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Crop production and irrigation: deciding factors of wastewater reuse in Spain?

Leticia Gallego-Valero[a,*], Encarnación Moral-Pajares[a], Isabel María Román-Sánchez[b,c]

[a]*Department of Economy, University of Jaén, Campus las Lagunillas, s/n, 23071 Jaén, Spain; Tel. +34-651-888-733; email: lgallego@ujaen.es (L. Gallego-Valero), Tel. +34-953-212-635; emoral@ujaen.es (E. Moral-Pajares)*
[b]*Department of Economics and Business, University of Almería, 04120 Almería, Spain; Tel. +34- 950-015-180; email: iroman@ual.es (I.M. Roman-Sánchez)*
[c]*Solar Energy Research Centre (CIESOL), Joint Centre University of Almería-CIEMAT, 04120 Almería, Spain*

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ABSTRACT

Water scarcity in Mediterranean countries, especially in drought periods, justifies the use of wastewater. The deficit of water resources influences crop productivity and threatens environmental sustainability. The objective of this paper is to analyse whether agricultural production and irrigation area determine the volume of reused wastewater in Spain. To that end, a panel data model is estimated with 187 observations from 17 Spanish regions between 2004 and 2014. The results obtained show that wastewater reuse depends on agricultural variables as well as factors which affect the supply and demand of water. These include the relative scarcity of water resources; the availability of surface water, groundwater and desalinated water; the population; and the revenues collected for sanitation and wastewater treatment. Prevailing economic conditions, however, are not a determining factor. Therefore, there is an urgent need to develop appropriate management systems that guarantee the financing of sanitation and water reclamation services in all the regions that have significant crop production and scarcity of water resources.

Keywords: Wastewater reuse; Crop production; Irrigation; Water scarcity; Wastewater taxes; Panel data

1. Introduction

The demand for water resources is constantly growing, with 70% of the total water extracted from aquifers, rivers and lakes currently, allocated to the agricultural sector. In light of this situation, the reclamation and reuse of wastewater can be seen as a unique opportunity to improve the availability of this resource [1–3]. In the last 50 years, the total cultivated area in the world has grown by 12%, and the resources allocated to irrigation have doubled in that time. At the same time, climate change, global warming, changing rainfall patterns, the growth of the world population and new dietary patterns have meant that communities around the world now face problems of water scarcity [4]. Reused wastewater is an alternative source of irrigation supply that is both economical and safe in terms of human health and the environment [5–7]. It boosts supply and lessens the dependence on groundwater and surface water resources [8–10].

In the European Union (EU), wastewater is regulated by Directive 91/271/EEC and the Water Framework Directive (WFD), which advocate the cost-recovery principle of water-related services. In this regard, in May 2018 the Commission proposed new regulations to encourage and facilitate the reuse of water for agricultural irrigation and for environmental purposes [11–13]. The EU regulation has promoted the reclamation and reuse of wastewater in all EU countries, with the main projects located in coastal and semi-arid areas in the south [14]. In Spain, this legislation has led to the modification of various taxes, established by local, regional and national administrations. These taxes are aimed at financing wastewater treatment services, enabling investment in infrastructure and improving the quality of water resources [15–16].

* Corresponding author.

Nowadays, Mediterranean countries frequently use treated wastewater in irrigated agriculture [17]. Spain, the driest country in the EU [18] and the one with the highest water stress index [19], registered a volume of 13.5 hm^3/d of treated wastewater in 2014, with 1.45 hm^3/d being reused, 61.3% of it in agriculture [20]. Three factors have contributed to this situation: (a) the boost to wastewater treatment resulting from Directive 91/271/EEC; (b) the development of wastewater reclamation techniques, enabling the creation of reliable systems at affordable prices; and (c) Royal Decree 1620/2007, which establishes the legal basis for the reuse of treated wastewater. The irregular distribution of these resources in Spain causes serious situations of permanent deficit in Mediterranean coastal areas and in the Canary and Balearic Islands [21]. In these areas, the inability to obtain conventional resources due to the deterioration of the water environment and the difficulty of carrying out public works for capturing new resources conflict with the growing demand from agricultural and tourist development.

