UNIVERSITAT ROVIRA I VIRGILI
DEPARTAMENT D'ECONOMIA

(creip) CENTRE DE RECERCA EN ECONOMIA INDUSTRIAL I ECONOMIA PÚBLICA

WORKING PAPERS

Col·lecció "DOCUMENTS DE TREBALL DEL DEPARTAMENT D'ECONOMIA - CREIP"

Decomposing the Changes in Water Intensity in a Mediterranean Region

Maria Llop

Document de treball n.18 - 2018

DEPARTAMENT D'ECONOMIA – CREIP
Facultat d'Economia i Empresa

UNIVERSITAT
ROVIRA I VIRGILI
DEPARTAMENT D'ECONOMIA

Edita:

Departament d'Economia
https://gandalf.fee.urv.cat/departaments/economia/web
Universitat Rovira i Virgili
Facultat d'Economia i Empresa
Av. de la Universitat, 1
43204 Reus
Tel.: +34 977 759 811
Fax: +34 977 758 907
Email: sde@urv.cat

CREIP
www.urv.cat/creip
Universitat Rovira i Virgili
Departament d'Economia
Av. de la Universitat, 1
43204 Reus
Tel.: +34 977 758 936
Email: creip@urv.cat

Adreçar comentaris al Departament d'Economia / CREIP

ISSN edició en paper: 1576 - 3382
ISSN edició electrònica: 1988 - 0820

DEPARTAMENT D'ECONOMIA – CREIP
Facultat d'Economia i Empresa

Decomposing the Changes in Water Intensity in a Mediterranean Region

Maria Llop

(*Universitat Rovira i Virgili* and *CREIP*)

Avinguda Universitat nº 1, 43204 Reus (Spain)

maria.llop@urv.cat

Abstract

This paper proposes a simple method for decomposing the temporal changes in water intensity into different driving factors. Specifically, total changes are split into three elements that clarify some of the hidden reasons behind the changes in water use over time. The first element captures the changes in water intensity due to sectoral uses, showing the effects of modifying the water intensity of the different production sectors; the second element shows the changes in sectoral output intensity, showing the influence on water consumption of altering the production structure; finally, the third element quantifies the effects of the changes in residential water intensity, showing the contribution that changing the final water uses makes to changing water intensity. The empirical application, which is for the Spanish region of Catalonia, uses the latest available water consumption data (for 2004 and 2007). The results show a reduction in the regional water intensity resulting from a reduction in the water intensity of agriculture and industrial activities, which was greater than the increase in the water intensity by the services sectors. In addition, the production structure made a mixed contribution to final water intensity, depending on the sector under consideration. In particular, the decrease in the importance of agricultural production had the highest influence on reducing regional water intensity. Finally, the residential uses of water made a negative contribution to the total water intensity. The different directions and magnitudes of the drivers identified in this paper highlight the importance of using detailed and precise methods for studying water issues.

Keywords

Sectoral Water Intensity, Sectoral Output Intensity, Residential Water Intensity, Mediterranean Region.

1. Introduction

Freshwater is an essential natural resource that ensures human survival, as it is used to replace body water and growth food sources. However, water is not only required for life, it is also required to guarantee adequate health. Water provides the means for cleaning and personal hygiene, which facilitates a good level of heath and acceptable quality of life.

In the Mediterranean area, with long drought seasons and irregular rainfall, water management ensures continuity in water provision. In addition, water management should also ensure the conservation of natural ecosystems by allowing a sufficient ecological water flow to preserve habitats and species. Catalonia is a typical Mediterranean region with limited water resources that depend considerably on rainfall.[1] The Catalan population is concentrated along the coast while the water resources are mainly in the mountains, and this leads to permanent imbalances between regional water resources (i.e. water availability) and regional water requirements (i.e. water demand). Water scarcity has thus become an important question for the regional authorities in the last decade, particularly during the periods of no or very low rainfall.

Recently, water issues in Catalonia have received some research attention. For instance, Llop and Ponce-Alifonso (2012) used a computable general equilibrium (CGE) framework to simulate the impacts of alternative water policies that could be implemented at the regional level. The results of this study suggest that the most important aspect when various alternative policy are compared is the trade-off between prioritizing the economic or the environmental values associated with water. Additionally, using a CGE approach, Llop and Ponce-Alifonso (2016) analysed the effects on the Catalan water uses caused by both technological changes in agriculture and the implementation of new taxation on water that would lead to an increase in the regional water price. This paper indicates the importance of institutions related to water markets in terms of the possible effects that agricultural policies may cause on water variables depending on the characteristics of

[1] Catalonia is in the north-east of Spain, and represents approximately 6% of Spanish territory. In 2017, the regional GDP was 19% of Spanish GDP and the total population was around 16% (7,496,276 inhabitants in 2017).

water institutions. Moreover, the results show that greater economic efficiency is not necessarily optimal from either an environmental or a social point of view.

