CIRCULAR ECONOMY AS A TOOL TO MITIGATE THE EFFECTS OF CLIMATE CHANGE ON WATER RESOURCES: THE CASE OF SPAIN.

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Received: 18/Jun/2019 - Reviewed: 5/Jul/2019 - Accepted: 8/Jul/2019 - DOI: http://dx.doi.org/10.6036/9310

ABSTRACT:

Circular economy has become in recent years one of the main strategies to achieve water sustainability and combat the effects of climate change. This study analyses the effectiveness of water reuse in Spain, as a circular economy strategy, in order to reduce the pressure on water resources used for agricultural, industrial and municipal uses. The results show that water reuse has the necessary potential to contribute to water sustainability, since a greater volume of reused water used in municipal uses reduces the volume of water collected from other sources. However, to reach this effectiveness also in the other uses, it would be necessary to increase the volume of reused water, something that Spain has certainly the capacity to carry out.

Keywords: circular economy, reuse, water, scarcity, climate change

1.- INTRODUCTION

We are facing a global change in our economic model derived from its unsustainability. The traditional linear model of production and consumption (production-consumption-waste), added to the population and economic growth and the effects of climate change, put increased pressure on natural resources until reaching critical limits. Given this situation, a change in the paradigm towards a circular economy model is essential, in which the value of resources and products is maintained in the economy as long as possible.

In the water sector, the circular economy involves numerous agents and phases of the water cycle: the hydrological planning, the improvement of efficiency in the urban water cycle, the valorisation of sludge and other secondary outputs [1], the responsible consumption of this resource, etc. But, undoubtedly, water reuse is the key point of the circular economy, allowing water resources to be used more than once before being discharged into the natural environment [2], but it requires a holistic approach considering all its political, technological, environmental and socio-economic aspects [3].

The circular economy model in the water sector is especially necessary in countries such as Spain, where water scarcity and quality problems, droughts and climate change effects are major problems. But Spain, as many other countries, is aware of this situation, as proved by the numerous examples of water reuse found in our country [4-5]. In fact, Spain is one of the leading European countries in water reuse, regenerating 10.4% of the treated wastewater in 2016 and using it afterwards for several uses, such as agriculture (61%), urban uses (basically, for the irrigation of green areas) (19%), industry (5%) and other uses [6]; a very positive data compared to the 2.4% average reuse in Europe [2]. In addition, water reuse in Spain increased from 733,894 m^3 per day in 2000 to 1,350,536 m^3 per day in 2016 [6]. However, the effort of the different Spanish Autonomous Communities (AACC) was very diverse, being the Valencian Community (59%), Murcia (50%) and the Balearic Islands (45%) those with a highest percentage of water reuse; regions characterized by a severe water scarcity.

In these water scarce areas, water reuse is particularly relevant because it allows a more efficient resource allocation, reserving tap water for those uses that require a high quality, and it may have the potential to reduce the pressure on other traditional water sources (surface and groundwater) if water from these sources is replaced by reused water.

To address this topic, the previous literature used different approaches: some studies analysed, for a small number of industrial companies, whether there is a substitutability relationship between the water reused by the companies themselves and the water they capture from the publicly-supply networks [7-11]; other studies focused on the potential effects of the circular economy analysing a WWTP [4-5]; and others evaluated different reuse schemes and supply alternatives [3].

However, we have not found previous studies attempting to analyse, for a whole country, whether the volume of water reused in the WWTPs is considered by the users as a substitute for traditional water sources (publicly-supplied or self-supplied water, coming from surface or groundwater sources), or it is considered as an extra volume of water that users can utilize additionally to generate new uses or demands.

The objective of this paper is to analyse the relationship between the water reused in the WWTPs and subsequently used for agricultural, industrial and municipal uses, and the volume of water collected by each of these users; as well as to examine other factors influencing water intake. To do so, we used a panel dataset for 10 Spanish AACC for the period 2000-2016, and we estimated the demand for water by each type of user (agricultural, industrial and municipal) depending on the volume of reused water used by each user and other economic variables (production level, price of water, etc.).