The aim of this article is to study the existing status of reused wastewater in Spain and analyse how a number of different factors affect reuse trends in the different Spanish regions. Specifically, we determine whether the volume of reclaimed wastewater depends on the crop production of the regions, their irrigated area, the relative scarcity of water resources, the accessibility of surface water, desalinated water and groundwater, and also variables such as the total population of the region, the public revenues from sanitation and wastewater treatment taxes collected in each region, and the state of the economy. To that end, we first study trends in wastewater reused nationally and in the different Autonomous Communities between 2004 and 2014, checking for notable differences between them. Second, we analyse the nature and significance of the relationship observed between the volume of wastewater reused and the relevant supply and demand variables. Our empirical results shed some light on the determinants of the volume of wastewater reused in Spain, thus adding to the few studies that apply econometric techniques to better understand the use of water resources. Our findings should be of use to both citizens and public administrations, helping them to achieve greater efficiency in the utilization of water resources. The rest of the paper is structured as follows: After this introduction, in section 2, we describe the theoretical model and the econometric specification, while in section 3 we present the data, the results of the panel data analysis, and a discussion of the findings. The last section provides the main conclusions of the study.

2. Econometric model

2.1. Materials and methods

The goal of our study is to identify the factors that influence the volume of wastewater reused in Spain, by conducting an analysis of the relevant variables and testing the association between the independent variables and the dependent variable. The study sample consists of data from 17 regions, covering the period 2004–2014. This time period was chosen due to the unavailability of data from 2014 on. A descriptive analysis of the variables was carried out, as well as a panel data analysis, following the methodology applied in previous articles [22]. The dependent variable in the model is wastewater reuse, defined as the volume of reclaimed wastewater used, expressed in cubic metres per year [20]. The nine explanatory variables, which are presented in Table 1, were selected according to the hypotheses set out in the following section.

The following equation tests the link between the independent variables and the dependent variable:

$$\text{Rww}_{it} = \alpha_{it} + \alpha 1\text{AgProd}_{it} + \alpha 2\text{IArea}_{it} + \alpha 3\text{Rsc}_{it} + \alpha 4\text{Swater}_{it} + \alpha 5\text{Gwater}_{it} + \alpha 6\text{Dwater}_{it} + \alpha 7\text{Pop}_{it} + \text{Rev}_{it} + \text{Rec}_{it} + \alpha e_{it}$$

Table 1
Independent variables used in the analysis: description, sources and expected relationship with the dependent variable

Variable	Description	Source	Expected sign
Agricultural production	Crop production (millions of euros)	MAPAMA	+
Irrigated area	Hectares of irrigated land with respect to total cropland (percentage)	MAPAMA	+
Relative scarcity of water resources	Ratio of supplied water to available water, compared with the national total	INE	+
Surface water for the agricultural sector	Volume of surface water allocated to the agricultural sector (thousands of cubic metres per year)	INE	+ or –
Groundwater for the agricultural sector	Volume of groundwater allocated to the agricultural sector (thousands of cubic metres per year)	INE	+ or –
Desalinated water	Volume of desalinated water (thousands of cubic metres per year)	INE	+ or –
Population	Population size (number of inhabitants)	INE	+
Revenues	Revenues collected for sanitation and treatment (euros per cubic metre)	INE	+
Recession	Dummy variable capturing the state of the Spanish economy	INE	–

Source: Own elaboration based on data from [20] and [23].

where Rww_{it}: reused wastewater; $AgProd_{it}$: agricultural land production; $IArea_{it}$: irrigated area; Rsc_{it}: relative scarcity of water resources; $Swater_{it}$: volume of surface water for the agricultural sector; $Gwater_{it}$: volume of groundwater for the agricultural sector; $Dwater_{it}$: volume of desalinated water; Pop_{it}: population; Rev_{it}: revenues collected; Rec_{it}: recession; α: estimated coefficients.

Lastly, α_{it} measures the influence of other exogenous variables not included in the model, and αe_{it} is the error term.

A panel data approach is appropriate due to the inclusion of time periods and the probable presence of unobserved individual effects. The use of this technique has multiple advantages, such as the fact that it reduces collinearity between variables, enables the construction of more complex models, eliminates or reduces bias in results when aggregating information, and identifies and evaluates effects not detected by cross-sectional or time-series analysis [24]. However, drawbacks include problems with design and data collection, cross-section dependence and short time series.

