts like the National Energy Efficiency Programme (NEEP), the 2008 energy policy called "Nuevos lineamientos", the setting up of the Chilean Association for Energy Efficiency in 2010, and the National Energy Strategy implementation in 2012 were considered to have not been sufficient to reduce the energy intensity of industry (Román-Collado et al., 2018, p. 289), and although the publication of an Energy Efficiency Law had been hinted for several years, there were not visible guidelines on what the industry should expect until the first part of the document was published on 2021 (Ministerio de Energía, 2023).

Previous research hinted the lack of public policy regarding this issue as well. Duran et al. (2015, p. 559) mentioned that it was “advisable to design energy efficiency policies that consider the specific behaviour of firms in each subsector”, raising the concern for specifically designed policies that addressed the diverse contexts present in the industry sector, adding than until that point, the Chilean energy agenda only considered a homogeneous and single energy efficiency policy for industry as a whole (Duran et al., 2015, p. 559). Román-Collado et al. (2018) also mentioned that the country’s energy policy was lacking the implementation of energy saving and efficiency measures that influence the key and most exporting sectors, such as industry.

Policies that were implemented after the analysed period of previous research might have had an impact on the numbers reviewed on this document that was unseen before, however, since policy of this nature does not reflect instantly on the results, there is insufficient evidence to assert that policies such as the National Energy Strategy helped increase energy efficiency of industry in the period from 2015 onwards.

Recent policy updates in Chile may have addressed the challenges previously identified in relation to energy efficiency in the country's industrial sector. One such policy update is the Energy Efficiency Law, which was approved in 2023 and focuses specifically on improving the energy efficiency of industry. The law requires companies to optimize their energy consumption through the implementation of energy management programs, which recommend specific projects and report the results using measuring and verification methods.

The Energy Efficiency Law has the potential to help close the gap between different sub-sectors of the industrial sector in Chile by tailoring energy efficiency measures to specific needs. By doing so, it may encourage greater uptake of energy efficiency measures and promote the adoption of best practices across the sector.

However, it is important for future policy makers to critically evaluate the effectiveness of the Energy Efficiency Law in achieving its intended goals. Future policy design that addresses this matter in particular, will have to consider the effects of this latest effort, and determine the extent to which this policy has contributed to improved energy efficiency in the sector, to identify any areas where further improvements may be necessary.

The results of the analysis that this thesis presents stresses that some subgroups within industry are already decoupled, which has led to an average decoupling of industry, and therefore future policies should not only consider addressing the subsectors that are more energy intensive, but also help strengthen the ones that have already achieve decoupling. As it was shown by the Food Product, Beverages and Wood Products subsectors, although they achieved relative decoupling during the analysed period, there were years where they struggled with their efficiency. In contrast, sectors such as Paper Products and Chemicals would benefit from direct policy recommendations to achieve decoupling. Public policy should address this issue to ensure that the decoupled subsectors constantly keep moving into more efficient production, and keep growing and gaining influence on the Chilean economy, while the least energy efficient ones move into achieving decoupling.

7 Conclusions

In the recent years, Chile has made great improvements in terms of sustainability and energy efficiency, and although these improvements were highlighted by international media, expert analysis still concludes that the country needs to make further efforts to reach the desired climate scenario for 2050.

For further understanding of the situation, energy consumption for the most intensive sectors of the economy has been analysed by previous researchers, and up to 2015, no clear improvements were seen when it comes to reducing emissions in relation to the economic output. However, recent policy changes and efficiency efforts had not been taken into consideration in these analysis.

This study researched the energy efficiency of one of the biggest energy consumers, the industry sector. The process was done with a method called Multiplicative LMDI-I, or decomposition analysis, that allows for deeper understanding of the reasons behind energy efficiency decoupling from economic output. The aim of this research was to critically discuss the improvements that were made by industry, while highlighting the efforts that are still necessary, using a dataset that specified subindustries energy consumption and economic contribution to GDP.