The input-output model has also been used to analyse the Catalan water context. In particular, Llop (2013) proposed transforming the input-output framework to show the water distribution within the economy, and applied this tool to Catalan water allocation among users. The results indicated that agriculture is an important activity not only in terms of the proportion of water consumed (i.e. water distribution) but also in terms of the water reallocation when there are both changes in final demand and in technical water requirements. More recently, Llop and Ponce-Alifonso (2015) used the input-output model of water consumption and defined a structural path analysis (SPA) method to determine more precisely the layers (and agents) responsible for the highest regional water uses. The outcomes in this paper reveal the importance of considering final water uses in the SPA model, especially to determine more precisely the relative importance of sectors and agents in terms of their contribution to water stress.

The objective of this paper is to determine the contribution of different determinants that explain the changes in water consumption and water intensity in Catalonia using an aggregated water accounting method. To the best of our knowledge, this is the first study that uses an inter-temporal approach for water analysis in the Catalan region. Therefore, the results of this paper will be useful for establishing possible directions for the water management and water policy at a regional level in the near future.

The method proposed consists in a structural decomposition analysis (SDA) that reveals how various determinants, encompassing distinct economic meanings, contribute to changing regional water intensity. The SDA approach, which has been used extensively in both the economic and ecological input-output model has proven to be extremely helpful for identifying the reasons behind the changes in key variables over time.[2] Unlike the detail provided by the input-output SDA methods, the structural decomposition analysis is used in this paper to disentangle an aggregated indicator. This decomposition provides insights

[2] Among the large set of input-output structural decomposition analyses, see for instance, Gowdy and Miller (1987), Han and Lakshmanan (1994), Rose and Casler (1996), Dietzenbacher and Los (1998), Alcántara et al. (2010), Guerra and Sancho (2011), Su and Ang, (2012), and Llop (2017).

into the hidden reasons influencing the changes in regional water consumption and regional water patterns. In particular, the changes in total water intensity are broken down into three different components that have different meanings: the changes in the (individual) water intensity of production sectors, the changes in sectoral output composition, and finally, the changes in the residential water intensity.

The empirical application uses data on the regional water consumed by agents. For the Catalan economy there is little information on water statistics and currently the most recent data refer to 2004 and 2007. These two years will thus define the period analysed in this paper. The results show a non-negligible reduction in the total water intensity due to different behaviours of the decomposed effects. Specifically, during the period 2004-2007 there was a decrease in water intensity in agriculture and industry, and an increase in water intensity in the services sectors. The production structure also contributed to water intensity positively or negatively (i.e. increases or decreases of the relative importance of sectors) depending on the specific production activity. Agriculture was the production sector with the highest negative influence on water intensity changes. Finally, residential water uses contributed to reducing the regional water intensity.

The rest of the paper is organised as follows. The next section shows the decomposition method proposed, which specifically divides the total changes in water intensity into three different determinants. Section 3 describes the regional data used for the Catalan economy and section 4 contains the empirical application. In the last section of the paper there are some concluding remarks.

2. Changes in Water Intensity and Decomposition

Water intensity relates the physical uses of water to social and/or economic indicators. The result is a relative measure of water consumption, that jointly links the ecological dimension of water use with the economic activity and social characteristics of the economy under consideration.

In fact, various methods can be used to define the water intensity. As the objective in this analysis is to determine the specific effect of various determinants within the total intensity indicator, the definition of water intensity considers 10 sectors of production individually

($j = 1, \dots, 10$). In addition, the proposed analysis also takes into consideration two components within the total water demand (W), as follows:

$$W = \sum_{j=1}^{10} W_j + W_r, \quad (1)$$

where W_j is water demand for sector j, and W_r is the residential water demand that specifically comprises the urban uses of water.

By using the division in Expression (1), water intensity is defined as:

$$w = \frac{W}{GDP} = \sum_{j=1}^{10} \frac{W_j}{GDP} + \frac{W_r}{GDP}$$

$$= \sum_{j=1}^{10} \frac{W_j}{VA_j} \frac{VA_j}{GDP} + \frac{W_r}{GDP} = \sum_{j=1}^{10} w_j g_j + w_r. \quad (2)$$

The term on the left side in Equation (2) shows the water intensity (w): total water consumption (W) divided by total GDP. By denoting VA_j as the value added of sector j, total water intensity is divided into *sectoral water intensity* ($\frac{W_j}{VA_j} = w_j$) multiplied by the *sectoral output intensity* ($\frac{VA_j}{GDP} = g_j$) plus the *residential water intensity* ($\frac{W_r}{GDP} = w_r$).[3]

To study the changes in water intensity variables it is necessary to compare two different time periods. These periods are hereinafter denoted using the subscripts 0 (first period, or 2004) and 1 (last period, or 2007). Moreover, as the variables involved correspond to different years, it is necessary to remove the inflationary effects inherent to the economic indicators to avoid the distorting effects of price changes. In particular, the sectoral value added and GDP are deflated by the corresponding price index by valuating the variables in the start period at the prices corresponding to the final year. As a result, all the economic data are given with 2007 prices by using the sectoral production prices to deflate sectoral value added, and using the general consumption price index to deflate the regional GDP.

