Economic Crises and Energy Use: An Input-Output Analysis of Catalonia's 2008–2014 Financial Crisis

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Abstract

The impact of economic crises on an economy's energy consumption, considering its sectorial interactions, remains an unexplored area. For this article, we investigated the structural sectorial relationships in energy terms before, during, and after Catalonia's 2008–2014 financial crisis, using environmentally extended input-output analysis. We used three input-output tables from 2005, 2011, and 2014, for which we constructed and employed five vectors representing sectorial energy consumption ('natural gas', 'coal', 'petroleum', 'electricity', and 'biomass and waste') for 41 economic sectors. We studied the evolution of backward and forward linkage coefficients in terms of energy, as well as key sectors over this period. Our findings reveal that most sectors, particularly energy-intensive ones, experienced a reduction in both backward and forward linkages. However, the relative importance of sectors in the Catalan economy remained relatively stable, indicating a certain level of persistence in this indicator throughout the period, despite the economic crisis.

Keywords: Financial crisis; energy use; environmentally extended input-output analysis; key sectors; economic structure.

JEL Classifications: C67, Q43.

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1. Introduction

In the opinion of many experts, the global financial crisis of 2007–2009 was the most impactful economic crisis since the Great Depression (1929–1939). The crisis triggered a significant global decline in economic activity (Claessens and Kose, 2013). In Spain, the crisis began a year later but had a heavy impact because of the housing bubble (Martin et al., 2018) and poor previous supervision of the financial sector (Santos, 2017). It is usually known as the "2008–2014 Spanish financial crisis," and it changed the socioeconomic landscape in many respects. From an environmental or an ecological economics perspective, one of the understudied aspects of this (and other) economic crises is the effect on the use of natural resources—not only in terms of their direct use but also from a structural perspective, considering the long-term changes that crises trigger in consumption and productive structures and the implications of these crises on their use.

By using a variety of tools, scholars can assess the direct and indirect economic impacts of policies or shocks such as an economic crisis. One of the most popular among applied researchers are input-output (I-O) models theoretically based upon the Arrow-Debreu model (Geanakoplos, 1989) and Walrasian equilibrium (Walras, 1954). These can reveal direct and indirect impacts at the sectoral level in terms of different macroeconomic indicators such as production, gross value added (GVA), jobs, or imports. They were first developed by Leontief (1941) as an abstract representation of the technology used by the productive sectors of an economy, specifying input requirements and other factors necessary to produce each good or service.

Some studies conducted in the 1970s related economic systems to natural systems and the environment. Isard et al. (1968) pioneered this type of study by proposing a methodology based on I-O tables, mixing economic and environmental variables to offer more economic policy alternatives. Other scholars (Leontief, 1970; Leontief and Ford, 1971; Chapman, 1974; Bullard III and Herendeen, 1975; Casler and Wilbur, 1984; Proops, 1988; Lenzen et al., 2004; Alcántara and Padilla, 2009) subsequently made further developments to this approach, modelling different aspects of the relationships between the productive structure of an economy and the environment. Related to the I-O analysis, Rasmussen (1956) first developed the concept of "key" sectors, which are defined as having high multiplier effects on final demand and can be linked to environmental impacts or the use of resources use such as different energy sources. For energy resources, for instance, "key" sectors are those which

have more importance than others in driving the energy consumption of other productive branches and, in turn, in inducing other sectors to consume energy. These sectors have high values for both their forward linkages and their backward linkages in terms of I-O analysis, as we will define later (Alcántara, 1995).

Focusing on economic and financial crises and energy, some scholars have analyzed this relationship; however, few have studied it from an economic structural perspective. Yuan et al. (2010) analyzed the influence on energy consumption and economic growth of the global financial crisis of 2007–2009 and the resulting stimulus plan using an I-O analysis. The results showed that the fall of exports led to a decrease of 7.33% in GDP (gross domestic product) and a 9.21% drop in energy consumption. Roinioti and Koroneos (2017) performed a decomposition analysis of CO_2 emissions in Greece to assess changes in the contributions of different factors during the economic crisis in Greece (2008–2013). Bekhet and Yasmin (2014) used I-O analysis to study the influence of the crisis on Malaysia's energy consumption, finding that a decline in exports produced a 13% decrease in GDP and a 16% reduction in energy consumption. Additionally, they found that the stimulus plans reduced the effects of the crisis and increased economic growth and energy consumption by 1.83% and 4.62%, respectively, by adapting and using an I-O table from 2005 with 19 sectors for the analyses.

In our research, we studied the impact of a financial crisis on direct and indirect energy use through energy I-O analysis and the concept of key sectors. We analyzed the case study of Catalonia during the 2008–2014 financial crisis by comparing the following three periods: precrisis (2005), midcrisis (2011), and postcrisis (2015). Unlike previous studies, we used three different I-O tables, reflecting the actual productive structures under the different stages of the crisis, as well as five different energy products for each of these three periods, at a highly disaggregated industry level (41 sectors). This article continues as follows: section 2 shows the data we used and the energy consumption vectors we built, section 3 describes our methodology, section 4 presents the main results of the research, and section 5 concludes the article.

2. Data

2.1. Data sources

I-O tables are a basic component in the construction of national accounting systems (NAS), as recognized by the United Nations Accounts Manual (SNA-93) and the European System

of National and Regional Accounts 1995 (SEC-95). They allow approximation of the main macro-magnitudes that define an economy such as gross domestic product (GDP), gross value added (GVA), income generated (wages and gross surplus), and other various concepts to include aggregate demand of the economy: private consumption, public consumption, investment, and foreign demand. Statistical institutes estimate these concepts by establishing a balance between the total resources available to the economy and their uses. The table is a double-entry matrix of the economic relationships of an economy over a given period, usually a year.

The Statistical Institute of Catalonia (Idescat) publishes the I-O tables for Catalonia (TIOC). Tables are currently available for the years 2001, 2005, 2011, 2014 and 2016, with different new sectoral breakdowns. The methodological reference used for its preparation is the SEC-95. For this study, we used the 2005 (before the financial crisis), 2011 (middle of the crisis), and 2014 (after the crisis) tables. Because the tables have different sectorial aggregations, we uniformly adopted a classification of 41 industries across all of them. Environmental satellite data provided information at the sectoral level at the same disaggregation as the I-O tables. Satellite data can include pollutant emissions, energy use, or other resource use within a homogeneous system compatible with the I-O table framework. Currently, regarding pollutant emissions in Catalonia, there are only the 2001 satellite accounts of atmospheric emissions (Alcántara et al., 2009), so we developed a matrix of different energy consumption vectors with the same aggregation level as the I-O tables for the relevant years of the analysis (2005, 2011, and 2014), which we detailed in section 2.3.

We used the following data sources to develop the energy satellite accounts for Catalonia: (1) Catalan energy balances from the Catalan Energy Institute;[3] (2) statistics on energy consumption in the industrial sector (ECESI)[4] from the Catalan Energy Institute; (3) electricity supply data from Endesa power supply company; and (4) EORA (Lenzen et al., 2013) to reallocate energy consumption to specific sectors. EORA is a multiregional I-O framework which includes inter-sectoral transfers, including trade, amongst 15,909 sectors across 190 countries, containing a complete time series for the period 1990–2021. It also includes satellite accounts with sectoral information on several resources such as energy use.

[3] https://icaen.gencat.cat/ca/energia/estadistiques/resultats/anuals/balanc_energetic/.
[4] https://icaen.gencat.cat/ca/energia/estadistiques/resultats/sectorials/ecesi/index.html.

2.2. Data homogenization and aggregations

The homogenization of the data structure was a key step in setting up a common framework for the sectoral disaggregation of both the economic and the energy data. The different data sources used to develop the I-O framework and the energy satellite accounts contain different levels of aggregation. The first task was to develop uniform sectorial aggregations with the highest possible sectorial detail while ensuring comparability between sources, as the Catalan I-O tables of 2001, 2005, and 2014 all have different aggregation levels. We finally fixed a total of 41 economic sectors.

To develop the energy accounts, we first had to align sectors of Catalan I-O tables with EORA tables. EORA data follow the ISIC methodology (United Nations, 2008) for sectorization, while the Statistic Institute of Catalonia uses CCAE (Catalan Classification of Economic Activities in Catalan) codes (IDESCAT, 2009), following the European NACE classification system. Hence, a direct comparison between the Catalan and EORA I-O tables is not feasible. During the aggregation process we found that: (i) some sectors included in the Catalan classification system were missing in EORA, and (ii) EORA had more sectoral detail for some industries, like the extractive industries sector. A summary of the aggregations conducted to align the Catalan tables (which include CCAE classifications) with EORA I-O tables can be seen in Appendix A.

2.3. Development of energy satellite accounts for Catalonia

We needed to create the Catalan energy accounts for the years 2005, 2011, and 2014 because there were no energy satellite accounts that could be integrated into Catalonia's input-output framework. We used energy balances from the Catalan Energy Institute (ICAEN)[5] as a main source, and we employed other supplementary data sources to distribute energy consumptions between the 41 economic sectors included in the Catalan I-O tables.

We were able to develop sectorial energy consumption vectors for the following five groups of energy products (41 sectors, years 2005, 2011, and 2014):

- Natural gas.

[5] The energy balance of Catalonia shows the production and consumption of primary energy, consumption in the transformation in electricity generation and in refineries and olefins plants, energy consumption specific to the sector, losses in energy transport and distribution, and non-energy consumption as well as final consumption by sector and energy source.

- Petroleum: aggregate of petroleum derivatives such as petroleum, LPG (liquified petroleum gas), gasoline, diesel, kerosene, fuel oil, etc.
- Coal.
- Biomass and waste.
- Electricity: This primary source includes all types of electricity generated from electricity generation with renewable energies to generation with fossil fuels.

Catalan energy balances provide information for these energy products but at very high levels of aggregation for just five major sectors: households, transport, primary sector, industry, and services. Therefore, we used additional information to break them down and obtain information for the 41 sectors of interest. For primary and tertiary sectors, we used information from EORA environmentally extended I-O tables, while for the secondary sector (industries), we could rely on other specific Catalan sources like ECESI or the power supply company Endesa, the main supplier in Catalonia. We extracted electricity consumption for all sectors from Endesa.

2.3.1. Industries

ECESI surveys provide information on the consumption of petroleum, coke, coal, fuel oil, diesel, liquefied petroleum gas (LPG), natural gas, forest biomass, biogas, solar thermal energy, non-renewable waste, and renewable waste for the different industrial sectors (from CCAE 05 to 32). In this case we just adapted the data of the different energy sources to match CCAEs used by the energy vectors developed at the industrial level.

Endesa is the main power supply company in Catalonia, representing around 96% of all supply excluding self-consumption. We disaggregated data from Endesa following the CNAE national classification system (Spanish classification), equivalent to the Catalan CCAE classification. We proceeded to aggregate the data at the same level as in the I-O matrix (41 sectors). Then, we projected this sectorial consumption to the remaining 4% of electricity consumption supplied by power supply companies other than Endesa. This electricity consumption was later compared with the Catalan energy balances to identify potential discrepancies, finding that the difference between the sources was just below 2%.

2.3.2. Primary and tertiary sectors

We first extracted the energy consumption data for primary and tertiary sectors—that is, those not included in the industry or the transport sectors—from the information provided by the Catalan energy balances and then reallocated them using the EORA I-O framework. We took as a reference the Spanish table from the EORA framework, including both the I-O table and the energy accounts for the economic sectors of Spain that EORA covers. We previously adapted the sectors of Spain included in EORA to the 41 sectors we could ultimately consolidate in the Catalan tables. Then, to allocate the energy consumption for each primary and tertiary sector to the Catalan tables, we compared the economic production for each specific sector between the Spanish economy and the Catalan economy as well as energy consumption, obtaining weights for the 41 aggregated sectors. Then, we used the Catalan energy balances published by ICAEN to multiply total primary and tertiary energy use to the weights, obtaining a proxy of the energy consumption realized by the different sectors included in the Catalan matrices. We applied this approach to all energy vectors described at the beginning of this section except for electricity, which we extracted from Endesa data following the same approach as the one followed for industries. With this approach, we assumed that Spanish and Catalan energy use have a similar sectorial structure and that production functions of both regions use a similar technology, which in our view is reasonable, considering that Catalonia represents around 20% of Spanish GDP.