2.2. Theoretical arguments and hypotheses to be tested

Crop production is a major component of the Spanish economy: in 2016, Spain contributed 13.89% of the EU-28's total value of field crops at basic prices but only 8.50% of EU gross domestic product (GDP). Spain is the second largest crop producer in the EU, ranking behind France (18.82%), slightly ahead of Italy (13.87%) and Germany (11.63%), and far ahead of other countries, such as the Netherlands (6.49%) and Poland (5.09%) [25]. This subsector contributes 33.7% of Spanish agri-food sector exports, with 18.3% corresponding to foreign sales of fruits, mostly citrus and 13.17% to vegetables and legumes [26]. Among the national agricultural production, certain crops have high water requirements: cereals, such as wheat, rice or corn; industrial crops, mainly sugar beet, sunflower, cotton, alfalfa, especially vegetables, and fruit trees. With an irrigated area of 3.8 million hectares in 2015, the national demand for blue water for irrigation often exceeds 15,000 hm^3/y, due to irregular rainfall patterns in terms of spatial and temporal distribution and quantity [27]. Irrigated land is distributed throughout the entire country, although more than three-quarters of the total is concentrated in the regions of Andalusia (29.53%), Castile-La Mancha (13.92%) Castile and Leon (13.33%), Aragon (11.63%) and Valencia (8.60%) [23]. Based on the above, and taking into account the fact that agriculture—especially irrigated crops—is a net demander of irrigation water and that reclaimed water can be used to meet this need [1,4,8,28–31], the following hypotheses are proposed:

- Hypothesis 1: The crop production of the region, which influences the demand for water for irrigation, is positively related to the volume of wastewater reused in agriculture.
- Hypothesis 2: The irrigated area of the region is positively related to the volume of water reused in agriculture.

Spain, the driest country of the EU-28 member states [18], presents a wide range of water resource conditions in its territory, due to the climatic differences related to altitude, the complex topography of the different regions, exposure to the Atlantic fronts and the influence of the Mediterranean. The country can be divided into two zones as regards to rainfall and accessibility of water resources: "dry Spain" in the south and "wet Spain" in the north [32]. The wet zone, which extends across the north of the peninsula, has a mean annual rainfall above 800 mm, sometimes reaching 2,000 mm. In the inland territories located in mountainous areas, there are humid regions between much drier zones. For example, the Sierra de Grazalema (Western Andalusia) in the Guadalquivir basin, registers the highest rainfall in the peninsular with 2,000 mm/y. Precipitation of over 700–800 mm/y is also found in Gredos, high territories of the Iberian Mountain Range, Guadarrama, Gata, Sierras de Cazorla and Segura, among others. The dry zone (400–600 mm) includes the northern and southern plateaus, the Ebro basin except the Pyrenees, the east, the Guadalquivir basin, the Southern basin and most of the archipelagos. The territories with the lowest water resources of the peninsula are in the southeast and certain areas of the interior, with mean rainfall of less than 400 mm/y, and at times below 200 mm/y. The situation of water scarcity that characterises certain regions in the dry zone justifies the implementation of reuse systems that reduce the pressure on aquatic ecosystems, by achieving an increase in available water resources [14,33–35]. In light of the above, hypothesis 3 has been formulated as follows:

- Hypothesis 3: The volume of wastewater reused depends on the relative water scarcity in the different Spanish regions.

In an average year in Spain, the annual rainfall provides 1,11,000 hm^3 of natural resources, of which slightly more than 82,000 hm^3 goes to surface water and around 29,000 hm^3 to groundwater. Approximately 2,000 hm^3 of that groundwater consists of aquifers that drain directly to the sea [32]. These water resources are very irregularly distributed between the northern third and the rest of the country, with the eastern coastal area having the lowest coverage per inhabitant [21]. There may be a significant relationship between the supply of water resources in the region from surface water, groundwater or desalinated water, with which to meet the needs of the agricultural sector, and the volume of reused wastewater [4,36–40]. Wastewater can be a complementary resource or, where required, an alternative to water from rivers, wetlands, reservoirs, aquifers or desalination plants [41]. Taking into account the above, hypotheses 4, 5 and 6 can be posited as follows:

- Hypothesis 4: The availability of surface water for the agricultural sector is related to the volume of reused wastewater in the region.
- Hypothesis 5: The availability of groundwater for the agricultural sector is related to the total wastewater reused in the region.
- Hypothesis 6: The volume of wastewater reused depends on the supply of desalinated water in the region.