[3] By using a similar method, Mendiluce et al. (2010) decomposed energy intensity in Spain. Without distinguishing the residential uses of water, Di Cosmo et al. (2014) used a (static) water intensity decomposition and applied it to the European Union countries.

Let us now assume that all the economic variables are at constant prices and let us also assume that the sectoral disaggregation is the same in the two study periods. By taking the first difference in Expression (2), changes in water intensity can be written as follows:

$$\Delta w = w_1 - w_0$$

$$= \sum_{j=1}^{10} w_{1,j} g_{1,j} + w_{1,r} - \sum_{j=1}^{10} w_{0,j} g_{0,j} - w_{0,r}$$

$$= \sum_{j=1}^{10} w_{1,j} \Delta g_j + \sum_{j=1}^{10} \Delta w_j g_{0,j} + \Delta w_r \quad (3.a)$$

$$= \sum_{j=1}^{10} \Delta w_j g_{1,j} + \sum_{j=1}^{10} w_{0,j} \Delta g_j + \Delta w_r \quad (3.b)$$

where Δw, Δw_j, Δg_j and Δw_r contain the first differences of the elements w, w_j , g_j and w_r, respectively and subscripts 0 and 1 denote the initial and final year. Note that although Expressions (3.a) and (3.b) are equivalent, the results provided will be different because the weights used to calculate the contribution of the increased components are different. For the input-output framework, Dietzenbacher and Los (1998) showed that the average of the two polar expressions provides a good approximation of the average of all the possible expressions. By taking this idea into account, the average of Expression (3) can be written as:

$$\Delta w = \sum_{j=1}^{10} \frac{1}{2} \Delta w_j g_{1,j} + \sum_{j=1}^{10} \frac{1}{2} w_{0,j} \Delta g_j + \Delta w_r \, , \quad (4)$$

where the term $\sum_{j=1}^{10} \frac{1}{2} \Delta w_j g_{1,j}$ shows the *sectoral water intensity effect*, $\sum_{j=1}^{10} \frac{1}{2} w_{0,j} \Delta g_j$ shows the *sectoral output intensity effect* and Δw_r shows the *residential water intensity effect*. Therefore, in Expression (4) the changes in total water intensity (Δw) have been calculated as the addition of three different components with a different economic meaning. The first component reflects how the changes in sectoral water uses have modified total water intensity; the second component reflects how the changes in sectoral output composition have influenced water intensity; and finally, the third term shows how the changes in residential water intensity have contributed to modifying total water intensity.

The simple decomposition proposed in Expression (4) makes it possible to determine some of the reasons behind the changes in water uses and water indicators. This method individually reflects the changes in variables with an ecological dimension (i.e. changes in sectoral and residential water intensities) and it also identifies the changes in variables with an economic dimension (i.e. changes in the sectoral composition of regional output). As both dimensions take place simultaneously, any water analysis should use methods able to integrate the two perspectives involved in environmental issues.

3. Data

There is little statistical information on water use in Catalonia. In this study, the empirical application is based on the data available at a regional level, which include the water used by sectors and the final water consumption in 2004 and 2007. The reason for choosing this period is because these are the only and most recent years covered by regional water statistics.

The information on water uses is measured in cubic hectometres (hm^3) consumed by each production sector and by final users. For 2004, this information was obtained from two different sources. Termes and Guiu (2009) provided the total water consumed in the region, and the Agència Catalana de l'Aigua (ACA, 2008) provided data on the water consumed within the production system and the water used by individual production sectors. For 2007, all the information was published by the Agència Catalana de l'Aigua (ACA, 2008).

To analyse changes in water intensity it is also necessary to use economic data, specifically comprising the sectoral value added and the regional GDP. These variables are published by the Catalan statistics office (IDESCAT, 2018). To avoid price distortions, the 2004 economic data was rescaled to the 2007 prices. In particular, sectoral value added (VA_j) and regional GDP in 2004 were valuated at the 2007 price levels by using individual price indices that reflect the particular price changes of the various production sectors. For the service activities, the corresponding price indices were obtained from the Consumption Prices Indices (INE, 2018a), which consider the various categories of consumption goods individually. For the industrial activities, the price indices were obtained from the

Production Prices Indices (INE, 2018b). Finally, the GDP in 2004 was rescaled to the price levels in 2007 by applying the general consumption price index of the regional economy (INE, 2018a).