2.3.3. Transport

We obtained Spanish energy consumption data from the Spanish Observatory of Logistics and Transport for energy consumption for different types of transport,[6] including maritime, land, and air transport. Then we applied the percentages recommended by transport experts of the Catalan Energy Institute, ICAEN: 43% of consumption is considered private (domestic), and the remaining 57% for the land transport sector itself, while for air and maritime transport, private consumption could be considered negligible.

3. Methodology

3.1. Input-output analysis

[6] https://apps.fomento.gob.es/BDOTLE/visorBDpop.aspx?i=314.

The simplified Leontief's production model makes the following assumptions: (i) each sector produces only one product; (ii) there are the same number of product suppliers and product users; (iii) technical coefficients are constant, representing the quantity of a commodity expressed in monetary units to produce one unit of another commodity; and (iv) there is exogeneity in alterations of the final demand or values added. A change in one of them will allow us to obtain the economic impact in terms of total production of the economy, both direct and indirect.

The row relationships within the I-O table can be symbolically represented as follows:

$$\begin{aligned} x_1 &= x_{11} + x_{12} + \ldots + x_{1n} + y_1 \\ x_2 &= x_{21} + x_{22} + \ldots + x_{2n} + y_2 \\ &\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ x_n &= x_{n1} + x_{n2} + \ldots + x_{nn} + y_n \end{aligned} \tag{1}$$

where x_{ij} is the economic flow from sector *i* (supplier) to sector *j* (user); x_i is the total production of sector *i*; y_i is the total demand of sector *i*; and *i, j* = 1, 2, …, n, is the number of sectors considered. This system of equations shows the total production of a sector as the sum of its intermediate demands plus final demand. This can also be expressed as:

$$\begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{n1} & x_{n2} & \cdots & x_{nn} \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix} + \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix} \tag{2}$$

The production of each sector requires fixed quantities of intermediate products supplied by other sectors and primary inputs. Therefore, the initial proportions of factors used by the sectors are invariable. The technical coefficients for intermediate products are defined as follows:

$$a_{ij} = x_{ij}/x_j \tag{3}$$

The model can also be expressed as:

$$\begin{aligned} x_1 &= a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n + y_1 \\ x_2 &= a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_n + y_2 \\ &\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ x_n &= a_{n1}x_1 + a_{n2}x_2 + \ldots + a_{nn}x_n + y_n \end{aligned} \tag{4}$$

or in matrix terms:

$$\begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix} + \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix} \tag{5}$$

This can be summarized as:

$$x = Ax + y \tag{6}$$

Or, by rearranging terms:

$$x = (I - A)^{-1}y \tag{7}$$

The solution presented by this equation is the new production that the different sectors assume when final demand changes.

3.2. The energy input-output analysis

Given the sectoral supply and demand of goods of an economy, the final energy use will depend both on the energy use of the different sectors across the economy and on its technological structure as defined by I-O relationships. We can adapt the fundamental

equation of the Leontief model to reflect energy flows in analogy with economic flows. Specifically, the total energy use of an economic sector depends on the relationships among all sectors of the economy. The fundamental assumptions of the original Leontief model are the same, but they are now interpreted within the context of energy use: (i) each sector uses a certain amount of energy to produce a single product; (ii) technical coefficients of energy use are constant: analogous to the technical coefficients, a technical coefficient of energy use is the amount of energy used directly by a sector to produce a good or service for another sector, in relation to the total direct energy use of the first; and (iii) there is exogeneity in the alterations of the final demand or the values added. Such an alteration allows us to obtain a measure of impact in terms of total energy use of the economy, both direct and indirect.

It is possible to develop an indicator of direct energy use per unit produced or energy intensity (E), which is defined as the direct energy use of each sector (e) per monetary unit produced directly by the sector (x), which is expressed as a column vector in which each element responds to the expression. This indicator is expressed in quantity of energy use per monetary unit, usually in tons/€:

$$E = \frac{e}{x} \tag{8}$$

Additionally, from equations (7) and (8), the following expression can be obtained:

$$e = E(I - A)^{-1}y \tag{9}$$

Equation (9) is the formula for estimating direct and indirect energy consumption (e) of an economic system based on changes in consumption patterns (y).

3.3. The "key" sectors in the consumption of energy

Returning to equation (9), we calculated the "key" sectors in the consumption of energy (Rasmussen, 1956). We can call F to the linear operator that transforms any increase in final demand into an increase in the energy use vector.

$$F = E(I - A)^{-1} \tag{10}$$

If we premultiply the matrix *F* by *u′*, a unit row vector of the appropriate dimension:

$$f' = u'F \tag{11}$$

where *f′* is the vector (1 x n) of total unitary energy use, direct and indirect, generated by a unit of final demand. Thus, *f′* expresses the multiplier effect of energy use driven by the expansion of the different components of the final demand. This is known in the literature as *backward linkages* (Hirschman, 1958). On the other hand, we can obtain the next expression:

$$f^* = Fu \tag{12}$$

in which *f** is a vector (n x 1) resulting from the sum by rows of the matrix *F* above. This corresponds to what the literature calls *forward linkages*. Finally, we can construct a relative coefficient for both backward and forward linkages:

$$\mu_j = \frac{f'_{gi}}{\sum_i f'_{gi}}\ n \tag{13}$$

$$\delta_j = \frac{f^*_{gi}}{\sum_i f^*_{gi}}\ n \tag{14}$$

where *n* is the number of sectors of the I-O matrix, μ_j are relative drag coefficients, and δ_j are relative impulse coefficients. Following the values obtained by each sector of an economy, we can classify them into four groups: (1) key sectors with values higher than 1 in both relative drag coefficients and relative impulse coefficients, so they are relevant in pushing other sectors and being pushed by other sectors to consume energy; (2) sectors of little relevance where both coefficients have values lower than 1; (3) relevant sectors from the perspective of the demand of other sectors in which relative drag coefficients are lower than 1, but relative impulse coefficients are higher than 1, so they increase their energy

consumption more than other sectors when the latter increase their final demand; and (4) relevant sectors from the perspective of their final demand: relative drag coefficients are higher than 1, but relative impulse coefficients are lower than 1, so other sectors increase energy consumption when they see their final demand increase more than when other sectors see their final demand increase.

Table 1 shows the relative importance in a scatterplot of each industry of pushing and being pushed to use energy in an economic system.

Table 1. Determination of key sectors in the consumption of energy.

	$\mu_j < 1$	$\mu_j > 1$
$\delta_j > 1$	A) Relevant sectors from the perspective of the demand of other sectors.	B) Key sectors push and are pushed to consume energy.
$\delta_j < 1$	C) Sectors of little relevance.	D) Relevant sectors from the perspective of final demand.

Note: Based on Alcántara and Padilla (2009).

4. Results

This section outlines the key findings of our analysis. The energy I-O analysis carried out for three different years allowed us to track the evolution and enable comparisons of some structural indicators in terms of direct and indirect energy use during that period across the different economic sectors. Specifically, we examined energy use within the Catalan economic system before the 2008–2014 financial crisis (with the 2005 energy I-O analysis), during the crisis (2011 analysis), and after the crisis (2015 analysis).

4.1. Analysis of backward and forward linkage coefficients

First, we assessed the obtained backward and forward linkages in Catalonia for energy consumption. In other words, we measured how different sectors influence energy use in other sectors given interindustry flow dynamics. As shown, the backward energy linkage of a sector quantifies its capacity to encourage other sectors to increase energy consumption after a rise in its final demand, while the forward energy linkage of a sector represents the ability of all economic sectors to induce that specific sector to consume energy, following an increase in the final demand of all sectors.

In Figure 1 we can observe both indicators for each sector during the analysis period for total energy use (the sum of all energy sources). One important general result is that on average, both backward and forward linkages declined during the whole period, particularly during the first period of the economic crisis (2005–2011), with an average annual change of -4.96% for backward linkages and -5.02% for forward linkages. During the second period of the economic crisis (2011–2014), they experienced an average annual change of -4.70% and -4.60%, respectively. These results mean that globally, after the crisis, economic sectors reduced their potential to induce energy use in the economic structure. As previously explained, sectors with linkages greater than 1 are considered to have a relevant effect on energy consumption. The high reduction in both backward and forward linkages of the *maritime transport and inland waterways* sector is noteworthy. Other sectors with high linkages also experienced reductions in both linkages such as *land transport, pipeline transport*, *industries other nonmetallic mineral products*, or *electricity, gas, steam, and air conditioning*. All of these are energy-intensive sectors. Another relevant sector in energy use like *coking plants and oil refining* reduced its linkages at first (2011) and then rebounded in 2014; however, coefficients in 2014 remained lower than in 2005. These results suggest an absolute reduction of the importance of energy-intensive sectors in inducing other sectors to consume energy during the period of analysis.

If we account for the whole period 2005–2014, only five sectors increased their backward linkages of total energy consumption: *research & development*, *metallurgy*, *forestry*, *auxiliary activities of financial and insurance mediation*, and *real estate activities*. Only six sectors increased their forward linkages: metallurgy; sanitation, waste management, and decontamination; construction; accommodation, food, and beverage services; other professional, technical, and veterinary activities; and travel agencies and tour operators. All these increases were low, ranging from

0.03 to 0.43 points. The remaining economic sectors reduced their linkages ranging from 0.01 to 24.30 points.

Figure 1. Total energy consumption: Backward and forward linkage coefficients for Catalonia 2005, 2011, and 2015.

Figure 2 shows the same analysis for natural gas consumption. In this case, we also observe that on average, both backward and forward linkages declined over the whole period, but to a lesser extent. For the period 2005–2011, we observed an average annual change of -1.92% for backward linkages and -1.93% for forward linkages, while for the period 2011–2014, we saw an average annual change of -2.95% and -3.15%, respectively. Again, after the crisis, economic sectors globally reduced their potential to induce gas natural consumption into the rest of the economic structure. Important reductions in backward and forward linkages can be seen in sectors such as *paper industries*; *textile, clothing, leather, and footwear industries*; *chemical industries*; and *industries other nonmetallic mineral products*. These are sectors with an intensive direct use of natural gas.

We noted that 13 sectors increased their backward linkages during this period with increases ranging from 0.01 to 0.12 points, while the rest of the sectors reduced their linkages ranging from 0.01 to 0.35 points. Conversely, 25 sectors increased their backward linkages, with increases ranging from 0.01 to 0.10 points, and the rest decreased with absolute variations from -0.01 to -0.76. So, for natural gas, there were no significant absolute variations in coefficients during the economic crisis period.

Figure 2. Natural gas consumption: backward and forward linkage coefficients. Catalonia 2005, 2011, and 2015.

Coal consumption in Catalonia is low compared with the other analyzed energy sources and is concentrated in specific sectors, seeing global reduction during the crisis period (see Figure 3). In this case, we noted an average increase for the first period of the crisis (2005–2011): 2.47% for both backward linkages and forward linkages, and decreases for the second

period of the crisis (2005–2011) of -5.39% and -4.38%, respectively. The overall lowest increase was experienced by the sector *metallurgy*, although there was a higher increase in 2011, and the highest increase was for *industries other than nonmetallic mineral products*. However, most sectors were not affected by coal linkages.

Figure 3. Coal consumption: Backward and forward linkage coefficients for Catalonia 2005, 2011, and 2015.

Petroleum is the most important consumed energy source in Catalonia's different economic sectors, and it saw important increases in average backward and forward linkages. Specifically, there was an average annual change of -6.29% for backward linkages and -5.56% for forward linkages for the first period 2005–2011, and an average annual change of -6.30% for backward linkages and -5.47% for forward linkages in the second period of 2011–2014. We also observe that again, after the crisis, economic sectors reduced their potential to induce petroleum consumption in the rest of the economy.

The most important reductions in backward and forward linkages were *maritime transport and inland waterways*; *land transport, pipeline transport*; *electricity, gas, steam, and air conditioning*; and *coking plants and oil refining* with different intensities. Some sectors with intensive petroleum usage are direct producers that exhibited the declining importance of petroleum during the crisis in relation to the precrisis period. In this context, only five sectors increased their backward linkages: *travel agencies and tour operators*, *research & development*, *real estate activities*, *auxiliary activities of financial and insurance mediation*, and *forestry*, with absolute variations ranging from 0.04 to 0.19. Remarkably, for petroleum, no single sector increased its forward linkages. Absolute reductions ranged from -0.03 to -24.23 for backward linkages and -0.01 to -24.25 for forward linkages.