The results of the analysis showed that, for the subset analysed, industry as a whole was in decoupling during the 2015-2020 period. Further analysis found that while some sectors contributed highly to this decoupling, others showed no signs of detaching their economic output from their energy intensity. The research also found that most of the decoupling was attributed to an intensity effect, which is related to technological improvements implemented by the different subsectors, and that there was not any clear structural effect of the whole industry, meaning that the mix of activities has not moved into less energy intensive areas.

The overall findings present a different conclusion than the previous research. While earlier publications argued that the country's industry was still far from decoupling, based on the analysed data, the current dataset presented with clear signs of an increased energy efficiency, in relation to the economic output. Policy implementations that were put in place in between the previous research analysis and this one, like the 2008 "Nuevos Lineamientos" policy and the National Energy Strategy in 2012, could have had an impact, but there is not enough evidence to affirm it.

Although conclusions from the current analysis of the available data show decoupling of industry, this is of a preliminary nature, and giving the limitations derived from the dataset, the studied period, the exclusion of the mining industry, and the use of electricity as an approximation for energy, further research that overcome these limitations is required to validate the findings of this thesis. If proven true, the implications for industry subsectors and policy making are of a positive nature, but also highlights areas in need of further attention and targeted efforts to increase decoupling for all subsectors, in and outside industry.

In summary, this study has presented evidence that the trend of energy efficiency in the Chilean industrial sector may be shifting in a positive direction in recent years. While further research is needed to validate these findings and extend them to a broader context, the results suggest a promising outlook for decoupling energy intensity from economic productivity. This underscores the potential for targeted policy interventions and private sector investments in energy efficiency to drive sustainable economic growth in Chile and other countries facing similar challenges.

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Appendix A: Industry Sub Sectors

Division	Group	Class	Description
Division 10			**Manufacture of food products**
	101	1010	Processing and preserving of meat
	102	1020	Processing and preserving of fish, crustaceans and molluscs
	103	1030	Processing and preserving of fruit and vegetables
	104	1040	Manufacture of vegetable and animal oils and fats
	105	1050	Manufacture of dairy products
	106		Manufacture of grain mill products, starches and starch products
		1061	Manufacture of grain mill products
		1062	Manufacture of starches and starch products
	107		Manufacture of other food products
		1071	Manufacture of bakery products
		1072	Manufacture of sugar
		1073	Manufacture of cocoa, chocolate and sugar confectionery
		1074	Manufacture of macaroni, noodles, couscous and similar farinaceous products
		1075	Manufacture of prepared meals and dishes
		1079	Manufacture of other food products n.e.c.
	108	1080	Manufacture of prepared animal feeds
Division 11			**Manufacture of beverages**
		1101	Distilling, rectifying and blending of spirits
		1102	Manufacture of wines
		1103	Manufacture of malt liquors and malt
		1104	Manufacture of soft drinks; production of mineral waters and other bottled waters
Division 12			**Manufacture of tobacco products**
	120	1200	Manufacture of tobacco products
Division 13			**Manufacture of textiles**
	131		Spinning, weaving and finishing of textiles
		1311	Preparation and spinning of textile fibres
		1312	Weaving of textiles
		1313	Finishing of textiles
	139		Manufacture of other textiles
		1391	Manufacture of knitted and crocheted fabrics
		1392	Manufacture of made-up textile articles, except apparel
		1393	Manufacture of carpets and rugs
		1394	Manufacture of cordage, rope, twine and netting
		1399	Manufacture of other textiles n.e.c.
Division 14			**Manufacture of wearing apparel**
	141	1410	Manufacture of wearing apparel, except fur apparel
	142	1420	Manufacture of articles of fur
	143	1430	Manufacture of knitted and crocheted apparel