For the two years, all variables have an identical sectoral disaggregation consisting of one aggregated primary sector (Agriculture), three industrial activities (Energy, Food Production and Other Industry), a Construction sector, and five services sectors (Commerce, Transport, Finance, Private Services and Public Services).

4. Empirical Application to Catalonia

4.1. Economic Variables

Determining how water intensity of an economy evolves over time is interesting for reducing water pressure and ensuring water provision. In addition, understanding the reasons for these (usually hidden) changes in water intensity makes it possible to define water measures that consider the automatic mechanisms governing water use.

This section contains the main results of the decomposition method previously proposed. To fully understand the subsequent outcomes, Table 1 shows the main economic indicators used in the empirical application. As indicated above, the 2004 values have been rescaled to the 2007 price levels. The price indices (third column in Table 1) show general increases in Catalan prices during the period analysed. In particular, the consumption price index (CPI), used for rescaling regional GDP, increased by 16%. The sectoral indices, which are used to rescale sectoral value added, show the largest sectoral price inflation in Energy (Sector 2) and Transport (Sector 7).

The total value added increased by around 4.7% in real terms (from 184,005 million euros in 2004 to 192,733 million euros in 2007). Despite these results, the value added of the various production sectors clearly behaved asymmetrically; the real value added in Agriculture (Sector 1) and all the Industrial sectors (Sectors 2 to 4) decreased, while it increased in Construction and all Services without exception (Sectors 6 to 10). This increase is especially significant for Construction (Sector 5, 19%), Private Services (Sector 9, 18%), and Finance (Sector 8, 18%). In addition, the value added in the Public Services (Sector 9) underwent an important increase (15% approximately). These sectoral trends suggest that the production system adapted to the intensification of the tertiarization of the regional economy during this period and to the decrease in both the industrial and agricultural specialisations.

Table 1. Economic indicators. Catalonia (Millions of Euros)

SECTOR	VALUE ADDED (VA_j)		PRICE INDEX (base 2007)
	2004*	2007	
1. Agriculture	2,285	2,048	0.85
2. Energy	3,380	3,298	0.75
3. Food Production	5,084	4,846	0.85
4. Other Industry	33,957	32,402	0.87
5. Construction	18,720	22,305	0.87
6. Commerce	37,877	38,164	0.83
7. Transport	8,426	8,586	0.81
8. Finance	8,100	9,564	0.83
9. Private Services	40,775	48,134	0.88
10. Public Services	20,393	23,386	0.88
TOTAL VALUE ADDED	**184,005**	**192,733**	**CPI (base 2007)**
GDP	**203,325**	**212,391**	0.84

* 2004 variables are valuated at 2007 prices.

In parallel to gross value added, the last row in Table 1 shows a rise in the regional GDP during 2004-2007, which is quantified at 4.4% (with values of 203,325 million euros in 2004 and 212,391 million euros in 2007, respectively).

4.2. Water Use

The water resource availability divides Catalonia into two differentiated areas. In the east are the Internal Basins and in the west are the Intercommunity Basins. The two areas are separated by an almost vertical line going from the north (i.e. the Pyrenees) to the south (i.e. the coast). These two hydrological zones are practically equal size, but there is a significant difference not only in the amount of water supplied but also in the water use made by the economic agents in each area.

The Internal Basins have rivers that flow entirely within Catalonia. In this area, the Catalan Government has the exclusive responsibility for developing water planning and water measures. The internal rivers supply 52% of the Catalan territory, including the Barcelona Metropolitan area. This area concentrates most of the regional economic activity; it covers 92% of the population and generates 95% of Catalonia's gross value added (ACA, 2010).

The Interregional Basins are basically the Catalan part of the River Ebro and also the rivers that flow into the River Ebro. Despite covering a similar territory as the Internal Basins (48%), the Interregional Basins provide water for 8% of the Catalan population and represent 5% of regional value added (ACA, 2010). In this area, the Catalan Government is responsible for some policies related to water but not all of them. For example, the Catalan Government is responsible for agricultural planning, but the Spanish Government is responsible for water planning through the Ebro Hydrographical Confederation.

The water uses are clearly different in the two hydrological areas. In the Internal Basins, which provide 38% of total water use in Catalonia, 64% of water demand is used for consumers and industry, and the remaining 36% is used for agriculture. In the Intercommunity Basins, which provide 62% of total water demand, 95% of water consumption is used for agriculture and the remaining 5% is consumed by households and industry (ACA, 2010).

