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# Analysis and decomposition of energy consumption in the Chilean industry

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## HIGHLIGHTS

- We use Index Decomposition Analysis to study energy consumption in Chilean industry.
- We use the Logarithmic Mean Divisia Index method I and econometric estimations.
- Energy consumption and intensity are studied for different sub-sectors and firms.
- We find energy efficiency looses in industry with stable energy consumption.
- Sectors are idiosyncratic so differentiated sectoral policies are preferable.

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## ABSTRACT

With rising energy costs and climate change concerns, energy efficiency will be important in maintaining competitiveness and reducing the environmental impact of industrial activities. In this paper we study the Chilean industrial sector, which is the largest consumer of energy within the country. Energy demand and $CO_2$ emissions in Chile have grown rapidly in recent years while energy supply is mostly imported and subject to disruption. Therefore, it is important to understand energy consumption in this sector and determine which sub-sectors have the greatest potential to reduce energy consumption. We used the Index Decomposition Analysis (IDA), applying the Logarithmic Mean Divisia Index method I (LMDI-I), to quantify the impact of diverse driving factors on energy consumption. Furthermore, a panel data analysis was used to determine whether there are differences in energy intensity across firms with different characteristics. Our results show that energy intensity has risen over time although energy consumption remains stable. This fact supports the idea that energy efficiency policies could play an important role for the industrial sector. Additionally, energy consumption and energy intensity follow different patterns in each sub-sector; therefore we conclude that the application of differentiated sectoral policies is preferable over a single global policy.



## 1. Introduction

As nations face rising energy costs and growing concerns about climate change, energy efficiency becomes a key element in achieving a secure energy supply. Energy efficiency can be considered as an additional energy source resulting from reducing energy consumption while maintaining a given level of output; this reduction in energy consumption is achieved by improving either technology or process efficiency. In the energy economic literature, changes in energy intensity are often used as a proxy of change in energy efficiency (Choi and Ang, 2010). Energy intensity is defined as the amount of energy consumed per unit of output. Improved energy efficiency allows industries to reduce their energy intensity, achieving the same level of output with lower costs and less pollution (Reddy and Ray, 2011).

The International Energy Agency (IEA) has argued that increases in the industrial sector's energy efficiency are central in maintaining a sustainable and secure energy supply. Moreover, industry is expected to achieve the highest level of $CO_2$ savings among all other priority areas (building, appliances, lighting and transport) if the appropriate measures are implemented (IEA,

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2011). In the case of Chile, the industrial sector is the largest energy consumer of the country accounting for approximately 36% of the total energy consumption. Together with the mining sector, the Chilean industry demands 64% of all electricity generated in the country (CNE, 2012). Total energy consumption in Chile has more than doubled since 1991 (Ministry of Energy, 2013). In order to meet the growing demand, Chile has intensified the use of coal as a source of electricity generation, which has increased the share of this fossil fuel in the current energy mix and has raised $CO_2$ emissions significantly (IEA, 2009). Current energy policies have focused on finding ways to improve energy efficiency, especially in the industrial and mining sectors. However, these policies are only at the planning stage and until now, they only provide general guidelines (Ministry of Energy, 2013).

The objective of this article is to analyze the factors that explain changes in energy consumption in different sub-sectors of the Chilean industry, and examine whether energy intensity differs across firms' industrial sub-sectors, size and ownership type. This information could help policymakers to determine which sub-sectors and firms should be prioritized in order to focus policies, reduce energy consumption and minimize costs.

During the last decade, the Index Decomposition Analysis (IDA) (Ang and Zhang, 2000; Ang, 2004; Liu and Ang, 2007) has been a technique widely used to track energy efficiency trends. This technique studies the impact of different factors on changes in energy consumption. The IDA considers that three different effects influence changes in energy consumption: (i) changes in the overall level of economic activity (the activity effect); (ii) changes in the structure or the activity mix of the economy (the structural effect) and (iii) changes in energy intensity (the intensity effect) (Ang et al., 2010). The intensity effect is used to measure changes in energy efficiency. Isolating the impact of changes in energy intensity is important to measure the real effect of energy efficiency policies and to determine the sectors that should be prioritized (IEA, 2014).