Division	Group	Class	Description
Division 15			**Manufacture of leather and related products**
	151		Tanning and dressing of leather; manufacture of luggage, handbags, saddlery and harness; dressing and dyeing of fur
		1511	Tanning and dressing of leather; dressing and dyeing of fur
		1512	Manufacture of luggage, handbags and the like, saddlery and harness
	152	1520	Manufacture of footwear
Division 16			**Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials**
	161	1610	Sawmilling and planing of wood
	162		Manufacture of products of wood, cork, straw and plaiting materials
		1621	Manufacture of veneer sheets and wood-based panels
		1622	Manufacture of builders' carpentry and joinery
		1623	Manufacture of wooden containers
		1629	Manufacture of other products of wood; manufacture of articles of cork, straw and plaiting materials
Division 17			**Manufacture of paper and paper products**
		1701	Manufacture of pulp, paper and paperboard
		1702	Manufacture of corrugated paper and paperboard and of containers of paper and paperboard
		1709	Manufacture of other articles of paper and paperboard
Division 18			**Printing and reproduction of recorded media**
	181		Printing and service activities related to printing
		1811	Printing
		1812	Service activities related to printing
	182	1820	Reproduction of recorded media
Division 19			**Manufacture of coke and refined petroleum products**
	191	1910	Manufacture of coke oven products
	192	1920	Manufacture of refined petroleum products
Division 20			**Manufacture of chemicals and chemical products**
	201		Manufacture of basic chemicals, fertilizers and nitrogen compounds, plastics and synthetic rubber in primary forms
		2011	Manufacture of basic chemicals
		2012	Manufacture of fertilizers and nitrogen compounds
		2013	Manufacture of plastics and synthetic rubber in primary forms
	202		Manufacture of other chemical products
		2021	Manufacture of pesticides and other agrochemical products
		2022	Manufacture of paints, varnishes and similar coatings, printing ink and mastics
		2023	Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations
		2029	Manufacture of other chemical products n.e.c.
	203	2030	Manufacture of man-made fibres
Division 21			**Manufacture of pharmaceuticals, medicinal chemical and botanical products**
	210	2100	Manufacture of pharmaceuticals, medicinal chemical and botanical products

Division	Group	Class	Description
Division 22			**Manufacture of rubber and plastics products**
	221		Manufacture of rubber products
		2211	Manufacture of rubber tyres and tubes; retreading and rebuilding of rubber tyres
		2219	Manufacture of other rubber products
	222	2220	Manufacture of plastics products
Division 23			**Manufacture of other non-metallic mineral products**
	231	2310	Manufacture of glass and glass products
	239		Manufacture of non-metallic mineral products n.e.c.
		2391	Manufacture of refractory products
		2392	Manufacture of clay building materials
		2393	Manufacture of other porcelain and ceramic products
		2394	Manufacture of cement, lime and plaster
		2395	Manufacture of articles of concrete, cement and plaster
		2396	Cutting, shaping and finishing of stone
		2399	Manufacture of other non-metallic mineral products n.e.c.
Division 24			**Manufacture of basic metals**
	241	2410	Manufacture of basic iron and steel
	242	2420	Manufacture of basic precious and other non-ferrous metals
	243		Casting of metals
		2431	Casting of iron and steel
		2432	Casting of non-ferrous metals
Division 25			**Manufacture of fabricated metal products, except machinery and equipment**
	251		Manufacture of structural metal products, tanks, reservoirs and steam generators
		2511	Manufacture of structural metal products
		2512	Manufacture of tanks, reservoirs and containers of metal
		2513	Manufacture of steam generators, except central heating hot water boilers
	252	2520	Manufacture of weapons and ammunition
	259		Manufacture of other fabricated metal products; metalworking service activities
		2591	Forging, pressing, stamping and roll-forming of metal; powder metallurgy
		2592	Treatment and coating of metals; machining
		2593	Manufacture of cutlery, hand tools and general hardware
		2599	Manufacture of other fabricated metal products n.e.c.
Division 26			**Manufacture of computer, electronic and optical products**
	261	2610	Manufacture of electronic components and boards
	262	2620	Manufacture of computers and peripheral equipment
	263	2630	Manufacture of communication equipment
	264	2640	Manufacture of consumer electronics
	265		Manufacture of measuring, testing, navigating and control equipment; watches and clocks
		2651	Manufacture of measuring, testing, navigating and control equipment
		2652	Manufacture of watches and clocks
	266	2660	Manufacture of irradiation, electromedical and electrotherapeutic equipment