The final purpose is to check whether a larger volume of water reused and subsequently used by each of these users allows reducing the volume of water collected from other traditional sources. If it were the case, the circular economy, through water reuse, could be an effective tool to reduce the pressure on water resources and thus contribute to mitigate the effects of climate change on this scarce resource.

After this Introduction, Section 2 describes the data and the model used, Section 3 shows the results obtained, and Section 4 presents the main conclusions.

2.- MATERIALS AND METHODOLOGY

2.1.- DATA

The data used in this study come from various official statistics of the Spanish National Statistics Institute (INE). Specifically, we have information for the Spanish AACC for the period 2000-2016 for the variables detailed in Table 1, along with their source of information. However, for some of these variables, information is not available for all the AACC. This makes necessary to limit the analysis to the following 10 AACC: Andalusia, Aragon, Castile-Leon, Castile-La Mancha, Catalonia, Valencian Community, Extremadura, Murcia, Navarre, and La Rioja. So that, we have a panel dataset with 170 observations (each observation is the data of an Autonomous Community -AC- in one year).

	Source	Average by AC for the whole period	2000	2016
Agricultural water collection (Hm^3)	[12]	1,880.50 (1,206.78)	2,188.32 (1,523.23)	1,809.64 (1,205.27)
Industrial water collection (Hm^3) (including publicly-supplied and self-supplied water)	[6]	260.52 (221.10)	279.38 (256.89)	249.09 (212.00)
Municipal water collection (Hm^3)	[6]	23.16 (19.99)	29.00 (26.18)	19.39 (14.45)
Agricultural water reuse (Hm^3)	[6]	20.99 (55.29)	7.49 (17.31)	26.10 (61.03)
Industrial water reuse (Hm^3)	[6]	3.98 (13.91)	2.10 (4.18)	16.49 (45.98)
Municipal water reuse (Hm^3)	[6]	10.07 (17.70)	8.48 (16.73)	12.76 (15.62)
Price of urban water (€)	[6]	0.70 (0.33)	0.37 (0.15)	1.00 (0.41)
Agricultural GDP (millions of €)	[13]	2.296,77 (1.962,85)	2.526,36 (2.049,73)	2.524,34 (2.477,40)
Industrial GDP (millions of €)	[13]	11,220.74 (10,941.41)	10,033.99 (11,144.02)	11,833.21 (11,913.19)
Municipal GDP (millions of € per municipality)	[13]	1,545.82 (924.27)	1,303.33 (966.37)	1,571.02 (732.11)
Population (inhabitants per municipality)	[14]	6,883.45 (8,647.53)	6,147.88 (7,797.89)	7,256.13 (9,794.24)

Table 1: Descriptive statistics. Average by AC. Standard deviation is shown in brackets. Economic magnitudes are expressed in real terms in 2016 prices, by applying the Spanish GDP deflator [13].

Table 1 also shows the average value of these variables by AC, that is, the value of each variable for the average AC of our sample. 87% of the water collected is used by agricultural users, 12% by industrial users and 1% by municipal users. Moreover, the water collected by the three types of users has substantially decreased during the period 2000-2016 (17%, 11% and 33%, respectively).

Regarding the volume of reused water, 60% is used afterwards by agricultural users, followed by municipal (29%) and industrial (11%) users. However, the volume of reused water utilise by industrial users has increased much more (684%), than in agricultural (248%) and municipal (50%) uses. The price of urban water has also increased notably (173%), which evidence that the water tariff has been used in Spain as an instrument to encourage water conservation, according to the cost recovery principle of the Water Framework Directive.

The GDP data show the large weight of the Spanish industrial sector (5 times larger than the agricultural sector) and that, unlike the agricultural sector, industrial GDP increased by 18% in these years. Finally, municipal GDP and the average population of the Spanish municipalities also increased during this period (21% and 18%, respectively).

2.2.- MODEL

The model used in this paper analyses the determinants of the volume of water collected by each of the three types of users considered, in order to know whether the use of a greater or lesser volume of reused water has an impact on the volume of water captured from other traditional sources; as well as to examine other factors influencing water intake.

