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Article

The role of the Water Framework Directive in enhancing water use efficiency in the EU

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Abstract. The increasing economic activity, population growth and urbanisation are placing increasing stress on Europe's freshwater resources. The European Union's Water Framework Directive (WFD) aimed to establish measures to foster efficient use of this valuable natural resource while simultaneously protecting the environment. This study allows for an assessment of the Directive's application of public policies to a natural resource, assuming that the efficiency of water use is measured by water productivity. For the purposes of this investigation, purely economic variables and specific variables pertaining to the implementation of the WFD will be considered. The final econometric model indicates that variables with a positive impact, including research and development (R&D) expenditure and the governance index, necessitate the updating of facilities, the implementation of public control of the resource, and the encouragement of citizen interest in influencing EU policies. Conversely, variables with a negative impact, including population density and water consumption, indicate that as the utilization of a given resource intensifies, the efficacy of that utilization diminishes. The analysis by country indicates that the northern and more industrialised economies have more efficient water use levels. The evolution over time demonstrates that the WFD is being implemented more extensively in regions where it is most needed, resulting in increased productivity values in areas where they are currently lower.

Keywords: water; Water Framework Directive; water productivity
JEL classification:I1; D53; G15; G12; C22

1. Introduction

In economic terms, water can be considered a public good, a scarce economic good and an essential component of the environment. These characteristics make water a highly valuable resource that must be managed carefully (Saleth, 2002). Most specialists acknowledge that there is a positive correlation between freshwater withdrawals and economic development. Nevertheless, the distribution of these withdrawals by country varies considerably, as evidenced by Revenga et al., 2000. The geographical distribution of the resource does not ensure that all consumptive requirements have access to an adequate quantity and quality of water ("WMO", World

Meteorological Organization, 1997). The distribution of water demands may be concentrated in regions with a limited national supply of resources (Cobacho, 2000). Faced with the problem of scarcity, water management seeks to integrate the three basic dimensions of water, with the objective of ensuring sustainable and efficient management of infrastructure (Cosgrove and Loucks, 2015).

A 2015 European Commission study indicates that the EU can reduce water consumption by 40% through measures in different sectors, including the use of recycled water in factories, improvements in irrigation systems, switching to more drought-resistant crops and repairing leaks in public distribution systems. (EEA, European Environment Agency, 2001). EU water policies encourage Member States to implement better water demand management practices. This response to the mounting pressures on water resources is being driven by the necessity to improve the existing supply-demand balance and to bring about a more water-efficient society. This is being achieved through the revision of management practices on water demand (EEA, 2017).

One of the objectives of both the European Union Circular Economy Plan and the Spanish 2030 Circular Economy Strategy is to enhance water use efficiency by 10%. The indicator designated as 6.4.1 of SDG 6 is employed to quantify the alterations in water use efficiency and is aimed at addressing the financial aspect of SDG target 6.4 (España Circular, 2030).

Barraqué (1995, 1998, 2000a, 2000b) is the French academic who has published extensively on water management policy in Europe. His work constitutes a valuable reference point for understanding the evolution of European water economics. Barbier (2000) also analyses the evolution of consumption patterns and best practices. These two authors, in conjunction with Aguilera Klink (2000, 2006), Arrojo and Martínez Gil (1999), Arrojo (1999, 2005, 2010) at the Spanish level, are the pioneers of water economics research.

A number of studies have been conducted that analyse water use in Europe on a comparative and joint basis. Cabrera-Marcet et al. (2002) carried out an evaluation of the implementation of the Water Framework Directive (WFD) at a European-wide level. This study highlighted the differences in behaviour between countries in Northern and Southern Europe and focused on three key areas: water consumption; contributions to improvements in pollution from runoff; and water stress. The study concluded that in countries where water resources are scarcest, the management of water is the worst in terms of environmental impact.

In their study (Wichelns, 2014), Wichelns estimated that the water productivity indicator enhances the understanding of farm-level water management in Europe. In their study, (Viaggi et al., 2014) examined the evolving economic perspectives on water in Europe. Gutiérrez-Martín et al. (2017) conducted an economic analysis of water use in the context of the EU Water Framework Directive (WFD), employing an environmental-economic framework for accounting for water based on a case study of the Guadalquivir river basin in Spain. In a special issue of the public policy analysis of Integrated Water Resource Management (IWRM) in Europe, Ingold and Tosun (2020) present a detailed examination of the topic. Mugambi et al. (2021), on the other hand, utilize an econometric model to investigate the relationship between economic growth and the sustainability of water consumption in European Union countries.