Access to drinking water is a fundamental right implicitly and explicitly recognised in international law and in national legislation [42]. All human beings must have water in sufficient quality and quantity to meet their basic needs. The 2006 Human Development Report [43] estimates that average water use varies between 200–300 L per person per day in most European states, but is less than 10 L per person per day in developing countries. Population growth and the increase in per capita income leads to greater domestic water use and limits the supply available for other uses, such as agricultural irrigation; this situation is driving changes in wastewater management towards a greater level of reuse [44–46]. In light of the above, the following hypothesis can be posited:

- Hypothesis 7: The size of the population in a region is linked to the quantity of wastewater treated and reused.

The WFD specifically incorporates fiscal tools and follows the cost recovery principle and the polluter pays principle [47–51]. This legislation has prompted the regional governments of the different Spanish Autonomous Communities to impose taxes on wastewater discharge, or in some cases, to modify existing taxes[1]. The revenues collected are used, in whole or in part, to finance wastewater treatment systems [16,52–53]. These systems include more advanced and expensive treatments, which require more funds to start up and run. [54] These are known as third generation systems, and the treated wastewater they produce is permitted for certain end uses, such as the irrigation of crops that can be consumed raw, vegetables and orchard fruits, or the cultivation of pastures for feeding milk- or meat-producing livestock [5,14,33]. The arguments set out above allow us to postulate the following hypothesis:

- Hypothesis 8: The revenues collected by wastewater taxes positively affect the volume of wastewater reused.

The economic crisis that afflicted the Spanish economy between 2008 and 2014—resulting in measures to stimulate production and austerity policies imposed by the EU—has had an adverse effect on its environmental protection policies [55], as occurred in other European countries [56–58]. A number of different studies have found that concern for the environment takes a back seat during a recession [59]. Possible actions to prevent the deterioration of the natural environment can even be seen as an obstacle to recovery [60]. Given the above, the following hypothesis is formulated:

- Hypothesis 9: The economic crisis has affected the measures implemented for the protection of water resources, thus influencing the use of reclaimed water for irrigation.

1 With the exception of the Castile and Leon, all Spanish regional administrations levy such a tax.

3. Results and discussion

3.1. Variables analysis

First, we provide a descriptive analysis of the variables examined, shown in Table 2. There is a high degree of dispersion in the main variable, the volume of wastewater reused per year, as well as in some of the independent variables, such as those that measure the available resources for irrigation sourced from surface water, groundwater or desalinated water. The value of the crop production of the different regions shows high heterogeneity, with values ranging from € 61.41 million for Cantabria in 2012 to € 9.12 billion for Andalusia in 2014. More uniform values are reported for the rest of the variables: relative scarcity of water resources, revenues collected for sanitation and wastewater treatment, irrigated area and population.

Between 2004 and 2014, there was an increasing trend in the total volume of reused wastewater in Spain as a whole, with the Valencian Community reporting the highest volume, as shown in Fig. 1. In these years, the volume of wastewater treated and reused in Spain registered a cumulative average annual growth of 3.73%. In 2006 and 2011, there were annual variations of over 20% leading to values 1.44 times greater. However, this variable does not show a uniform trend in all the regions considered: while the Canary Islands, Extremadura and Galicia reduced the amount of wastewater reused in this period, Madrid registered a threefold increase in volume.