For this purpose, we used the economic model usually applied to estimate the demand for water by productive activities, based on the microeconomic theory, in which the level of production depends on the use of several inputs (including water). Applying the duality theorem we can derive a cost function from the production function, and using Shephard's lemma, the cost-minimising input demand functions can be obtained. In these resulting functions, the quantity demanded of each input depends on its own price, the price of the other inputs and the level of production [15]. In addition, input separability hypothesis [16] allows for specifying simplified demand functions, in which the demand of each input (in this case, water) depends on its own price and on the production level. This methodology has been widely used by the previous literature [7-11] and it was also applied in this study, including the volume of reused water as a variable that can mean a lower water intake from other traditional sources.

We applied this model to our case study by specifying double-logarithmic water demand functions as in equations (1) - (3). Each of the three equations was estimated as a data panel where each observation refers to the value of the variables for each AC (i) in each year (t). The units of measure of the variables are detailed in Table 1; α is the constant, β are the coefficients that measure the percentage variation in the volume of water captured due to a 1% variation in each of the exogenous variables (that is, the elasticities), and u is the error term distributed as a normal.

Therefore, for the agricultural uses we have:

$$\ln AGRICULTURAL\ WATER\ COLLECTION_{it} = \alpha + \beta_1 \ln AGRICULTURAL\ GDP_{it} + \beta_2 \ln AGRICULTURAL\ WATER\ REUSE_{it} + u_{it} \quad (1)$$

where the total volume of water collected by the agricultural sector depends on the GDP of this sector and the volume of reused water used for agricultural uses. In this case, the price of agricultural water was not included as an explanatory variable due to the small size of this price (around 0.03 €/m^3) and because official statistics are not available by AACC.

For the industrial sector, we have:

$$\ln INDUSTRIAL\ WATER\ COLLECTION_{it} = \alpha + \beta_1 \ln INDUSTRIAL\ GDP_{it} + \beta_2 \ln INDUSTRIAL\ WATER\ REUSE_{it} + \beta_3 \ln WATER\ PRICE_{it-1} + u_{it} \quad (2)$$

where the volume of water collected by the industrial sector depends on the GDP of this sector, the volume of reused water used by the industry and the price of urban water, lagged one period to avoid endogeneity, as usual in this literature [17-18].

Finally, for the municipal uses, the demand function is slightly different since it is not a productive activity:

$$\ln MUNICIPAL\ WATER\ COLLECTION_{it} = \alpha + \beta_1 \ln MUNICIPAL\ GDP_{it} + \beta_2 POPULATION_{it} + \beta_3 \ln MUNICIPAL\ WATER\ REUSE_{it} + \beta_4 \ln WATER\ PRICE_{it-1} + u_{it} \quad (3)$$

where the volume of water collected for the municipal uses depends on the average size of the municipalities (proxied by the municipal GDP and the population), the volume of reused water used for this uses and the price of urban water (lagged one period).

3.- RESULTS AND DISCUSSION

The results of the estimation of equations (1-3), applying a panel model with fixed effects, are shown in Table 2.

For the agricultural uses, a 1% increase in agricultural GDP increases water collection in this sector by 0.60%, being this effect statistically significant. On the contrary, the coefficient of the variable water reuse is not significant, indicating that a greater volume of reused water used in the agricultural sector has no effect on the quantity of water captured by this sector. So, in this case, water reuse could not be an effective tool to reduce the pressure on water bodies and thus contribute to mitigate the effects of climate change on water resources. This implies that the volume of reused water may be used to satisfy new uses and demands, instead of being used as a substitute for traditional water sources; a result that has been also observed when studying irrigation modernization plans, where the high profitability that farmers can obtain by expanding their cultivated area makes that the water savings achieved through modernization were used to irrigate a larger cultivation area.