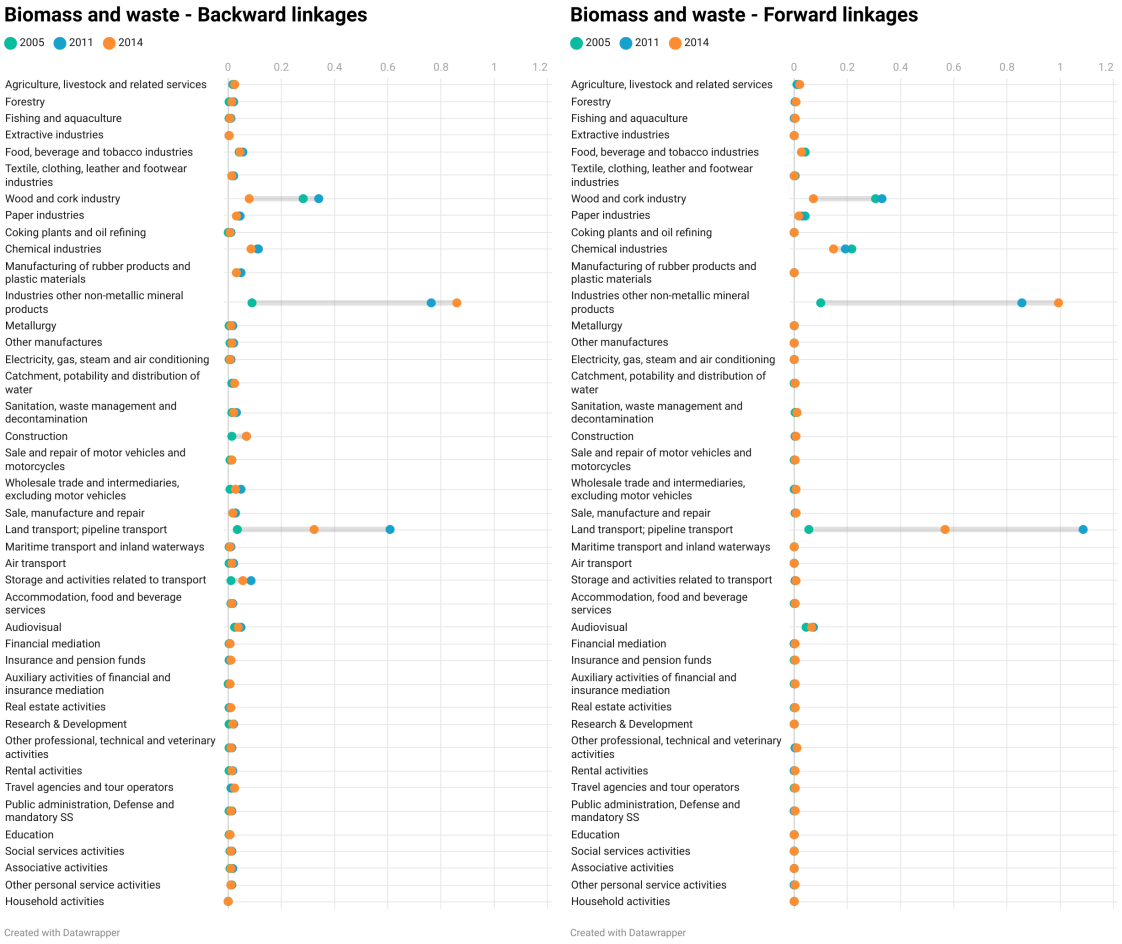
Figure 4. Petroleum consumption: Backward and forward linkage coefficients for Catalonia 2005, 2011, and 2015.

Regarding electricity, both backward and forward linkages were more dispersed than other energy sources, reaching some level of linkage in most sectors. On average, both coefficients went down during the economic crisis, with an annual average variation of -3.04% (for backward linkages) and -3.42% (for forward linkages) during the period 2005–2011 and -3.42% and -2.34%, respectively, during the period 2011–2014. The potential impact of sectors in triggering other sectors to consume electricity was reduced, but below that of the remaining energy sources on average, as shown in the analysis of total energy consumption (Figure 1). The sectors experiencing higher coefficient reduction in absolute terms during the crisis were *associative activities*; *catchment, potability, and distribution of water*; *storage and activities related to transport*; and *electricity, gas, steam, and air conditioning*. Eight sectors increased their backward linkages with absolute variations ranging from 0.01 to 0.14. In contrast, six sectors increased their forward linkages ranging from 0.02 to 0.27 in absolute variations.

Figure 5. Electricity consumption: Backward and forward linkage coefficients for Catalonia 2005, 2011, and 2015.

Finally, biomass and waste energy showed important differences between the two periods analyzed. In the first period (2005–2011), there was an average annual increase of 35.59% for backward linkages and 35.56% for forward linkages for the period 2005–2011, and an average annual reduction of -8.20% for backward linkages and -8.16% for forward linkages for the period 2011–2014. Therefore, there was a global increase in both coefficients during the whole period. Three sectors stood out above the rest in terms of variations: *wood and cork industry*, which experienced the higher reduction in absolute terms; and on the other side, *industries other nonmetallic mineral products*, and *land transport; pipeline transport* showed the higher increase in absolute terms. The sector *wood and cork industry* is the only one that showed reduced backward and forward linkage coefficients during the whole period.

Figure 6. Biomass and waste electricity consumption: Backward and forward linkage coefficients for Catalonia 2005, 2011, and 2015.

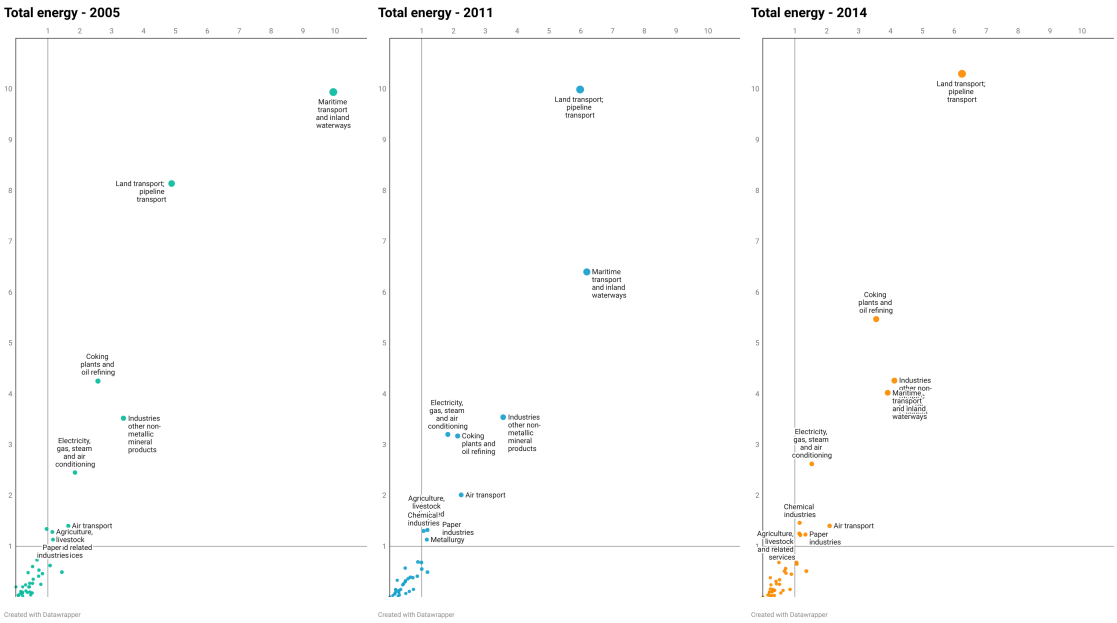


4.2. Analysis of relative coefficients

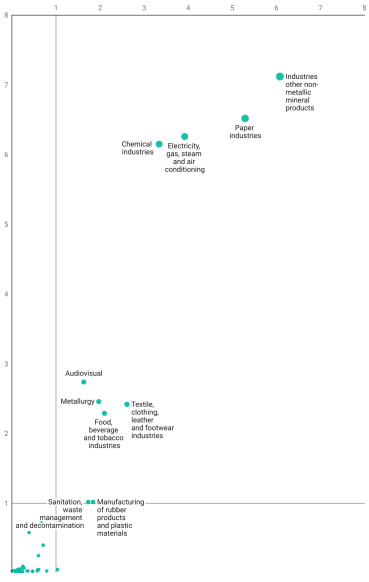
The relative coefficients of a sector show its position in terms of the importance of its total emissions relative to the rest of the sectors within an economy (see equations 13 and 14), and they therefore have a different interpretation than absolute coefficients. They are used to identify the key sectors of an economy and construct the relative coefficients matrix illustrated in Table 1. In our analysis, we focused on relative drag and relative impulse coefficients. We explored the relative linkages for the five energy product categories for which we have developed energy accounts for Catalonia, plus a total energy consumption category that represents a sum of all the other sources. As previously stated, the energy sources assessed are natural gas; petroleum; coal; electricity; and biomass and waste.

Figure 7 shows the evolution of relative drag and impulse coefficients for 2005, 2011, and 2014 for each sector and energy product, following the same scheme developed in the matrix shown in Table 1. The key sectors of the Catalan economy for a specific year of analysis (the ones with relative drag and impulse coefficients higher than 1) are in the upper right box of the figures. We displayed the names for these key sectors in the same figure. The dimension of the dots is an approximate representation of the total sum of both coefficients. For more detail on this classification for all sectors, energy products, and years, see Appendix C.

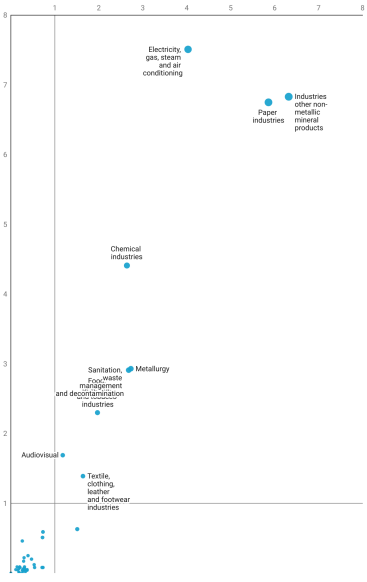
Figure 7. Key sectors matrices for the consumption of energy for different energy categories in Catalonia 2005, 2011, and 2014.