To analyse water issues for the Catalan economy it is necessary to integrate the information for both the Internal and the Intercommunity Basins. Therefore, water studies at the regional level cannot reflect the distinct socioeconomic characteristics of the two territories nor the different areas where the two levels of government have water competences (i.e. the different policy scenarios regarding the application of water measures).

Table 2. Water use. Catalonia (Hm^3 per year)

SECTOR	2004	2007
1. Agriculture	2,268	2,114
2. Energy	10	9
3. Food Production	33	31
4. Other Industry	138	127
5. Construction	13	12
6. Commerce	8	11
7. Transport	10	13
8. Finance	7	10
9. Private Services	78	101
10. Public Services	27	26
TOTAL PRODUCTION	**2,592**	**2,454**
Residential	574	512
TOTAL REGIONAL	**3,167**	**2,966**

Table 2 contains the information on water uses (in cubic hectometres). The comparison of water uses during the period 2004-2007 shows that there was a decrease in the total amount of water consumed of around 6.3% (from 3,167 cubic hectometres in 2004 to 2,966 cubic hectometres in 2007). Among the various water users, Table 2 shows that Agriculture (Sector 1), Energy (Sector 2), Food Production (Sector 3), Other Industries (Sector 4) and, to a lesser extent, Construction (Sector 5) reduced their water use. However, all Private Services (Sectors 6 to 9) increased their water consumption. Among the tertiary activities, only Public Services (Sector 10) slightly reduced their water uses. The sectoral values in Table 2 show an interesting increase of around 29.5% in the Private Services (from 78 cubic hectometres in 2004 to 101 cubic hectometres in 2007). In total, the production system decreased water use by 138 cubic hectometres (from 2,592 to 2,454), which represents a decrease of approximately 5.3%.

The residential water consumption also decreased, and to a greater degree than the reduction in the productive system. Specifically, Table 2 shows that the amount of residential water consumed went from 574 cubic hectometres in 2004 to 512 in 2007, representing a decrease of around 10.8%. This suggests that final users made a great effort to move towards a more sustainable and efficient consumption of water.

The comparison of the annual water consumption by the various consumers shows interesting information for water management policies because the individual trends are not symmetrical. This is important when water measures are applied to different agents and users, especially bearing in mind that the expected impacts could be influenced by the specific behaviour of the various water users.

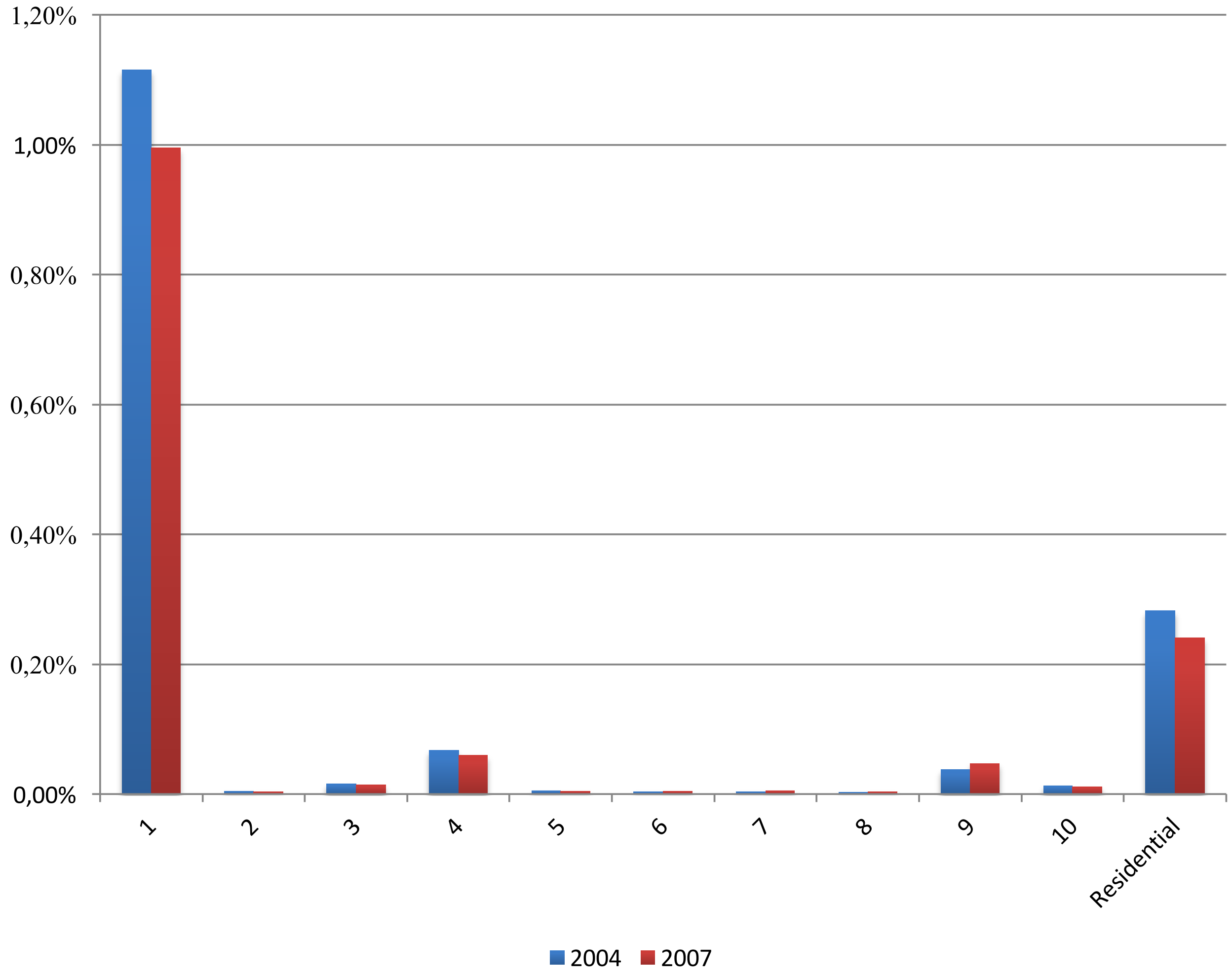
4.3. Changes in Water Intensity and Decomposition