	Agricultural water collection	Industrial water collection	Municipal water collection
Water reuse	0.0092551 (0.57)	-0.0076725 (0.71)	-0.0913419 (0.00)
Water Price	-	-0.3206212 (0.00)	-0.4273173 (0.00)
GDP	0.600535 (0.00)	1.099472 (0.01)	-0.2797764 (0.14)
Population	-	-	1.467113 (0.08)

Table 2: Results of estimation. P-value is shown in brackets.

In the industrial sector, a 1% increase in industrial GDP leads to a 1.1% increase in water collection in this sector, being this effect more than proportional. As for the water tariff, a 1% increase in the price of urban water reduces the volume of water captured by industrial users by 0.32%. This result is in line with the previous literature [19] and corroborates that pricing policies encourage users to reduce their use of water, contributing to resource sustainability. On the contrary, as for the agricultural uses, the use of a larger volume of reused water does not have a significant effect on the volume of water captured by the industrial sector. This result may seem contradictory with those obtained by the previous literature [7-11]. However, the aforementioned studies focused on the water reused by the companies themselves, whereas this paper analyses the water reused in the WWTPs and later used by the industry; a volume of water that, in addition, represents a very small proportion of the total volume of reused water (11%).

However, in the municipal uses, a 1% increase in the volume of reused water for these uses does reduce the municipal water collection by 0.09%. A reduced but statistically significant effect which indicates that, in this case, water reuse does reduce the pressure on traditional water sources and therefore contribute to water sustainability. This result is consistent with the large volume that represent reused water for municipal uses with respect to the volume of water captured by this sector (43.5%, against 1.5% and 1.1% for industrial and agricultural uses) and reused water for municipal uses with respect to the total volume of water reused (34% on average, but even reaching 100% in some AACC).

The volume of water captured for municipal uses also depends inversely on the price of water, since a 1% increase in the urban water price (that is, its cost) reduces water collection by 0.43%. In addition, the size of the municipalities (measured through their population) and the volume of intake water are positively correlated (elasticity of 1.47), while the municipal GDP does not determine the volume of water used for municipal uses.

4.- CONCLUSIONS

This paper aims to analyse the effectiveness of water reuse, as a circular economy strategy, to reduce the pressure on traditional water sources and thus contribute to mitigate the effects of climate change on this scarce resource. The main conclusions obtained are the following:

1. Water reuse has the potential to contribute to water sustainability, as evidenced by the fact that, for the municipal uses, a greater volume of reused water implies a lesser volume of water captured from other sources. However, since the volume of reused water used by other users (agricultural and industrial) only represents a small share of the total volume of water captured by these sectors, these users utilise this volume of reused water as an extra volume that can be used additionally to satisfy new demands; so that implies that water reuse loses its effectiveness as an instrument to reduce the pressure on water resources.

   This highlight the need to increase the volume of water reused in Spain, especially for agricultural and industrial uses. Something that Spain has certainly the capacity to carry out given their available infrastructures and technologies. And to do so, Spain should continue working on the Spanish Circular Economy Strategy presented in 2018, in line with the EU Action Plan for the Circular Economy of the European Commission. This would allow increasing the proportion of reused water with respect to the total volume of water captured, and thus improving its effectiveness as an instrument to achieve greater water sustainability and faced the effects of climate change on this resource.

2. The results obtained also show that an increase in the price of urban water encourages industrial and municipal users to make a more efficient use of this resource, which confirms the need to continue implementing pricing policies, according to the Water Framework Directive. However, the effectiveness of price policies leads to lower water consumption, mining that users will have an increasingly smaller margin to reduce their consumption, so pricing policies effectiveness will decrease

over time. So, policy makers should implement integrated water policies addressing both the supply and demand sphere, and complement pricing policies with other holistic strategies, such as the circular economy.

3. We also found that an increase in production and population increases the volume of water captured, showing a direct relationship between growth and water use. In a situation in which the effects of climate change on water resources are aggravated by a greater population and production, it is necessary to implement all those measures that may contribute to greater resource sustainability, such as encouraging investment in less water consumer technologies, or promoting the use of other alternative water sources. And for the latter, the circular economy could be an effective tool to stop and reverse this trend of increasing pressure on water resources and thus help mitigate the effects of climate change on water.

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