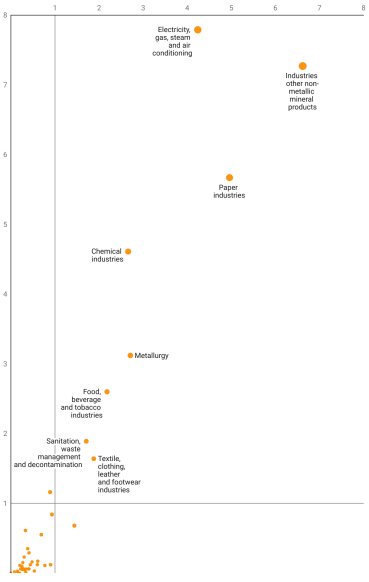
Natural gas - 2005



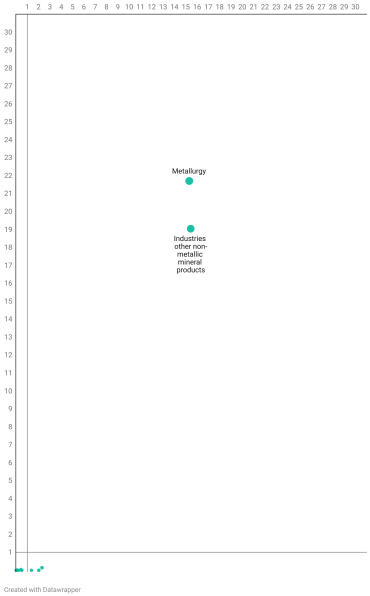
Natural gas - 2011



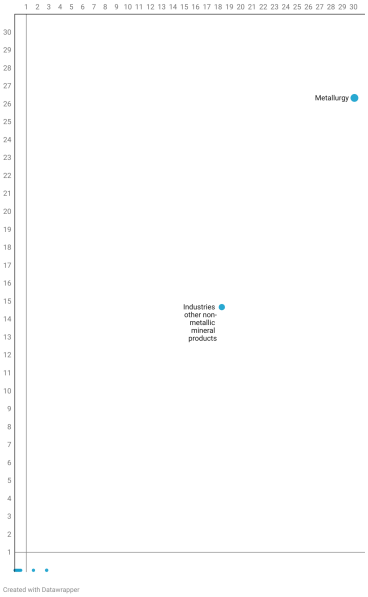
Natural gas - 2014



Coal - 2005

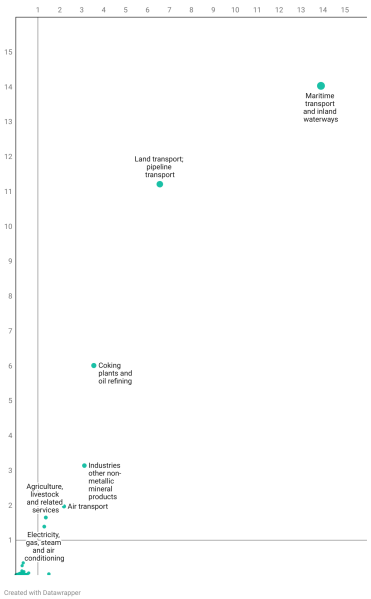


Coal - 2011

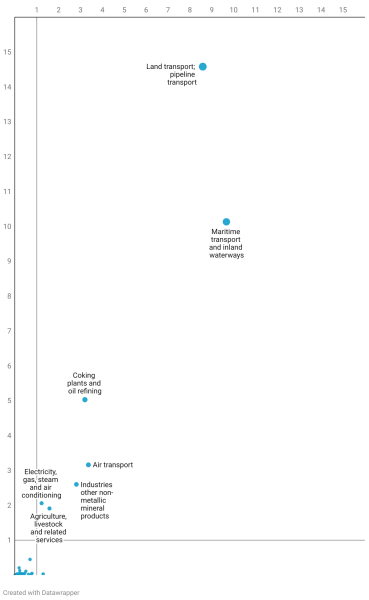


Coal - 2014

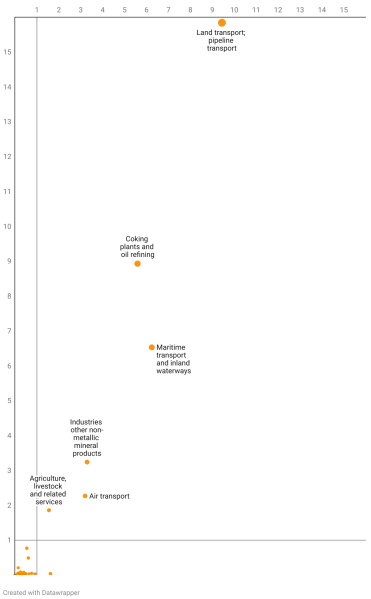
Petroleum - 2005



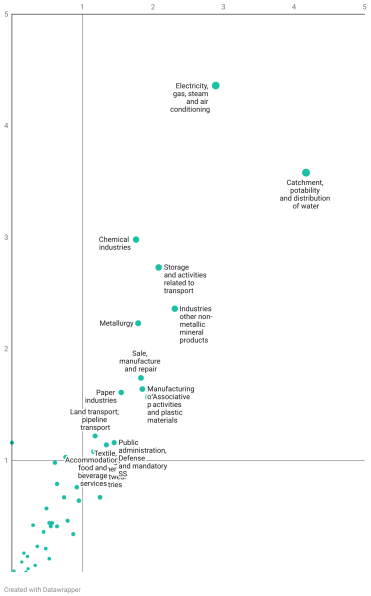
Petroleum - 2011



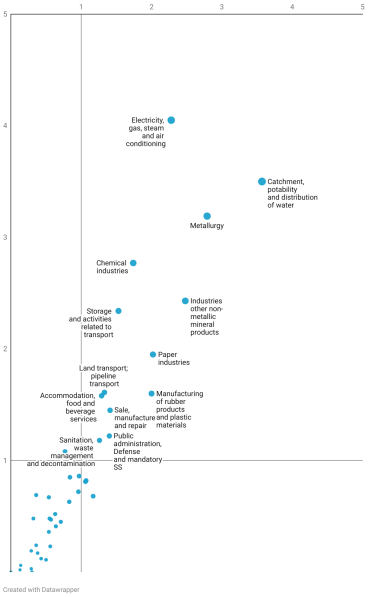
Petroleum - 2014



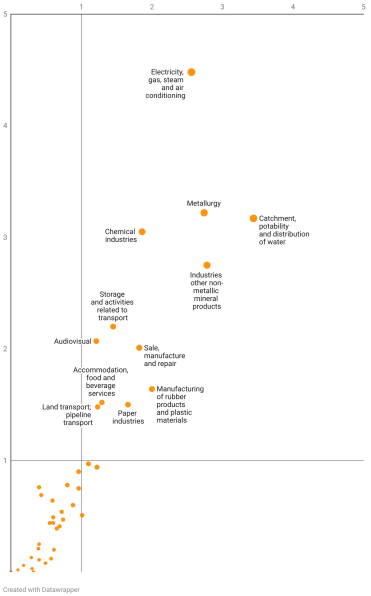
Electricity - 2005

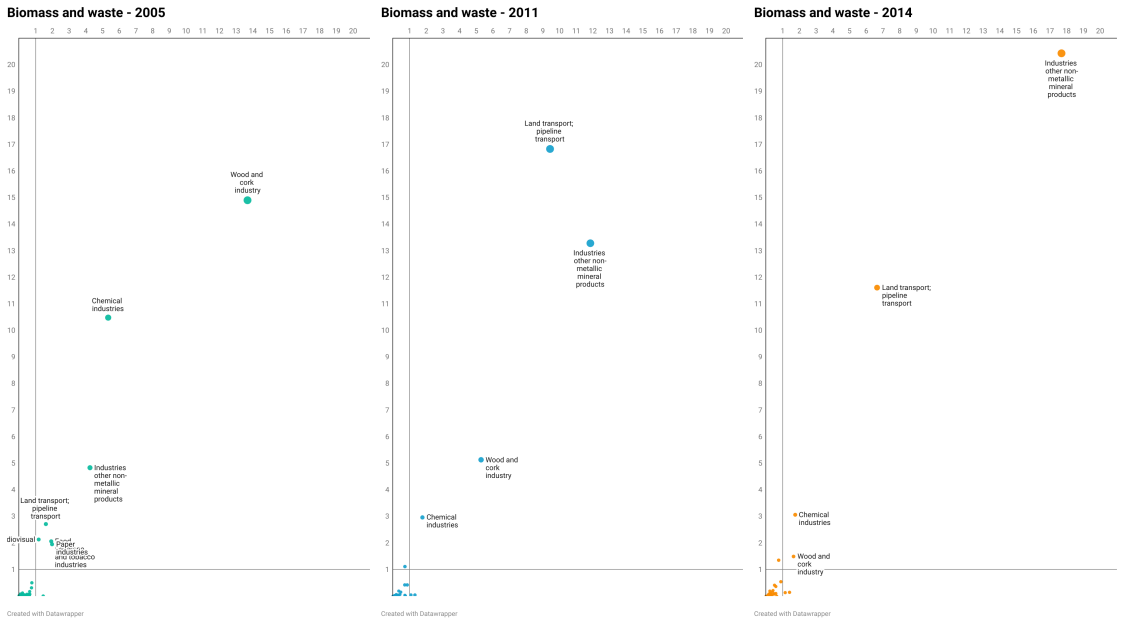


Electricity - 2011



Electricity - 2014





Most key sectors in 2005 remained key sectors in 2011 and 2014, with changes in the values of the coefficients. However, some less relevant sectors have become key during the economic crisis, while some key sectors have become less relevant. If we focus on total energy consumption, the sectors *industries other nonmetallic mineral products* and *metallurgy* became key in 2011 and remained so until 2014. For natural gas consumption, *manufacturing of rubber products and plastic materials* ceased being a key sector in 2011 and 2014, and the sector *audiovisuals*, which was a key sector in 2005 and 2011, stopped being a key sector in 2014. For coal, the same sectors considered key in 2005, *industries other nonmetallic mineral products* and *metallurgy*, were also key in 2011 and 2014. For petroleum consumption, *electricity, gas, steam and air conditioning*, one of the key sectors in 2005 and 2011, stopped being key in 2014, and the others remained key with different values. For electricity consumption, the sectors *textile, clothing, leather, and footwear industries* and *associative activities*, which were key in 2005, stopped being key in 2005 and 2014. The sector *sanitation, waste management and decontamination* was not key in 2005, became key in 2011, but again stopped being key in 2014. The sector *public administration, defense and mandatory SS*," which was key in 2005 and 2011, stopped being key in 2014. Finally, for biomass and waste, the sectors *food, beverage, and tobacco industries*, *paper industries*, and *audiovisuals*, which were key in 2005, stopped being key in 2011 and 2014. In general, we observed a reduction in the number of key sectors for all energy products. If we link these coefficients with economic activity, it is interesting to see how, for example, the sector *maritime transport and inland waterways* exhibits a significant contraction in absolute and not so high in relative coefficients from 2005 to 2014, while at the level of maritime activity,

this change is nonexistent or even the reverse. Total freight transport (in tonnes) in the Ports of Barcelona and Tarragona, which are the most important ports in Catalonia, was 74,823 in 2005, 74,526 in 2011, and 77,085 in 2014. Container transit (in million TEUs) was 2,080 (2005), 2,239 (2011) and 2,041 (2014).[7]

Our analysis suggests that changes observed in backward and forward linkages coefficients (coefficients in absolute terms) have not been transferred to the determination of the relative importance of each sector within the Catalan economic structure, showing some persistence in relative sectorial importance over time. If we focus, for instance, on total energy consumption, we observe that some energy-intensive sectors like *maritime transport and inland waterways*; *land transport, pipeline transport*; *industries other than nonmetallic mineral products*; and *electricity, gas, steam, and air conditioning* showed significant reductions in their backward and forward linkages. Despite this reduction, they all were key sectors before the crisis and continued to be key sectors after the crisis. Something similar happens when we break down energy consumption by energy sources, with some exceptions.

5. Conclusions

There is some uncertainty regarding the effect of specific economic crises on structural energy consumption along the economic structure and their interactions. In this article, we shared the structural relationships in energy terms before, during, and after an economic crisis using the case study of Catalonia during the 2008–2014 financial crisis and environmentally extended input-output analysis methodology. The use of five different energy resources is observed along three input-output tables for different years. These sources are as follows: natural gas; coal; petroleum; electricity; and biomass and waste. Total energy has also been considered as an additional source that adds up all the other energy sources. We studied the evolution of linkage coefficients and key sectors, and beyond the interest level of the results in merely descriptive terms, some important conclusions can be drawn from the static and dynamic analysis we performed.

Because there are no sectoral energy accounts for Catalonia, we built the energy vectors using different sources and applying homogeneity with the input-output framework of Catalonia using detail for 41 sectors. Sectoral energy consumption has globally dropped for

[7] https://www.idescat.cat/indicadors/?id=anuals&n=10512&t=201400&lang=en.

all vectors. This drop has been higher in energy-intensive sectors than in others, although there are some nuances depending on the sector and energy source analyzed.

The backward and forward linkage analysis shows that most economic sectors have reduced their potential to induce energy use in the economic structure after the economic crisis. At the same time, they also show that economic sectors are generally less susceptible to others in terms of consuming energy. This has probably been the effect of different causes occurring during this period, but at an economic structural level, the economic crisis may have had an important role in shaping a new energy consumption structure.

Both backward and forward linkage coefficients (coefficients in absolute terms), experienced important changes for some sectors, but in general these changes did not translate into important changes in the relative importance of each sector within the Catalan economic structure. We illustrated this by analyzing the key sectors analysis performed, where the relative importance of each sector within the economic structure is analyzed with the dynamic sequence proportioned by the energy input-output analysis of the three years of interest. This persistence in the relative importance of sectors over the studied time frame can point to a structural problem that policymakers working on energy policies should be aware of.

From a policymaking perspective, beyond the importance of using economic structural indicators with techniques like input-output analysis, our results highlight the importance of considering not just absolute indicators in shaping energy strategies, plans, or programs, but also relative indicators providing essential information to understand the use of energy carried out by an economic structure. Additionally, analyses through different time frames helps with understanding the dynamics of sectoral energy use through different economic events like an economic crisis and can therefore consequently redefine economic and energy policies.