Water intensity makes it possible to relativize the (absolute) water variables by linking water use to the production activity and the social characteristics of the economy. The first calculation in this section consists of obtaining the water intensity indicator for both the sectors of production and residential users, as shown in the preceding Expression (2). Figure 1 illustrates the individual relevance in the water intensity in the two years analysed.

A first look at Figure 1 shows that there are two major contributors to water intensity, specifically comprising Agriculture (Sector 1) and, at a considerable distance, Residential users. The influence of the rest of production sectors is comparatively much lower, and only Other Industry (Sector 4) and Private Services (Sector 9) have water intensity values above 5%.

The comparison of the two years shows that changes in water intensity for the two most influencing users (Agriculture and Residential users) are negative, which implies that these two consumer groups gained efficiency in water use. In other words, the reductions in water intensity of agriculture and final consumers suggest a more sustainable situation regarding the water pressure caused by these users. However, Figure 1 illustrates that the water intensity of the Private Services (Sector 9) increased in 2007 compared with the corresponding value in 2004.

Figure 1. Sectoral water intensity in Catalonia. 2004 and 2007



The decomposition of the changes in water intensity (Expression (4)) makes it possible to visualize the hidden trends that contribute to modifying the water indicator. Specifically,

Table 3 divides the percentage of the change in water intensity into the sectoral water intensity effect (i.e. changes in sectoral water used in relation to sectoral value added), the sectoral production intensity effect (i.e. changes in sectoral value added in relation to regional GDP) and, finally, the residential water intensity effect (i.e. changes in residential water use in relation to regional GDP).

The sectoral water intensity effect (first column in Table 3) shows a combination of positive and negative values; Agriculture (Sector 1) leads the positive impact (0.0413%), followed at a significant distance by Private Services (Sector 9), with 0.0039%. On the other hand, Energy (Sector 2), Food Production (Sector 3), Other Industries (Sector 4), and Public Services (Sector 10) make a negative contribution to the sectoral water intensity effect. By integrating these individual impacts, the total change in water intensity caused by the usages in the production system is quantified at 0.0414%, thus positively contributing to changes in the regional water intensity.

The second column in Table 3 indicates that the production structure negatively affected water intensity (-0.1615%). This result is due to individual asymmetric impacts: while Agriculture (Sector 1), Food Production (Sector 3), Other Industries (Sector 4), Commerce (Sector 6) and Transport (Sector 7) had a negative influence on the production structure that contributed to decreasing water intensity, Construction (Sector 5), Finance (Sector 8), Private Services (Sector 9) and Public Services (Sector 10) had a positive impact.

The last column in Table 3 shows the total contribution by the production activities to water intensity. The impacts are negative for Agriculture (Sector 1), Energy (Sector 2), Food Production (Sector 3), Other Industries (Sector 4), Construction (Sector 5), and Public Services (Sector 10). Interestingly, the sectoral values are positive for the rest of sectors, which comprise all the private service activities. By aggregating these individual trends, it can be seen that the whole production system negatively influenced regional water intensity (specifically quantified at -0.1201%).

Table 3 also shows that the changes in residential uses had a negative influence on water intensity, which means that the water consumed by final demand in relation to regional production decreased during the period 2004-2007. This reduction is specifically quantified at -0.0412%.