The value of Spanish crop production was € 25,584.93 million in 2014, 4.06% less than in 2004. Bucking the general trend, three regions -Andalusia, the Valencian Community and Murcia- increased the value of their crop production in this period. Specifically, the Valencian Community registered a notable variation of 6.85%. In 2014, the Andalusian region provided 35.66% of all national production, while the Valencian Community and Murcia were responsible for 10.53% and 6.12%, respectively. In the whole of Spain, the Valencian Community had the highest percentage of irrigated agricultural land in 2014, at 49.67% of all its arable land, followed by Murcia with 45.35%. In Andalusia, irrigated land covers 1,122,000 hectares, representing 31.40% of the land under cultivation. Other regions where irrigated land represented over 25% of the total agriculture land are

Table 2
Descriptive statistics of the volume of wastewater reused and the independent variables

Variable	Obs	Mean	Sd. Dev.	Coef. Var	Min	Max
Rww	187	2.94e+07	5.42e+07	1.84353741	0	3.05e+08
AgProd	187	1,452.21	1,863.43	1.28316488	61.41	9,124.14
IArea	187	21.25	14.60	0.68702649	0	49.67
Rsc	187	1.003	0.203	0.202	0.59	1.78
Swater	187	8,72,740.70	10,57,000	1.2111	0	46,13,699
Gwater	187	2,05,439.50	3,41,905.30	1.664	0	16,39,523
Dwater	187	6,681.70	20,525.44	3.07188843	0	1,25,386
Pop	187	26,94,420	23,93,487	0.88831251	293553	84,49,985
Rev	187	0.53	0.22	0.418	0.15	1.41
Rec	187	0.45	0.499	1.108	0	1

Source: Own elaboration based on data from [20] and [23].

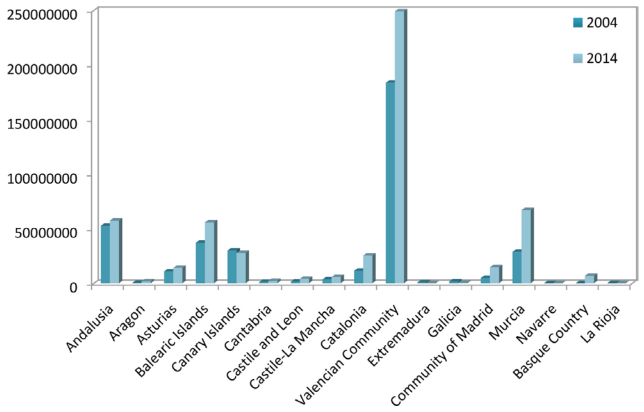

Fig. 1. Volume of wastewater reused in the different Spanish regions in the years 2004 and 2014 (m^3/y). Source: [20].

Navarre (32.30%), Catalonia (31.99%), La Rioja (29.61%) and Aragon (25.90%).

The relative scarcity of water resources is measured by an index that calculates the volume of water supplied as a proportion of the total available volume, and compares it with the national average values. As expected, taking into account the climatic and hydrological conditions of the different regions analysed, Catalonia, the Balearic Islands, Murcia and the Valencian Community are the Communities that registered the highest value for this index, with results for Murcia ranging from 0.87 in 2007 to 1.79 in 2014. The corresponding values for Aragon, Castile and Leon and Extremadura did not exceed 1 in any of the years under study.

The variables surface water for irrigation, groundwater for irrigation and desalination show a high degree of dispersion, which is especially significant in the last case. The regions that have had a regular flow of desalinated water since the mid-2000s are Andalusia, the Valencian Community and the Balearic and Canary Islands. In the period analysis, the availability of this resource has increased in Andalusia, the Balearic and Canary Islands. In the Valencian Community, on the other hand, the desalinated water used fell to a quarter of the initial volume. The rest of the regions do not have this resource.

Between 2004 and 2014, the volume of surface water for irrigation sourced from rivers, streams, reservoirs or lakes dropped by 21.6%. Andalusia, in the south of the country, is the primary consumer, accounting for between 26% and 22% of the national total, depending on the year in question. This region is followed by Aragon, Castile and Leon, Catalonia, Extremadura and the Valencian Community, all of which used over 14 million m^3 of surface water for irrigation in 2014. Over the same period, the total m^3 of groundwater used to irrigate Spanish crops increased 3.8 times with the regions of Andalusia, Castile and Leon, Castile-La Mancha and the Valencian Community consuming more than three quarters of the total. In contrast, the Canary Islands do not use any groundwater or surface water for irrigation.