Future researchers should look more deeply into the causes and consequences of this persistence in the relative importance of sectors despite their volatile absolute importance, as well as contemplate strategies to modify undesirable situations. The consideration of other periods, regions, and methodologies would also consolidate the interpretation of energy input-output analyses through dynamic frameworks. Finally, if it is difficult to change the relative importance of these sectors, particularly those considered key, their decarbonization becomes more important for fighting climate change.

References

Alcántara, V., 1995. Economia y contaminacion atmosferica: Hacia un nuevo enfoque desde el analisis input-output. Universitat Autonoma de Barcelona. Doctoral Thesis.

Alcántara, V., Freire-González, J., Puig-Ventosa, I., 2009. El compte satèllit de les emissions atmosfèriques a Catalunya 2001. Departament de Medi Ambient i habitatge i Idescat. Generalitat de Catalunya.

Alcántara, V., Padilla, E., 2009. Input–output subsystems and pollution: An application to the service sector and CO2 emissions in Spain. Ecol. Econ. 68, 905–914.

Bekhet, H.A., Yasmin, T., 2014. Assessment of the global financial crisis effects on energy consumption and economic growth in Malaysia: An input–output analysis. Int. Econ. 140, 49–70.

Bullard III, C.W., Herendeen, R.A., 1975. The energy cost of goods and services. Energy Policy 3, 268–278.

Casler, S., Wilbur, S., 1984. Energy input-output analysis: A simple guide. Resour. Energy 6, 187–201.

Chapman, P.F., 1974. 1. Energy costs: A review of methods. Energy Policy 2, 91–103.

Claessens, M.S., Kose, M.A., 2013. Financial crises explanations, types, and implications.

Geanakoplos, J., 1989. Arrow-Debreu model of general equilibrium. Springer.

Hirschman, A.O., 1958. Interdependence and industrialization. Strategy Econ. Dev. 98–119.

IDESCAT, 2009. Classificació catalana d'activitats econòmiques. Adaptació de la CNAE-09.

Isard, W., Bassett, K., Choguill, C., Furtado, J., Izumita, R., Kissin, J., Romanoff, E., Seyfarth, R., Tatlock, R., 1968. On the linkage of socio-economic and ecologic systems, in: Papers of the Regional Science Association. Springer, pp. 79–99.

Lenzen, M., Moran, D., Kanemoto, K., Geschke, A., 2013. Building Eora: A global multi-region input–output database at high country and sector resolution. Econ. Syst. Res. 25, 20–49.

Lenzen, M., Pade, L.-L., Munksgaard, J., 2004. CO2 multipliers in multi-region input-output models. Econ. Syst. Res. 16, 391–412.

Leontief, W., 1970. Environmental repercussions and the economic structure: an input-output approach. Rev. Econ. Stat. 262–271.

Leontief, W., Ford, D., 1971. Air pollution and the economic structure: Empirical results of input-output calculations, in: Fifth International Conference on Input-Output Techniques North Holland Pub. Co Geneva, Switzerland.

Leontief, W.W., 1941. Structure of American economy, 1919–1929.

Martin, A., Moral-Benito, E., Schmitz, T., 2018. The financial transmission of housing bubbles: Evidence from Spain.

Proops, J.L., 1988. Energy intensities, input-output analysis and economic development. Ciaschini M1988 201–215.

Rasmussen, P., 1956. Studies in intersectoral relations. North-Holland Publishing Company, Amsterdam.

Roinioti, A., Koroneos, C., 2017. The decomposition of CO2 emissions from energy use in Greece before and during the economic crisis and their decoupling from economic growth. Renew. Sustain. Energy Rev. 76, 448–459.

Santos, T., 2017. Antes del diluvio: The Spanish banking system in the first decade of the euro. Flood Gt. Recess. Chang. Econ. Thought 153–208.

United Nations, 2008. International Standard Industrial Classification of All Economic Activities (ISIC), Statistical Division. ed. United Nations Publications, New York.

Walras, L., 1954. Elements of Pure Economics. 1874. Transl. Fr. William Jaffé.

Yuan, C., Liu, S., Xie, N., 2010. The impact on Chinese economic growth and energy consumption of the global financial crisis: An input–output analysis. Energy 35, 1805–1812.

Appendix A. Aggregation correspondences for input-output tables

Table A1. Sectoral correspondences between CCAE/CNAE (national accounts) and EORA dataset to conduct aggregations.

Aggregation	CCAE / CNAE	EORA
Extractive industries		Mining of coal and lignite; extraction of peat, extraction of crude petroleum and natural gas; mining of uranium and thorium ores, mining of metal ores, and other mining and quarrying.
Food, drinks, and tobacco industries		Manufacture of meat products Manufacture of dairy products Manufacture of other food products Manufacture of beverages Manufacture of tobacco products
Textile, clothing, leather, and shoe industries		Manufacture of textiles, manufacture of wearing apparel; dressing and dyeing of fur, and manufacture of leather and leather products
Other mineral nonmetallic products		Manufacture of cement, lime, and plaster Manufacture of glass and glass products Manufacture of ceramic products Manufacture of other nonmetallic mineral products
Manufacture of informatic and electronic products		Manufacture of office machinery and computers, manufacture of electrical machinery and apparatus n.e.c., manufacture of electronic equipment and apparatus Manufacture of medical, precision, and optical instruments
Electric power, gas, steam, and air conditioning		Production and distribution of electricity and manufacture of gas; distribution of gaseous fuels through mains; steam and hot water supply
Sanitation, waste management, and decontamination		Recycling, market sewage and refuse disposal, sanitation, and similar activities
Land and pipe transport		Railway transport and other land transport; transport via pipelines

Accommodation, food, and beverage services		Hotels and restaurants
Public administration, defense, and compulsory social security		Public administration, nonmarket health and social work. Public administration, nonmarket sewage and refuse disposal, sanitation, and similar activities, public administration and nonmarket recreational, cultural, and sporting activities
Education		Market education and nonmarket education
Social services activities		Market health and social work and nonmarket health and social work–NPISHs
Artistic and cultural activities; gambling		Market recreational, cultural, and sporting activities and nonmarket recreational, cultural, and sporting activities—NPISHs
Activities of membership organization		Market activities of membership organization n.e.c. and nonmarket activities of membership organization n.e.c.–NPISHs.
Chemical industry	Manufacture of chemical products Manufacture of pharmaceutical products	
Various manufacturing	Manufacture of metal products, exc. machinery Manufacture of computer and electronic products Manufacture of electrical materials and equipment Manufacture of machinery and equipment ncaa Manufacture of motor vehicles, trailers and semi-trailers, Manufacture of other transport materials Repair and installation of machinery and equipment	
Various fabrication, repair, and sale	Furniture and various manufacturing industries manufacturing, sale and various repairs repair of computers, personal and household effects	

Audio-visuals, communication, and recreation	Postal and postal activities, publishing, audio-visual activities, telecommunications IT activities and information services graphic arts and recorded media, artistic and cultural activities; gambling, sports, and recreational activities
Other professional and technical activities	Legal, accounting, and tax advisory activities, architectural and engineering technical services, advertising and market studies, employment-related activities security activities, building services and administrative activities

Note: The column CCAE/CNAE shows sectors aggregated from national accounts while EORA column shows sectors aggregated from the EORA dataset.

Appendix B. Detailed sectoral results of relative drag coefficients and relative impulse coefficients for the five energy product categories in Catalonia 2005, 2011, and 2014.

Table A2. Natural gas: Sectorial energy relative drag coefficients and relative impulse coefficients in Catalonia for 2005, 2011, and 2014.

CCAE	Sector	Relative drag coefficients $\mu_j = \frac{f'_{gi}}{\sum_i f'_{gi}}\, n$			Relative impulse coefficients $\delta_j = \frac{f^*_{gi}}{\sum_i f^*_{gi}}\, n$		
		2005	2011	2014	2005	2011	2014
1	Agriculture, livestock, and related services	0.58	0.47	0.40	0.25	0.20	0.06
02	Forestry	0.06	0.12	0.08	0.04	0.05	0.02
03	Fishing and aquaculture	0.15	0.14	0.17	0.00	0.01	0.00
05-09	Extractive industries	0.41	0.23	0.33	0.57	0.46	0.61
10-12	Food, beverage, and tobacco industries	2.04	1.94	2.18	2.25	2.33	2.60
13-15	Textile, clothing, leather, and footwear industries	2.53	1.61	1.88	2.38	1.40	1.64
16	Wood and cork industry	0.25	0.28	0.26	0.08	0.07	0.05
17	Paper industries	5.14	5.74	4.96	6.41	6.83	5.67
19	Coking plants and oil refining	4.10	3.96	0.53	6.92	5.94	0.26
20+21	Chemical industries	3.32	2.70	2.67	6.04	4.46	4.61
22	Manufacturing of rubber products and plastic materials	1.78	1.47	1.44	1.00	0.64	0.68
23	Industries other nonmetallic mineral products	6.04	6.28	6.62	6.99	6.91	7.27
24	Metallurgy	1.93	2.69	2.71	2.41	2.96	3.11
25/26/27/28/29/30/33	Other manufactures	0.65	0.70	0.69	0.71	0.60	0.55
35	Electricity, gas, steam, and air conditioning	0.58	0.81	4.17	0.00	1.23	7.65
36	Catchment, potability, and distribution of water	0.65	0.50	0.89	0.05	0.08	0.12
37-39	Sanitation, waste management, and decontamination	1.77	2.70	1.71	1.00	2.95	1.89
41-43	Construction	0.78	0.67	0.77	0.03	0.08	0.11
45	Sale and repair of motor vehicles and motorcycles	0.44	0.21	0.30	0.02	0.03	0.05
46	Wholesale trade and intermediaries, excluding motor vehicles	0.26	0.48	0.61	0.07	0.12	0.17
31/32/47/95	Sale, manufacture, and repair	0.64	0.64	0.93	0.39	0.52	0.84

49	Land transport; pipeline transport	0.46	0.68	0.41	0.05	0.25	0.29
50	Maritime transport and inland waterways	0.14	0.28	0.14	0.00	0.00	0.00
51	Air transport	0.61	0.78	0.21	0.00	0.00	0.00
52	Storage and activities related to transport	0.29	0.31	0.30	0.10	0.17	0.23
55-56	Accommodation, food, and beverage services	0.52	0.42	0.60	0.04	0.08	0.12
53/62-63/58/59-60/61/18/90-92/93	Audiovisual	1.54	1.13	0.89	2.69	1.71	1.16
64	Financial mediation	0.14	0.16	0.25	0.04	0.06	0.10
65	Insurance and pension funds	0.15	0.19	0.27	0.06	0.09	0.15
66	Auxiliary activities of financial and insurance mediation	0.07	0.20	0.22	0.02	0.08	0.06
68	Real estate activities	0.11	0.13	0.20	0.05	0.09	0.11
72	Research & Development	0.12	0.30	0.53	0.01	0.05	0.03
74-75	Other professional, technical, and veterinary activities	0.25	0.28	0.38	0.09	0.22	0.35
77	Rental activities	0.30	0.26	0.26	0.03	0.06	0.07
79	Travel agencies and tour operators	0.57	0.37	0.48	0.05	0.09	0.16
84	Public administration, defense and mandatory social security	0.30	0.20	0.40	0.03	0.04	0.06
85	Education	0.15	0.14	0.15	0.01	0.04	0.03
86-87-88	Social services activities	0.30	0.29	0.32	0.03	0.02	0.04
94	Associative activities	0.48	0.32	0.34	0.03	0.04	0.01
96	Other personal service activities	0.40	0.23	0.34	0.03	0.05	0.06
97-98	Household activities	0.00	0.00	0.00	0.03	0.00	0.00

Table A3. Coal: Sectorial energy relative drag coefficients and relative impulse coefficients in Catalonia for 2005, 2011, and 2014.