Table 3. Water Intensity decomposition (%)

SECTOR	Water Intensity Effect	Production Intensity Effect	Total Effect
1. Agriculture	0.0413%	-0.1614%	**-0.1201%**
2. Energy	-0.0003%	-0.0003%	**-0.0006%**
3. Food Production	-0.0005%	-0.0014%	**-0.0019%**
4. Other Industry	-0.0020%	-0.0058%	**-0.0078%**
5. Construction	-0.0015%	0.0008%	**-0.0007%**
6. Commerce	0.0011%	-0.0002%	**0.0010%**
7. Transport	0.0013%	-0.0001%	**0.0011%**
8. Finance	0.0004%	0.0005%	**0.0009%**
9. Private Services	0.0039%	0.0052%	**0.0091%**
10. Public Services	-0.0023%	0.0012%	**-0.0011%**
TOTAL SECTORS OF PRODUCTION	**0.0414%**	**-0.1615%**	**-0.1201%**
Residential Water Intensity Effect			**-0.0412%**
TOTAL WATER INTENSITY EFFECT			**-0.1613%**

Finally, the combination (i.e. the aggregation) of the negative contribution of both the production system and the residential users gives rise to a (greater) reduction in total water intensity, which is specifically quantified at -0.1613%.

The results in Table 3 suggest that the different water consumers and the various drivers evolved asymmetrically during the period studied. In particular, the total reduction observed in water intensity is the result of integrating components with a different sign, comprising therefore a different dynamic adaptation in terms of the pressure exerted on the natural resource. In total terms, the production system increased its water consumption related to its value added, while the changes in the production structure were linked to a negative impact. These outcomes indicate that the ability of controlling water pressure could be limited to a considerable extent, as it is not temporally linked to consumption decisions but rather to changes in the production structure. As aspects such as the economic cycle, the production specialization, or the production capacities of an economy affect production structure, monitoring water use could depend on issues outside the strict context of the water system. Successful water management thus may involve (more general) economic goals and economic variables apart from those of the specific hydrological context.

The decomposition proposed illustrates the importance of breaking down the overall changes in water intensity into their driving determinants. The changes in water use are the result of combining a huge amount of individual effects, which are extremely difficult to identify when the analysis is limited to the final aggregated impacts. The empirical results in this paper clarify some of the hidden effects and their individual influence on water intensity. These effects should be taken into account when water measures are developed to achieve more sustainable water use.

5. Conclusions

This paper analysed the changes in the Catalan water intensity during the period 2004-2007 by dividing the observed modifications into three different components: sectoral water intensity effect, sectoral output intensity effect, and residential water intensity effect. The sectoral water intensity effect shows the impacts on water intensity of changing the water consumed by each sector in relation to its value added. The sectoral output intensity effect shows the impacts of changing the sectoral value added in relation to regional GDP. Finally, the residential water intensity effect shows the contribution of the changes in the residential uses of water in relation to regional GDP.

The results show a decrease in the regional water intensity, which is the result of combining various driving factors with different dynamic behaviour. Specifically, the reduction in regional water intensity is due to a positive contribution of the sectoral water intensity effect and a (greater) negative contribution of both the production structure effect and the residential water intensity effect. In terms of individual activities, there are different sectoral repercussions for the changes in water intensity. In particular, the sectoral water effect was positively affected by agriculture and private services and negatively affected by industry and public services. However, the changes in the production structure had a negative contribution in agriculture, industry and construction, and a positive one in all services.

One interesting finding is therefore that intertemporal changes in the regional water intensity are mainly explained by two factors: first, agriculture's reduced contribution to GDP; and second, the reduction in the residential water uses in relation to regional GDP. In light of these results, particular attention should be given to these partial aspects of water use, especially if the aim is to successfully reduce the regional water pressure and ensure water provision.

The decomposition method proposed in this paper clarifies some aspects within the complex process of changes in water use. In particular, the SDA analysis is an appropriate tool for determining the driving forces of temporal modifications in water variables. Logically, this information is extremely useful for gaining further knowledge that can be used to attribute environmental responsibilities, because it makes it possible to identify the different agents involved in water consumption and how they change over time. The outcomes in the paper (i.e. the different individual adaptation to water use and water pressure over time) suggest that it is necessary to use disaggregated methods to gain further insights into the driving forces behind changes in the usages of natural resources in general, and in the consumption of water in particular.