Between 2004 and 2014, the Spanish population registered a 9.31% increase. The Balearic and Canary Islands were the regions reporting the highest increase, with variations of over 15%. On the other hand, the population of Asturias fell slightly. Andalusia was the Community with the largest population in 2014, with over 18% of the national total, followed by Catalonia with 7.52 million and Madrid with 6.45 million. Conversely, three smaller regions in northern Spain had less than one million inhabitants in 2014: Cantabria, Navarre and La Rioja, with 5,88,656, 6,40,790 and 3,19,002 inhabitants, respectively.

The taxes on wastewater are charged to the users of the water services provided by the Administration, whether directly or through a concessionary company. The revenue collected can only be used to finance this service. In the 17 Spanish regions, the rates per cubic metre charged for sanitation and wastewater treatment are relatively homogenous. All regions report a growing trend, with increases in absolute terms and a cumulative average growth rate of over 10% in Spain. In 2014, the Balearic Islands, Catalonia, the Valencian Community, Murcia and the Basque Country were the regions with the more elevated rates, collecting more than € 0.85 per m^3. They are followed by Andalusia, Aragon, Asturias, Cantabria and Madrid, with a charge per cubic metre of between € 0.72 and € 0.77. All the other regions charged less; and the Canary Islands is the region with the lowest average rate (€ 0.37).

Due to the uneven evolution of the Spanish economy during the time period analysed, we use a dummy variable to capture economic activity in terms of real GDP growth. This dummy variable takes a value of 1 if GDP growth is positive (years 2004, 2005, 2006, 2007, 2008 and 2014) and 0 if it is negative or if there is no change (years 2009, 2010, 2011, 2012 and 2013).

3.2. Panel data analysis

Table 3 shows the results of the estimations, presenting the feasible generalised least squares model (FGLS). The model contains data from 17 regions, with a total of 187 observations, for the time period 2004 to 2014.

The optimum model is chosen by testing a number of econometric models to identify the best one. First, we estimate the model with pooled data, comparing it with the random effects model. To decide which is better, the Breusch-Pagan Lagrangian Multiplier Test is performed, rejecting the hypothesis that there is no variation across regions. Accordingly, the random effects model is chosen. Then, the estimation is carried out with fixed effects, performing the Hausman test to compare the fixed and random effects models, and rejecting the fixed effects one. The other tests applied are the Wooldridge test, the modified Wald test and the Breusch-Pagan for cross-sectional independence test to control for autocorrelation or first-order serial correlation, for groupwise heteroscedasticity, and for contemporaneous heteroscedasticity, respectively. The absence of autocorrelation is thus confirmed; however, the tests show heteroscedasticity in the data and contemporaneous correlation. To solve all these problems, the FGLS model is applied, since it is the recommended option for random effects [61].

The variables capturing agricultural production, the irrigated area, the relative scarcity of water resources, the population and the revenues collected from sanitation and wastewater are all significant at 1%, confirming the expected positive relationship. The variables desalinated water and surface water for the agricultural sector are also significant

Table 3
Panel data estimates

Rww	FGLS		
	Coef.	Z	P-value
AgProd	10,286.72[a]	7.15	0.000
IArea	19,98,436[a]	20.30	0.000
Rsc	2.17e+07[a]	7.36	0.000
Swater	–13.0737[a]	–10.32	0.000
Gwater	2.2528	0.77	0.444
Dwater	–404.7185[a]	–7.33	0.000
Pop	3.4857[a]	5.25	0.000
Rev	2.24e+07[a]	9.35	0.000
Rec	–980,973.8	–1.28	0.201
Constant	–5.80e+07[a]	–15.83	0.000
Observations	187		
N. of regions	17		
Wald chi^2	Wald $chi^2(9)$ = 1,972.19 Prob>chi^2 = 0.0000		
Hausman test	$Chi^2(5)$ = (b–B) ʻ [(v_b–v_B)^(–1)](b–B) = 5.90 Prob>chi^2 = 0.3164		
Breusch-Pagan test	$Chi^2(136)$ = 228.786 Pr = 0.0000		

[a]Significant at 1%.
Source: Own elaboration based on data from [20] and [23].

at 1%, showing a negative relationship with the volume of wastewater reused. They can thus be seen as substitutes for reused wastewater, whereas the positive relationship with groundwater allocated to the agricultural sector indicates that it is a complementary resource.