CCAE	**Sector**	**Relative drag coefficients** $\mu_j = \frac{f'_{gi}}{\sum_i f'_{gi}}\, n$			**Relative impulse coefficients** $\delta_j = \frac{f^*_{gi}}{\sum_i f^*_{gi}}\, n$		
		2005	**2011**	**2014**	**2005**	**2011**	**2014**
1	Agriculture, livestock, and related services	0.07	0.07	0.06	0.00	0.00	0.00
02	Forestry	0.01	0.03	0.07	0.00	0.00	0.00
03	Fishing and aquaculture	0.05	0.05	0.03	0.00	0.00	0.00
05-09	Extractive industries	0.09	0.03	0.02	0.00	0.00	0.00
10-12	Food, beverage, and tobacco industries	0.24	0.15	0.18	0.00	0.00	0.00

13-15	Textile, clothing, leather, and footwear industries	0.07	0.08	0.06	0.00	0.00	0.00
16	Wood and cork industry	0.11	0.37	0.27	0.00	0.00	0.00
17	Paper industries	0.08	0.16	0.16	0.00	0.00	0.00
19	Coking plants and oil refining	0.04	0.03	0.02	0.00	0.00	0.00
20+21	Chemical industries	0.13	0.16	0.14	0.00	0.00	0.00
22	Manufacturing of rubber products and plastic materials	0.18	0.20	0.12	0.00	0.00	0.00
23	Industries other nonmetallic mineral products	15.44	18.33	17.33	19.04	14.67	19.57
24	Metallurgy	15.31	30.08	16.93	21.70	26.33	21.43
25/26/27/28/29/30/33	Other manufacturing	1.37	2.81	1.37	0.00	0.00	0.00
35	Electricity, gas, steam, and air conditioning	0.08	0.52	0.16	0.00	0.00	0.00
36	Catchment, potability, and distribution of water	0.53	0.40	0.34	0.00	0.00	0.00
37-39	Sanitation, waste management, and decontamination	2.30	0.32	0.15	0.14	0.00	0.00
41-43	Construction	2.02	1.64	1.35	0.00	0.00	0.00
45	Sale and repair of motor vehicles and motorcycles	0.46	0.29	0.18	0.00	0.00	0.00
46	Wholesale trade and intermediaries, excluding motor vehicles	0.10	0.23	0.14	0.00	0.00	0.00
31/32/47/95	Sale, manufacture, and repair	0.45	0.35	0.08	0.05	0.00	0.00
49	Land transport; pipeline transport	0.11	0.14	0.09	0.00	0.00	0.00
50	Maritime transport and inland waterways	0.06	0.10	0.04	0.00	0.00	0.00
51	Air transport	0.13	0.09	0.05	0.00	0.00	0.00
52	Storage and activities related to transport	0.18	0.16	0.08	0.01	0.00	0.00
55-56	Accommodation, food, and beverage services	0.16	0.12	0.08	0.00	0.00	0.00
53/62-63/58/59-60/61/18/90-92/93	Audiovisual	0.10	0.18	0.11	0.02	0.00	0.00
64	Financial mediation	0.05	0.06	0.06	0.00	0.00	0.00
65	Insurance and pension funds	0.04	0.05	0.04	0.00	0.00	0.00
66	Auxiliary activities of financial and insurance mediation	0.01	0.06	0.05	0.00	0.00	0.00
68	Real estate activities	0.13	0.15	0.15	0.00	0.00	0.00
72	Research & Development	0.04	0.44	0.42	0.00	0.00	0.00
74-75	Other professional, technical, and veterinary activities	0.10	0.18	0.09	0.01	0.00	0.00
77	Rental activities	0.12	0.23	0.12	0.00	0.00	0.00

79	Travel agencies and tour operators	0.13	0.08	0.07	0.00	0.00	0.00
84	Public administration, defense, and mandatory social security	0.09	0.12	0.07	0.00	0.00	0.00
85	Education	0.06	0.06	0.04	0.00	0.00	0.00
86-87-88	Social services activities	0.12	0.10	0.08	0.00	0.00	0.00
94	Associative activities	0.17	0.13	0.09	0.00	0.00	0.00
96	Other personal service activities	0.06	0.06	0.09	0.00	0.00	0.00
97-98	Household activities	0.00	0.00	0.00	0.00	0.00	0.00

Table A4. Petroleum: Sectorial energy relative drag coefficients and relative impulse coefficients in Catalonia for 2005, 2011, and 2014.

CCAE	**Sector**	**Relative drag coefficients** $\mu_j = \frac{f'_{gi}}{\sum_i f'_{gi}}\, n$			**Relative impulse coefficients** $\delta_j = \frac{f^*_{gi}}{\sum_i f^*_{gi}}\, n$		
		2005	**2011**	**2014**	**2005**	**2011**	**2014**
1	Agriculture, livestock, and related services	1.37	1.58	1.56	1.66	1.91	1.86
02	Forestry	0.27	0.68	0.61	0.27	0.45	0.49
03	Fishing and aquaculture	0.15	0.23	0.27	0.05	0.06	0.09
05-09	Extractive industries	0.32	0.19	0.16	0.35	0.21	0.21
10-12	Food, beverage, and tobacco industries	0.59	0.79	0.78	0.06	0.05	0.05
13-15	Textile, clothing, leather, and footwear industries	0.27	0.30	0.28	0.07	0.04	0.03
16	Wood and cork industry	0.27	0.50	0.41	0.08	0.11	0.08
17	Paper industries	0.38	0.39	0.35	0.10	0.03	0.02
19	Coking plants and oil refining	2.61	2.60	4.20	4.38	4.05	6.65
20+21	Chemical industries	0.33	0.45	0.48	0.07	0.05	0.04
22	Manufacturing of rubber products and plastic materials	0.26	0.38	0.40	0.03	0.02	0.02
23	Industries, other nonmetallic mineral products	3.12	2.82	3.33	3.15	2.60	3.24
24	Metallurgy	0.15	0.26	0.23	0.04	0.02	0.02
25/26/27/28/29/30/33	Other manufacturing	0.16	0.24	0.23	0.03	0.02	0.02
35	Electricity, gas, steam, and air conditioning	2.08	1.76	1.75	2.87	3.11	3.05
36	Catchment, potability, and distribution of water	0.46	0.34	0.40	0.02	0.01	0.02
37-39	Sanitation, waste management, and decontamination	0.49	0.35	0.31	0.02	0.04	0.03
41-43	Construction	0.39	0.40	0.46	0.02	0.02	0.03

45	Sale and repair of motor vehicles and motorcycles	0.25	0.19	0.30	0.01	0.01	0.01
46	Wholesale trade and intermediaries, excluding motor vehicles	0.46	0.63	0.64	0.02	0.02	0.03
31/32/47/95	Sale, manufacture, and repair	0.23	0.31	0.33	0.02	0.01	0.02
49	Land transport; pipeline transport	6.53	8.53	9.37	11.26	14.56	15.85
50	Maritime transport and inland waterways	13.95	9.65	6.26	14.09	10.11	6.53
51	Air transport	2.11	3.25	2.96	1.98	3.16	2.27
52	Storage and activities related to transport	1.50	1.28	1.61	0.03	0.03	0.04
55-56	Accommodation, food, and beverage services	0.24	0.27	0.29	0.02	0.01	0.02
53/62-63/58/59-60/61/18/90-92/93	Audiovisual	0.29	0.23	0.16	0.12	0.13	0.06
64	Financial mediation	0.08	0.08	0.11	0.01	0.01	0.02
65	Insurance and pension funds	0.07	0.09	0.11	0.02	0.02	0.03
66	Auxiliary activities of financial and insurance mediation	0.04	0.12	0.13	0.01	0.01	0.01
68	Real estate activities	0.05	0.06	0.13	0.02	0.02	0.02
72	Research & Development	0.05	0.25	0.26	0.00	0.01	0.00
74-75	Other professional, technical, and veterinary activities	0.12	0.12	0.17	0.03	0.04	0.06
77	Rental activities	0.19	0.25	0.28	0.01	0.01	0.01
79	Travel agencies and tour operators	0.42	0.74	0.89	0.02	0.02	0.03
84	Public administration, defense, and mandatory social security	0.18	0.16	0.17	0.01	0.01	0.01
85	Education	0.11	0.08	0.11	0.00	0.00	0.01
86-87-88	Social services activities	0.10	0.14	0.15	0.01	0.01	0.01
94	Associative activities	0.20	0.16	0.16	0.01	0.01	0.00
96	Other personal service activities	0.15	0.13	0.20	0.01	0.01	0.01
97-98	Household activities	0.00	0.00	0.00	0.01	0.00	0.00

Table A5. Electricity: Sectorial energy relative drag coefficients and relative impulse coefficients in Catalonia for 2005, 2011, and 2014.

CCAE	**Sector**	**Relative drag coefficients** $\mu_j = \frac{f'_{gi}}{\sum_i f'_{gi}}\, n$			**Relative impulse coefficients** $\delta_j = \frac{f^*_{gi}}{\sum_i f^*_{gi}}\, n$		
		2005	**2011**	**2014**	**2005**	**2011**	**2014**

1	Agriculture, livestock, and related services	0.57	0.57	0.60	0.44	0.47	0.49
02	Forestry	0.03	0.13	0.10	0.01	0.02	0.02
03	Fishing and aquaculture	0.45	0.54	0.60	0.36	0.36	0.44
05-09	Extractive industries	0.61	0.36	0.40	0.98	0.69	0.76
10-12	Food, beverage, and tobacco industries	0.92	0.97	1.10	0.76	0.86	0.97
13-15	Textile, clothing, leather, and footwear industries	1.34	1.06	1.22	1.14	0.81	0.94
16	Wood and cork industry	0.74	1.07	0.96	0.67	0.82	0.75
17	Paper industries	1.55	2.02	1.65	1.61	1.95	1.50
19	Coking plants and oil refining	0.20	0.31	0.41	0.01	0.01	0.15
20+21	Chemical industries	1.76	1.74	1.86	2.98	2.77	3.05
22	Manufacturing of rubber products and plastic materials	1.85	2.00	2.00	1.64	1.60	1.64
23	Industries other nonmetallic mineral products	2.31	2.48	2.78	2.36	2.43	2.75
24	Metallurgy	1.79	2.79	2.74	2.23	3.19	3.22
25/26/27/28/29/30/33	Other manufacturing	0.64	0.84	0.80	0.79	0.85	0.78
35	Electricity, gas, steam, and air conditioning	2.88	2.28	2.48	4.35	4.04	4.33
36	Catchment, potability, and distribution of water	4.17	3.57	3.43	3.58	3.50	3.17
37-39	Sanitation, waste management, and decontamination	1.25	1.26	0.96	0.67	1.18	0.90
41-43	Construction	0.53	0.56	0.61	0.12	0.23	0.20
45	Sale and repair of motor vehicles and motorcycles	0.79	0.63	0.71	0.46	0.52	0.54
46	Wholesale trade and intermediaries, excluding motor vehicles	0.53	0.64	0.69	0.44	0.41	0.41
31/32/47/95	Sale, manufacture, and repair	1.83	1.41	1.82	1.74	1.45	2.01
49	Land transport; pipeline transport	1.18	1.33	1.24	1.22	1.61	1.48
50	Maritime transport and inland waterways	0.48	0.38	0.39	0.21	0.17	0.21
51	Air transport	0.33	0.50	0.51	0.06	0.11	0.08
52	Storage and activities related to transport	2.08	1.53	1.45	2.73	2.34	2.20
55-56	Accommodation, food, and beverage services	1.16	1.28	1.29	1.08	1.58	1.52
53/62-63/58/59-60/61/18/90-92/93	Audiovisual	0.76	0.77	1.21	1.03	1.08	2.07
64	Financial mediation	0.49	0.54	0.59	0.57	0.67	0.64
65	Insurance and pension funds	0.36	0.36	0.40	0.23	0.24	0.25

66	Auxiliary activities of financial and insurance mediation	0.17	0.29	0.29	0.17	0.19	0.13
68	Real estate activities	0.14	0.14	0.18	0.09	0.06	0.06
72	Research & Development	0.22	0.43	0.57	0.14	0.12	0.12
74-75	Other professional, technical, and veterinary activities	0.30	0.32	0.42	0.42	0.48	0.69
77	Rental activities	0.23	0.29	0.30	0.03	0.03	0.03
79	Travel agencies and tour operators	0.87	1.17	1.01	0.34	0.68	0.51
84	Public administration, defense, and mandatory social security	1.45	1.40	0.88	1.16	1.22	0.60
85	Education	0.55	0.55	0.54	0.41	0.48	0.44
86-87-88	Social services activities	0.64	0.71	0.74	0.41	0.45	0.47
94	Associative activities	1.93	0.96	0.40	1.57	0.72	0.11
96	Other personal service activities	0.95	0.83	0.65	0.64	0.63	0.39
97-98	Household activities	0.57	0.57	0.60	0.44	0.47	0.49

Table A6. Biomass and waste: Sectorial energy relative drag coefficients and relative impulse coefficients in Catalonia for 2005, 2011, and 2014.