Some limitations of the analysis should also be taken into account. In particular, the research is limited to two periods that do not correspond to a general dynamic trend of water use in Catalonia. To facilitate water analysis at the regional level, efforts should be made to improve the water statistics not only in terms of the temporal periods covered, but also in terms of the detail provided in relation to the agents behind the water use. Moreover, the simplicity of the method proposed means that is cannot be used to determine some interesting features inherent to the water context, such as the water footprint of the different products and services. This limitation notwithstanding, the results of the paper may be useful for visualising some general aspects related to the (non-symmetric) intertemporal changes in water use at the individual level. Water pollution and water quality are also extremely important issues involved in water management, which have recently received much research attention. In addition, the possible reforms in water markets, involving water pricing systems, privatisation mechanisms, efficiency measures, and improvement in water provision systems, among others, are aspects that are considered to be clearly beyond the scope of this paper.

Water management and water provision are among the most important environmental policies that regional and local authorities will have to face in the immediate future, especially in those areas affected by water scarcity to some extent. Indeed, the global challenges in water issues will only be addressed if important research efforts are made to help the water policy-decision processes. The need to guarantee water resources for individuals and firms, avoid water pollution and cope with the water induced changes due to climate change will continue to require research efforts in the following years. To achieve all these goals it is necessary to use of precise tools and clear information about the water consequences of both economic activity and social behaviour. The results in this paper make it possible to unmask some of the underlying factors affecting water use and thus help to clarify the complex questions that affect water consumption in an economy.

Acknowledgements

The author gratefully acknowledges the financial support of the Spanish Ministry of Economy and Competitiveness (grant ECO2016-75204-P), the Government of Catalonia (grant SGR2014-299 and "Xarxa de Referència d'R+D+I en Economia Aplicada"), and the Universitat Rovira i Virgili (grant PFR2018).

References

ACA, 2008. *Water in Catalonia: Diagnosis and Proposals for Action*. Catalan Water Agency, Generalitat de Catalunya, Barcelona, Spain.

ACA, 2010. *Catalan Water Management Plan*. Catalan Water Agency, Generalitat de Catalunya, Barcelona, Spain.

Alcántara, V., Del Río, P., Hernández, F. 2010. Structural analysis of electricity consumption by productive sectors. The Spanish case. *Energy* 35, 2088-2098.

Di Cosmo, V., Hyland, M., Llop, M. 2014. Disentangling water usage in the European Union: A decomposition analysis. *Water Resources Management* 28 (5), 1463-1479.

Dietzenbacher, E., Los, B. 1998. Structural decomposition techniques: sense and sensitivity. *Economic Systems Research* 10, 307-323.

Gowdy, J. M., Miller, J. L. 1987. Technological and demand change in energy use: an input-output analysis. *Environment and Planning A* 19, 1387-1398.

Guerra, A. I., Sancho, F. 2011. An analysis of primary energy requirements and emission levels using the structural decomposition approach: The Spanish case. In: Llop, M. (Editor), *Air Pollution: Economic Modelling and Control Policies*. Bentham E-Books Series.

Han, X., Lakshmanan, T. K. 1994. Structural changes and energy consumption in the Japanese economy 1975-1985: an input-output analysis. *Energy Journal* 15, 165-188.

IDESCAT, 2018. *Producte Interior Brut de Catalunya*. Institut d'Estadística de Catalunya, Barcelona.

INE, 2018a. *Índice de Precios al Consumo*. Instituto Nacional de Estadística, Madrid, Spain.

INE, 2018b. *Índice de Precios de Producción*. Instituto Nacional de Estadística, Madrid, Spain.

Llop, M. 2013. Water reallocation in the input-output model. *Ecological Economics* 86, 21-27.

Llop, M. 2017. Changes in energy output in a regional economy: A structural decomposition analysis. *Energy* 128, 145-151.

Llop, M., Ponce-Alifonso, X. 2012. A never-ending debate: demand versus supply water policies. A CGE analysis for Catalonia. *Water Policy* 14 (4), 694-708.

Llop, M., Ponce-Alifonso, X. 2015. Identifying the role of final consumption in structural path analysis: An application to water uses. *Ecological Economics* 109, 203-210.

Llop, M., Ponce-Alifonso, X. 2016. Water and agriculture in a Mediterranean region: The search for a sustainable water policy strategy. *Water* 8 (2), 1-14.

Mendiluce, M., Pérez-Arriaga, I., Ocaña, C. 2010. Comparison of the evolution of energy intensity in Spain and in the EU15. Why is Spain different?. *Energy Policy* 38 (1), 639-645.

Rose, A., Casler, S. 1996. Input-output structural decomposition analysis: A critical appraisal. *Economic Systems Research* 8, 33-62.

Su, B., Ang, B. W. 2012. Structural decomposition analysis applied to energy and emissions: Some methodological developments. *Energy Economics* 34, 177-188.

Termes, M., Guiu, R. 2009. Anàlisi de la tendència del consum d'aigua a Catalunya i marges d'estalvi. *Nota d'Economia* 93-94, 21-33.