Division	Group	Class	Description
	267	2670	Manufacture of optical instruments and photographic equipment
	268	2680	Manufacture of magnetic and optical media
Division 27			**Manufacture of electrical equipment**
	271	2710	Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus
	272	2720	Manufacture of batteries and accumulators
	273		Manufacture of wiring and wiring devices
		2731	Manufacture of fibre optic cables
		2732	Manufacture of other electronic and electric wires and cables
		2733	Manufacture of wiring devices
	274	2740	Manufacture of electric lighting equipment
	275	2750	Manufacture of domestic appliances
	279	2790	Manufacture of other electrical equipment
Division 28			**Manufacture of machinery and equipment n.e.c.**
	281		Manufacture of general-purpose machinery
		2811	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines
		2812	Manufacture of fluid power equipment
		2813	Manufacture of other pumps, compressors, taps and valves
		2814	Manufacture of bearings, gears, gearing and driving elements
		2815	Manufacture of ovens, furnaces and furnace burners
		2816	Manufacture of lifting and handling equipment
		2817	Manufacture of office machinery and equipment (except computers and peripheral equipment)
		2818	Manufacture of power-driven hand tools
		2819	Manufacture of other general-purpose machinery
	282		Manufacture of special-purpose machinery
		2821	Manufacture of agricultural and forestry machinery
		2822	Manufacture of metal-forming machinery and machine tools
		2823	Manufacture of machinery for metallurgy
		2824	Manufacture of machinery for mining, quarrying and construction
		2825	Manufacture of machinery for food, beverage and tobacco processing
		2826	Manufacture of machinery for textile, apparel and leather production
		2829	Manufacture of other special-purpose machinery
Division 29			**Manufacture of motor vehicles, trailers and semi-trailers**
	291	2910	Manufacture of motor vehicles
	292	2920	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers
	293	2930	Manufacture of parts and accessories for motor vehicles
Division 30			**Manufacture of other transport equipment**
	301		Building of ships and boats
		3011	Building of ships and floating structures
		3012	Building of pleasure and sporting boats
	302	3020	Manufacture of railway locomotives and rolling stock

Division	Group	Class	Description
	303	3030	Manufacture of air and spacecraft and related machinery
	304	3040	Manufacture of military fighting vehicles
	309		Manufacture of transport equipment n.e.c.
		3091	Manufacture of motorcycles
		3092	Manufacture of bicycles and invalid carriages
		3099	Manufacture of other transport equipment n.e.c.
Division 31			**Manufacture of furniture**
	310	3100	Manufacture of furniture
Division 32			**Other manufacturing**
	321		Manufacture of jewellery, bijouterie and related articles
		3211	Manufacture of jewellery and related articles
		3212	Manufacture of imitation jewellery and related articles
	322	3220	Manufacture of musical instruments
	323	3230	Manufacture of sports goods
	324	3240	Manufacture of games and toys
	325	3250	Manufacture of medical and dental instruments and supplies
	329	3290	Other manufacturing n.e.c.
Division 33			**Repair and installation of machinery and equipment**
	331		Repair of fabricated metal products, machinery and equipment
		3311	Repair of fabricated metal products
		3312	Repair of machinery
		3313	Repair of electronic and optical equipment
		3314	Repair of electrical equipment
		3315	Repair of transport equipment, except motor vehicles
		3319	Repair of other equipment
	332	3320	Installation of industrial machinery and equipment