CCAE	**Sector**	**Relative drag coefficients** $\mu_j = \frac{f'_{gi}}{\sum_i f'_{gi}}\, n$			**Relative impulse coefficients** $\delta_j = \frac{f^*_{gi}}{\sum_i f^*_{gi}}\, n$		
		2005	**2011**	**2014**	**2005**	**2011**	**2014**
1	Agriculture, livestock, and related services	0.77	0.35	0.51	0.50	0.19	0.41
02	Forestry	0.08	0.31	0.25	0.08	0.04	0.11
03	Fishing and aquaculture	0.21	0.13	0.15	0.12	0.01	0.05
05-09	Extractive industries	0.07	0.06	0.04	0.00	0.00	0.00
10-12	Food, beverage, and tobacco industries	1.93	0.86	0.89	2.06	0.42	0.54
13-15	Textile, clothing, leather, and footwear industries	0.60	0.31	0.25	0.07	0.00	0.00
16	Wood and cork industry	13.68	5.29	1.65	14.90	5.13	1.49
17	Paper industries	1.98	0.71	0.59	1.95	0.42	0.36
19	Coking plants and oil refining	0.03	0.18	0.16	0.00	0.00	0.00
20+21	Chemical industries	5.34	1.77	1.75	10.48	2.96	3.06
22	Manufacturing of rubber products and plastic materials	1.45	0.75	0.64	0.00	0.00	0.00
23	Industries other nonmetallic mineral products	4.25	11.85	17.69	4.83	13.28	20.43
24	Metallurgy	0.12	0.25	0.24	0.00	0.00	0.00
25/26/27/28/29/30/33	Other manufacturing	0.28	0.30	0.30	0.00	0.00	0.00

35	Electricity, gas, steam, and air conditioning	0.11	0.18	0.15	0.00	0.00	0.00
36	Catchment, potability, and distribution of water	0.59	0.32	0.47	0.04	0.02	0.07
37-39	Sanitation, waste management and decontamination	0.64	0.47	0.42	0.17	0.15	0.21
41-43	Construction	0.65	1.08	1.41	0.07	0.04	0.14
45	Sale and repair of motor vehicles and motorcycles	0.34	0.20	0.29	0.03	0.02	0.06
46	Wholesale trade and intermediaries, excluding motor vehicles	0.32	0.72	0.59	0.05	0.03	0.10
31/32/47/95	Sale, manufacture, and repair	0.75	0.42	0.37	0.31	0.06	0.15
49	Land transport; pipeline transport	1.61	9.43	6.65	2.71	16.83	11.61
50	Maritime transport and inland waterways	0.08	0.13	0.12	0.00	0.00	0.00
51	Air transport	0.16	0.33	0.30	0.00	0.00	0.00
52	Storage and activities related to transport	0.48	1.32	1.15	0.07	0.04	0.13
55-56	Accommodation, food, and beverage services	0.46	0.25	0.29	0.03	0.02	0.07
53/62-63/58/59-60/61/18/90-92/93	Audiovisual	1.18	0.72	0.76	2.13	1.11	1.35
64	Financial mediation	0.10	0.10	0.16	0.03	0.01	0.05
65	Insurance and pension funds	0.11	0.10	0.17	0.04	0.02	0.08
66	Auxiliary activities of financial and insurance mediation	0.04	0.11	0.14	0.02	0.02	0.03
68	Real estate activities	0.09	0.12	0.23	0.03	0.02	0.06
72	Research & Development	0.12	0.29	0.34	0.00	0.01	0.02
74-75	Other professional, technical, and veterinary activities	0.19	0.20	0.23	0.07	0.06	0.19
77	Rental activities	0.17	0.28	0.26	0.02	0.02	0.04
79	Travel agencies and tour operators	0.40	0.21	0.49	0.04	0.02	0.09
84	Public administration, defense, and mandatory social security	0.22	0.18	0.20	0.02	0.01	0.03
85	Education	0.12	0.11	0.12	0.01	0.00	0.02
86-87-88	Social services activities	0.33	0.22	0.20	0.02	0.00	0.02
94	Associative activities	0.36	0.24	0.17	0.02	0.01	0.01
96	Other personal service activities	0.62	0.17	0.20	0.02	0.01	0.03
97-98	Household activities	0.00	0.00	0.00	0.02	0.00	0.00

Appendix C. Details of key sector matrices by energy product and year

Table A7. Key sectors in the consumption of total energy for Catalonia 2005, 2011, and 2014.

	$\mu_j < 1$			$\mu_j > 1$		
$\delta_j > 1$	**2005**	**2011**	**2014**	**2005**	**2011**	**2014**
	Chemical industries			Agriculture, livestock, and related services Paper industries Coking plants and oil refining Industries other nonmetallic mineral products Electricity, gas, steam, and air conditioning Land transport; pipeline transport Maritime transport and inland waterways Air transport	Agriculture, livestock, and related services Paper industries Coking plants and oil refining Chemical industries Industries other nonmetallic mineral products Metallurgy Electricity, gas, steam, and air conditioning Land transport; pipeline transport Maritime transport and inland waterways Air transport	Agriculture, livestock, and related services Paper industries Coking plants and oil refining Chemical industries Industries other nonmetallic mineral products Metallurgy Electricity, gas, steam, and air conditioning Land transport; pipeline transport Maritime transport and inland waterways Air transport
$\delta_j < 1$	**2005**	**2011**	**2014**	**2005**	**2011**	**2014**
	Forestry Fishing and aquaculture Extractive industries Food, beverage, and tobacco industries Textile, clothing, leather, and footwear industries Wood and cork industry Manufacturing rubber products and plastic materials Metallurgy Various manufacturing Sanitation, waste management, and decontamination Construction Sale and repair of motor vehicles and motorcycles	Forestry Fishing and aquaculture Extractive industries Food, beverage, and tobacco industries Textile, clothing, leather, and footwear industries Wood and cork industry Manufacturing rubber products and plastic materials Metallurgy Various manufacturing Sanitation, waste management, and decontamination Construction Sale and repair of motor vehicles and motorcycles	Forestry Fishing and aquaculture Extractive industries Textile, clothing, leather, and footwear industries Wood and cork industry Manufacturing rubber products and plastic materials Various manufacturing Sanitation, waste management, and decontamination Construction Sale and repair of motor vehicles and motorcycles Wholesale trade and intermediaries, exc. motor vehicles Sale, manufacture, and repair	Catchment, potability, and distribution of water Storage and activities related to transport	Storage and activities related to transport	Food, beverage, and tobacco industries Catchment, potability, and distribution of water Storage and activities related to transport

	Wholesale trade and intermediaries, exc. motor vehicles Sale, manufacture, and repair Accommodation, food, and beverage services Audiovisual aggregate Financial mediation Insurance and pension funds Auxiliary activities of financial and insurance mediation Real estate activities Research & Development Other professional, technical, and veterinary activities Rental activities Travel agencies and tour operators Public administration, defense, and mandatory SS Education Social services activities Associative activities Other personal service activities Household activities	Wholesale trade and intermediaries, exc. motor vehicles Sale, manufacture, and repair Accommodation, food, and beverage services Audiovisual aggregate Financial mediation Insurance and pension funds Auxiliary activities of financial and insurance mediation Real estate activities Research & Development Other professional, technical, and veterinary activities Rental activities Travel agencies and tour operators Public administration, defense, and mandatory SS Education Social services activities Associative activities Other personal service activities Household activities	Accommodation, food, and beverage services Audiovisual aggregate Financial mediation Insurance and pension funds Auxiliary activities of financial and insurance mediation Real estate activities Research & Development Other professional, technical, and veterinary activities Rental activities Travel agencies and tour operators Public administration, defense and mandatory SS Education Social services activities Associative activities Other personal service activities Household activities			

Table A8. Key sectors in the consumption of natural gas, Catalonia 2005, 2011, and 2014.

	$\mu_j < 1$			$\mu_j > 1$		
	2005	**2011**	**2014**	**2005**	**2011**	**2014**
$\delta_j > 1$			Audio-visual	Food, beverage, and tobacco industries Textile, clothing, leather, and shoe industries Paper industries Chemical industries Manufacturing of rubber products and plastic materials Industries other nonmetallic mineral products Metallurgy Electric power, gas, steam, and air conditioning	Food, beverage, and tobacco industries Textile, clothing, leather, and shoe industries Paper industries Chemical industries Industries other nonmetallic mineral products Metallurgy Electric power, gas, steam, and air conditioning Sanitation, waste management, and decontamination	Food, beverage, and tobacco industries Textile, clothing, leather, and shoe industries Paper industries Chemical industries Industries other nonmetallic mineral products Metallurgy Electric power, gas, steam, and air conditioning Sanitation, waste management, and decontamination

				Sanitation, waste management, and decontamination Audiovisuals	Audio-visuals	
	2005	**2011**	**2014**	**2005**	**2011**	**2014**
$\delta_j < 1$	Agriculture, farming, and related services Forestry and forest exploitation Fishing and aquaculture Extractive industries Wood and cork industry Coking plants and oil refining Various manufacturing Construction Sell and repair motor vehicles and motorcycles Wholesale trade and intermediaries, excluding motor vehicles Sell, manufacture, and repair land transport; transport for cannonades Maritime transport and inland waterways Air transport Storage and activities related to transport Accommodation, food, and beverage services Financial mediation Insurance and pension funds Auxiliary activities of financial and insurance mediation Real estate activities Research and development Other professional, technical, and veterinary activities Rental activities Travel agencies and tour operators Public Administration, defense, and compulsory SS	Agriculture, farming, and related services Forestry and forest exploitation Fishing and aquaculture Extractive industries Wood and cork industry Coking plants and oil refining Various manufacturing Catchment, potability, and distribution of water Construction Sell and repair motor vehicles and motorcycles Wholesale trade and intermediaries, excluding motor vehicles Sell, manufacture, and repair Land transport; transport for cannonades Maritime transport and inland waterways Air transport Storage and activities related to transport Accommodation, food, and beverage services Financial mediation Insurance and pension funds Auxiliary activities of financial and insurance mediation Real estate activities Research and development Other professional, technical, and veterinary activities Rental activities Travel agencies and tour operators	Agriculture, farming, and related services Forestry and forest exploitation Fishing and aquaculture Extractive industries Wood and cork industry Coking plants and oil refining Various manufacturing Catchment, potability, and distribution of water Construction Sell and repair motor vehicles and motorcycles Wholesale trade and intermediaries, excluding motor vehicles Sell, manufacture, and repair Land transport; transport for cannonades Maritime transport and inland waterways Air transport Storage and activities related to transport Accommodation, food, and beverage services Financial mediation Insurance and pension funds Auxiliary activities of financial and insurance mediation Real estate activities Research and development Other professional, technical, and veterinary activities Rental activities Travel agencies and tour operators	Catchment, potability, and distribution of water	Manufacturing rubber products and plastic materials	Manufacturing rubber products and plastic materials

	Education Social service activities Associative activities Other activities of personal services Household activities	Public administration, defense, and compulsory SS Education Social services activities Associative activities Other activities of personal services Household activities	Public administration, defense, and compulsory SS Education Social services activities Associative activities Other activities of personal services Household activities			

Table A9. Key sectors in the consumption of coal, Catalonia 2005, 2011, and 2014.