The present study uses the Logarithmic Mean Divisia Index decomposition method I (LMDI-I) (Ang, 2005; Ang et al., 2010) to analyze the impact that energy intensity changes have on energy consumption in different sub-sectors of the Chilean industry. In addition, an econometric analysis is used to study the determinants of energy intensity; specifically, the effects that some firms' characteristics have on this variable. The main contribution of our paper to existing literature is the extension of the analysis to the inclusion of other characteristics of the firms such as size and ownership type (in addition to the industrial sub-sector) in the design of energy policies.[1]

The organization of this paper is as follows. Section 2 describes the Chilean energy and industrial background. Section 3 presents the IDA framework and the LMDI-I approach in greater detail. Section 4 shows the results of the IDA in the Chilean industry by industrial sub-sector, size and ownership type. This section also presents the results of the econometric analysis. Finally, Section 5 concludes the paper and presents policy recommendations.

## 2. The Chilean energy background

Total energy consumption in Chile increased by 122% between 1991 and 2011. This increase is primarily explained by the continued expansion in the scale of the economy with rising gross domestic product (GDP). The goal of Chile's Energy Ministry is to promote the decoupling between economic growth and energy consumption (Ministry of Energy, 2013). Oil, gas, and coal represent 78% of the total primary energy consumption, and the country imports close to 80% of these fossil fuels (IEA, 2009). This external dependence makes Chile highly vulnerable to external shocks in energy markets. This became clear when in 2004 the gas crisis took place in Argentina (See Ponzo et al. (2011) for a detailed explanation of the Argentinean gas crisis and Reinhardt et al. (2011) for an analysis of the impact of the Argentinean gas crisis in Chile). On this occasion, the neighboring country interrupted all natural gas exports to meet its domestic demand, leaving Chile in a critical situation.

National emissions of $CO_2$ increased by almost 125% between 1990 and 2010, reaching a level of 69.7 million tons. Industrial activity, including the generation of electricity and heat for industrial use, accounts for about 50% of national $CO_2$ emissions (IEA, 2012). Investment in new coal-powered plants is expanding at a much faster rate than renewable energy sources (IEA, 2009). For these reasons, both energy efficiency policies and the promotion of renewable energy sources are necessary to meet the national emissions' targets.

The current energy efficiency target of the Chilean government is to achieve a 12% reduction respect to 2010 in the projected energy consumption by 2020. In order to meet this target, the new action plan requires that 39% of the expected reduction occur in the industrial and mining sectors (Ministry of Energy, 2013). The policy measures identified by the government to help meet these targets are: first, promoting the implementation of energy management systems; second, promoting and encouraging cogeneration; third, promoting technical assistance; and lastly, incorporating efficient technologies. Although Chilean policies are in line with the recommendations given by the IEA (2011), they only present general guidelines and there are no energy policies in place which directly address specific energy efficiency goals. The objective of this paper is to help identify where to focus future energy efficiency policies in order to achieve cost-effective reductions of energy consumption.

## 3. Methodology and data

IDA has been widely used to study the factors behind changes in energy consumption. Although a wide variety of decomposition techniques have been proposed during 1980s and 1990s (Ang, 1995b), IDA is today a consolidated technique in standardization process (Liu and Ang, 2007). In the last two decades, IDA has been used to study energy-related $CO_2$ emissions (Su and Ang, 2012; Xu and Ang, 2013) and more recently to deal with spatial issues in multi-region comparisons (Ma, 2014; Ang et al., 2015). IDA estimates the impacts of three different effects driving changes on energy consumption. These effects are:

(i) The *activity effect*. This effect considers changes in the scale of economic activity or in the level of output of the entire economy, under the assumption that an increase in the level of this output involves an increase in energy consumption. At the aggregated and sectoral level, this effect is usually measured by monetary indicators (e.g. Gross Domestic Product or value added).
(ii) The *structural effect*. This effect considers changes in the mix of activities. These changes have an impact on energy consumption because each activity has different energy intensiveness; for example, energy consumption will grow if a high intensity industry (e.g. oil extraction) increases its output share within the economy (Rue du Can et al., 2012).[2]

[1] Previous studies have limited the application of IDA to different sectors of the economy (e.g. transport, residential, commercial and industrial) and further sub-sectors (e.g. food, agriculture, etc.). However, to our knowledge, no previous studies have introduced the analysis of differentiated characteristics of firms, such as size or ownership type.

[2] Note that this is the standard definition provided by the decomposition analysis literature. We will perform decomposition analysis for three different sub-categories and the interpretation of the structural effect will depend on the categorization applied. This is explained in more detail later in this section.