The variables agricultural production and irrigated area both present a strongly positive relationship with the reuse of wastewater, underlining the fact that the agricultural sector is a major consumer of this resource and the main recipient of the wastewater that is reused in Spain; the positive and significant relationships found confirm hypotheses 1 and 2. The relative scarcity of water resources has a direct impact on the volume of wastewater reused since water scarcity justifies the implementation of reuse systems that reduce the pressure on aquatic ecosystems; hypothesis 3 is thus confirmed. Finally, the analysis also shows the strong link between the volume of wastewater reused and both desalinated water and surface water; whether these two sources are used as complements or substitutes is determined, in line with the classic supply and demand model, by the availability of resources. Specifically, the availability of surface water from natural stream flows, whether continuous or discontinuous, shows a negative relationship with the use of reclaimed water, which requires more expensive treatment systems [62]. Similarly, there is an inverse relationship between access to treated surface water for irrigation and water from desalination, whose production cost far exceeds the treatment process [63].

On the contrary, however, when it comes to groundwater used for irrigation in the agricultural sector, the reused water is perceived as a complementary resource, aimed at augmenting existing supply. Nevertheless, the relationship between the two is not found to be significant.

The positive association between population and volume of reused wastewater is confirmed, consistent with hypothesis 7, which posits a positive correlation between population levels and water demand. The results obtained also confirm that the Autonomous Communities with the highest revenues from taxes levied on the collection, transport and treatment of wastewater have the highest volumes of reuse, confirming hypothesis 8. In line with the reviewed literature, tax instruments are shown to be an effective mechanism for guaranteeing better treatment and ensuring that discharged wastewater can be reused. Also confirmed is the link between tax revenues and wastewater reuse in the regions analysed.

Finally, the recession variable does not have a significant relationship with the use of reclaimed wastewater, although the expected negative sign is confirmed.

4. Conclusions

This study analyses the relationship between wastewater reuse in 17 Spanish regions and a number of influential factors proposed by the literature. The main aim of our research was to provide empirical evidence on the elements that influence wastewater reuse in Spain. The volume of reused wastewater has risen in recent years, driven by Directive 91/271 and the WFD. This legislation is aimed at alleviating water scarcity, especially in areas of the Mediterranean basin, and reducing overexploitation and pollution levels of aquatic ecosystems. Thus, between 2004 and 2014, the volume of water reclaimed and reused throughout the country increased by 44.24%, registering a cumulative average annual growth rate of 3.73%. The results obtained in this research show, however, that the different Spanish regions do not follow a single strategy. On the contrary, important differences can be observed: while the Valencian Community managed to reclaim and reuse 6,82,044 m^3 per day in 2014, representing 59% of all the wastewater it treats daily and 46.9% of the national total, La Rioja does not reuse wastewater. Surprisingly, the Canary Islands—which have traditionally suffered from a shortage of water resources—and Extremadura have reduced the volume of wastewater reused, contrary to the overall national trend. The results of the panel data analysis verify the hypotheses, confirming that the volume of reclaimed water in a territory depends on the needs stemming from irrigated crop production, relative water scarcity, access to desalinated and surface water and the total population living in the area. In addition, wastewater reuse is closely related to having sufficient financial resources to fund appropriate wastewater reclamation systems.

The proposed model, which examines the main determinants of the volume of wastewater reused in a water-stressed country, is limited by the available statistical data. The model could thus be applied in future research when more information becomes available. In Spain, with areas of high water deficit and growing demand for water, it would clearly be a mistake not to take advantage of the possibilities offered by better wastewater management. Looking to the future, reclaimed wastewater would enable an increase in supply, facilitating the artificial recharge of aquifers that are overexploited or at risk of becoming so, and helping to maintain ecological surface water flows. The initiatives required to achieve the proposed objective include concerted public education schemes, to raise awareness of the need to address this issue, and the development by the relevant authorities of appropriate, transparent financing systems. These systems should be based on collaboration between public and private initiatives, with a greater role played by the fees paid both by those responsible for the discharged wastewater and the user of the reclaimed water. Above all, the system must cover the operational and investment costs of the required treatment facilities and ensure compliance with the cost recovery principle.

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