	$\mu_j < 1$			$\mu_j > 1$		
$\delta_j > 1$	**2005**	**2011**	**2014**	**2005**	**2011**	**2014**
				Industries other nonmetallic mineral products Metallurgy	Industries other nonmetallic mineral products Metallurgy	Industries other nonmetallic mineral products Metallurgy
$\delta_j < 1$	**2005**	**2011**	**2014**	**2005**	**2011**	**2014**
	Agriculture, livestock, and related services Forestry Fishing and aquaculture Extractive industries Food, beverage, and tobacco industries Textile, clothing, leather, and footwear industries Wood and cork industry Paper industries Coking plants and oil refining Chemical industries Manufacturing rubber products and plastic materials Electricity, gas, steam, and air conditioning Catchment, potability, and distribution of water Sale and repair of motor vehicles and motorcycles Wholesale trade and intermediaries, exc. motor vehicles	Agriculture, livestock, and related services Forestry Fishing and aquaculture Extractive industries Food, beverage, and tobacco industries Textile, clothing, leather, and footwear industries Wood and cork industry Paper industries Coking plants and oil refining Chemical industries Manufacturing rubber products and plastic materials Electricity, gas, steam, and air conditioning Catchment, potability, and distribution of water Sanitation, waste management, and decontamination Sale and repair of motor vehicles and motorcycles	Agriculture, livestock, and related services Forestry Fishing and aquaculture Extractive industries Food, beverage, and tobacco industries Textile, clothing, leather, and footwear industries Wood and cork industry Paper industries Coking plants and oil refining Chemical industries Manufacturing rubber products and plastic materials Electricity, gas, steam, and air conditioning Catchment, potability, and distribution of water Sanitation, waste management, and decontamination Sale and repair of motor vehicles and motorcycles	Various manufacturing Sanitation, waste management, and decontamination Construction	Various manufacturing Construction	Various manufacturing Construction

	Sale, manufacture, and repair Land transport; pipeline transport Maritime transport and inland waterways Air transport Storage and activities related to transport Accommodation, food, and beverage services Audiovisual aggregate Financial mediation Insurance and pension funds Auxiliary activities of financial and insurance mediation Real estate activities Research & Development Other professional, technical, and veterinary activities Rental activities Travel agencies and tour operators Public administration, defense, and mandatory SS Education Social services activities Associative activities Other personal service activities Household activities	Wholesale trade and intermediaries, exc. motor vehicles Sale, manufacture ,and repair Land transport; pipeline transport Maritime transport and inland waterways Air transport Storage and activities related to transport Accommodation, food, and beverage services Audiovisual aggregate Financial mediation Insurance and pension funds Auxiliary activities of financial and insurance mediation Real estate activities Research & Development Other professional, technical, and veterinary activities Rental activities Travel agencies and tour operators Public administration, defense, and mandatory SS Education Social services activities Associative activities Other personal service activities Household activities	Wholesale trade and intermediaries, exc. Motor vehicles Sale, manufacture, and repair Land transport; pipeline transport Maritime transport and inland waterways Air transport Storage and activities related to transport Accommodation, food, and beverage services Audiovisual aggregate Financial mediation Insurance and pension funds Auxiliary activities of financial and insurance mediation Real estate activities Research & Development Other professional, technical, and veterinary activities Rental activities Travel agencies and tour operators Public administration, defense, and mandatory SS Education Social services activities Associative activities Other personal service activities Household activities			

Table A10. Key sectors in the consumption of petroleum, Catalonia 2005, 2011, and 2014.

	$\mu_j < 1$			$\mu_j > 1$		
	2005	**2011**	**2014**	**2005**	**2011**	**2014**
$\delta_j > 1$				Agriculture, livestock, and related services Coking plants and oil refining Industries other nonmetallic mineral products	Agriculture, livestock, and related services Coking plants and oil refining Industries other nonmetallic mineral products	Agriculture, livestock, and related services Coking plants and oil refining Industries other nonmetallic mineral products

				Electricity, gas, steam, and air conditioning Land transport; pipeline transport Maritime transport and inland waterways Air transport	Electricity, gas, steam, and air conditioning Land transport; pipeline transport Maritime transport and inland waterways Air transport	Electricity, gas, steam, and air conditioning Land transport; pipeline transport Maritime transport and inland waterways Air transport
	2005	**2011**	**2014**	**2005**	**2011**	**2014**
$\delta_j < 1$	Forestry Fishing and aquaculture Extractive industries Food, beverage, and tobacco industries Textile, clothing, leather, and footwear industries Wood and cork industry Paper industries Chemical industries Manufacturing rubber products and plastic materials Metallurgy Various manufacturing Catchment, potability, and distribution of water Sanitation, waste management, and decontamination Construction Sale and repair of motor vehicles and motorcycles Wholesale trade and intermediaries, exc. motor vehicles Sale, manufacture, and repair Accommodation, food, and beverage services Audiovisual aggregate Financial mediation Insurance and pension funds Auxiliary activities of financial and insurance mediation Real estate activities Research & Development	Forestry Fishing and aquaculture Extractive industries Food, beverage, and tobacco industries Textile, clothing, leather, and footwear industries Wood and cork industry Paper industries Chemical industries Manufacturing rubber products and plastic materials Metallurgy Various manufacturing Catchment, potability, and distribution of water Sanitation, waste management, and decontamination Construction Sale and repair of motor vehicles and motorcycles Wholesale trade and intermediaries, exc. Motor vehicles Sale, manufacture, and repair Accommodation, food, and beverage services Audiovisual aggregate Financial mediation Insurance and pension funds Auxiliary activities of financial and insurance mediation Real estate activities Research & Development	Forestry Fishing and aquaculture Extractive industries Food, beverage, and tobacco industries Textile, clothing, leather, and footwear industries Wood and cork industry Paper industries Chemical industries Manufacturing rubber products and plastic materials Metallurgy Various manufacturing Catchment, potability, and distribution of water Sanitation, waste management, and decontamination Construction Sale and repair of motor vehicles and motorcycles Wholesale trade and intermediaries, exc. motor vehicles Sale, manufacture, and repair Accommodation, food, and beverage services Audiovisual aggregate Financial mediation Insurance and pension funds Auxiliary activities of financial and insurance mediation Real estate activities Research & Development	Storage and activities related to transport	Storage and activities related to transport	Storage and activities related to transport

	Other professional, technical, and veterinary activities Rental activities Travel agencies and tour operators Public administration, defense, and mandatory SS Education Social services activities Associative activities Other personal service activities Household activities	Other professional, technical, and veterinary activities Rental activities Travel agencies and tour operators Public administration, defense, and mandatory SS Education Social services activities Associative activities Other personal service activities Household activities	Other professional, technical, and veterinary activities Rental activities Travel agencies and tour operators Public administration, defense, and mandatory SS Education Social services activities Associative activities Other personal service activities Household activities			

Table A11. Key sectors in the consumption of electricity, Catalonia 2005, 2011, and 2014.

	$\mu_j < 1$			$\mu_j > 1$		
	2005	**2011**	**2014**	**2005**	**2011**	**2014**
$\delta_j > 1$	Audiovisual aggregate Household activities	Audiovisual aggregate	Audiovisual aggregate Household activities	Textile, clothing, leather, and footwear industries Paper industries Chemical industries Manufacturing rubber products and plastic materials Industries other nonmetallic mineral products Metallurgy Electricity, gas, steam, and air conditioning Catchment, potability, and distribution of water Sale, manufacture, and repair Land transport; pipeline transport Storage and activities related to transport Accommodation, food, and beverage services Public administration, defense, and mandatory SS Associative activities	Paper industries Chemical industries Manufacturing rubber products and plastic materials Industries other nonmetallic mineral products Metallurgy Electricity, gas, steam, and air conditioning Catchment, potability, and distribution of water Sanitation, waste management, and decontamination Sale, manufacture, and repair Land transport; pipeline transport Storage and activities related to transport Accommodation, food, and beverage services Public administration, defense, and mandatory SS	Paper industries Chemical industries Manufacturing rubber products and plastic materials Industries other nonmetallic mineral products Metallurgy Electricity, gas, steam, and air conditioning Catchment, potability, and distribution of water Sale, manufacture, and repair Land transport; pipeline transport Storage and activities related to transport Accommodation, food, and beverage services Audiovisual aggregate

	2005	2011	2014	2005	2011	2014
$\delta_j < 1$	Agriculture, livestock, and related services Forestry Fishing and aquaculture Extractive industries Food, beverage, and tobacco industries Wood and cork industry Coking plants and oil refining Various manufacturing Construction Sale and repair of motor vehicles and motorcycles Wholesale trade and intermediaries, exc. motor vehicles Maritime transport and inland waterways Air transport Financial mediation Insurance and pension funds Auxiliary activities of financial and insurance mediation Real estate activities Research & Development Other professional, technical, and veterinary activities Rental activities Travel agencies and tour operators Education Social services activities Other personal service activities	Agriculture, livestock, and related services Forestry Fishing and aquaculture Extractive industries Food, beverage, and tobacco industries Coking plants and oil refining Various manufacturing Construction Sale and repair of motor vehicles and motorcycles Wholesale trade and intermediaries, exc. motor vehicles Maritime transport and inland waterways Air transport Financial mediation Insurance and pension funds Auxiliary activities of financial and insurance mediation Real estate activities Research & Development Other professional, technical, and veterinary activities Rental activities Education Social services activities Associative activities Other personal service activities Household activities	Agriculture, livestock, and related services Forestry Fishing and aquaculture Extractive industries Wood and cork industry Coking plants and oil refining Various manufacturing Sanitation, waste management, and decontamination Construction Sale and repair of motor vehicles and motorcycles Wholesale trade and intermediaries, exc. motor vehicles Maritime transport and inland waterways Air transport Financial mediation Insurance and pension funds Auxiliary activities of financial and insurance mediation Real estate activities Research & Development Other professional, technical, and veterinary activities Rental activities Public administration, defense, and mandatory SS Education Social services activities Associative activities Other personal service activities Household activities	Sanitation, waste management, and decontamination	Textile, clothing, leather, and footwear industries Wood and cork industry Travel agencies and tour operators	Food, beverage, and tobacco industries Textile, clothing, leather, and footwear industries Travel agencies and tour operators

Table A12. Key sectors in the consumption of biomass and waste for Catalonia 2005, 2011, and 2014.

	$\mu_j < 1$			$\mu_j > 1$		
	2005	**2011**	**2014**	**2005**	**2011**	**2014**
$\delta_j > 1$		Audiovisual aggregate	Audiovisual aggregate	Food, beverage, and tobacco industries Wood and cork industry Paper industries Chemical industries Industries other nonmetallic mineral products Land transport; pipeline transport Audiovisual aggregate	Wood and cork industry Chemical industries Industries other nonmetallic mineral products Land transport; pipeline transport	Wood and cork industry Chemical industries Industries other nonmetallic mineral products Land transport; pipeline transport
	2005	**2011**	**2014**	**2005**	**2011**	**2014**
$\delta_j < 1$	Agriculture, livestock, and related services Forestry Fishing and aquaculture Extractive industries Textile, clothing, leather, and footwear industries Coking plants and oil refining Metallurgy Various manufactures Electricity, gas, steam, and air conditioning Catchment, potability, and distribution of water Sanitation, waste management, and decontamination Construction Sale and repair of motor vehicles and motorcycles Wholesale trade and intermediaries, exc. motor vehicles Sale, manufacture, and repair	Agriculture, livestock, and related services Forestry Fishing and aquaculture Extractive industries Food, beverage, and tobacco industries Textile, clothing, leather, and footwear industries Paper industries Coking plants and oil refining Manufacturing rubber products and plastic materials Metallurgy Various manufacturing Electricity, gas, steam, and air conditioning Catchment, potability, and distribution of water Sanitation, waste management, and decontamination Sale and repair of motor vehicles and motorcycles	Agriculture, livestock, and related services Forestry Fishing and aquaculture Extractive industries Food, beverage, and tobacco industries Textile, clothing, leather, and footwear industries Paper industries Coking plants and oil refining Manufacturing rubber products and plastic materials Metallurgy Various manufacturing Electricity, gas, steam, and air conditioning Catchment, potability, and distribution of water Sanitation, waste management, and decontamination Sale and repair of motor vehicles and motorcycles	Manufacturing rubber products and plastic materials	Construction Storage and activities related to transport	Construction Storage and activities related to transport

	Maritime transport and inland waterways Air transport Storage and activities related to transport Accommodation, food and beverage services Financial mediation Insurance and pension funds Auxiliary activities of financial and insurance mediation Real estate activities Research & Development Other professional, technical, and veterinary activities Rental activities Travel agencies and tour operators Public administration, defense, and mandatory SS Education Social services activities Associative activities Other personal service activities Household activities	Wholesale trade and intermediaries, exc. motor vehicles Sale, manufacture, and repair Maritime transport and inland waterways Air transport Accommodation, food, and beverage services Financial mediation Insurance and pension funds Auxiliary activities of financial and insurance mediation Real estate activities Research & Development Other professional, technical, and veterinary activities Rental activities Travel agencies and tour operators Public administration, defense, and mandatory SS Education Social services activities Associative activities Other personal service activities Household activities	Wholesale trade and intermediaries, exc. motor vehicles Sale, manufacture, and repair Maritime transport and inland waterways Air transport Accommodation, food, and beverage services Financial mediation Insurance and pension funds Auxiliary activities of financial and insurance mediation Real estate activities Research & Development Other professional, technical, and veterinary activities Rental activities Travel agencies and tour operators Public administration, defense, and mandatory SS Education Social services activities Associative activities Other personal service activities Household activities			