The objective of this article is to examine the efficiency with which water is used within the context of the EU-28. To this end, water productivity is employed as a key indicator, with the aim of identifying the variables that explain this use from an economic standpoint and in accordance with the implementation of the directives set out in the WFD. The following hypotheses are proposed in order to inform the study:

1) Which of the macroeconomic variables that affect the normal functioning of the economy also affect water productivity?
2) What directives have the WFD established to promote higher water productivity?

2. Materials and methods

At the European level, the WFD introduces the economic principles and methods for the management of European waters, and promotes a more efficient use of the resource. However, the Directive does not have direct tools that enable the measurement of the results obtained from improvement initiatives established in accordance with the Directive. The European Commission (EC, 2001), the European Parliament (EP, 2000), Avellà et al. (2009), Bueno Hernández (2007), Embid Irujo (2007), and Carles (2001) all provide valuable insights into this subject matter.

The conclusions of the World Economic Forum (WEF, 2002) posit that Northern European countries exhibit greater water capture potential due to climatic conditions and a reduced dependence on agriculture, given their advanced economic status and greater focus on the secondary and tertiary sectors than on the primary sector. In consequence, the degree of water stress in these regions differs considerably from southern European countries, where the opposite is the case.

The climatological characteristics of these regions result in lower water abstraction rates, coupled with higher rates of water utilisation in agriculture, which represents a significant component of their respective economies. The European Environment Agency (EEA, 2001) reported that the average water availability in Greece, Spain, and Portugal was 2,847 cubic metres per capita. In Denmark, Germany, and the United Kingdom, however, this figure was lower at 2,313 cubic metres per capita. However, as the quantity of water used for agricultural purposes is inconsequential in northern regions, the resultant stress is relatively low (with an average of 9.3). Conversely, the opposite is true in the south (average 61.67), where agricultural water demand is clearly significant. This evidence suggests that the need for sustainable water management is much higher in the south than in the north. The implementation of the WFD is therefore particularly important in the weaker areas, while the work carried out in the Danube river basin is of particular importance, giving specific impetus to South-East Europe.

There are examples of how some of the strongest European economies, defined as countries with a high level of GDP and an economic structure based on high technology and service sectors, use water efficiently and the path they have taken in order to achieve this. This includes studies by Solanes (1996, 1998), Solanes and González-Villarreal (1996). In contrast, in the United Kingdom (UK) many residential customers lacked the benefit of water meters and their water consumption charges were not related to their usage levels. In England, a government strategy from 2008 permitted the introduction of metering as a means of promoting more effective use of this resource, with the objective of ensuring the availability of sufficient water supplies in the face of anticipated future trends in the population and climate change (HM Government; Defra Department for the Environment, Food and Rural Affairs, 2008). In France, a similar approach was taken with respect to irrigation systems. Once the limits of abstraction were exceeded, water counters were installed. The proportion of irrigation systems equipped with water counters between the years 2000 and 2003 increased from 54% to 71%, representing 85% of the total irrigated area (Rouillard, 2020).

As outlined by Beecher et al. (1998), these countries have long been aware that water conservation is not a standalone goal, but rather one component of a comprehensive strategy to guarantee a dependable and secure supply of potable water. Significant differences are also evident between northern and southern Europe at the urban level. Given that water stress is a pressing concern for many Southern European countries within the European Union, there is a clear need to foster greater social awareness about the importance of water conservation and efficient water usage (Barraqué, 1995).

The EU-28 Member States employ a range of policies and measures to enhance water use efficiency. One key instrument is the Productivity Variable, which serves to quantify the efficiency of water use in terms of its relationship with economic output. Each country reports annually to EUROSTAT on the economic output produced per cubic metre of water abstracted, inclusive of all water abstraction sources and exclusive of water utilised in the generation of electricity by hydropower plants. It would be beneficial to perform a global test of this indicator in order to ascertain the correlation between this indicator and the application of the WFD or other macroeconomic variables for which absolute, harmonised values are available for the EU. This could help to identify the key factors that influence the optimal utilisation of water resources across Europe.

2.1 Data: base composition

For the purposes of this study, we utilised data from the official data source of the European Union, EUROSTAT. In all instances, the annual data published by each country was employed as an annual average for the period between 2006 and 2015. This information was obtained from the EU-28 dataset. There is no data available which can be associated with governance. Consequently, we have employed an alternative data source, the WBGI (World Bank Governance Indicators), which contains governance indicators published by the World Bank and which has been compiled as a yearly average for each country between 1996-2017.

2.2 Bibliographic justification of the selected variables

-Y: Water productivity (€/m^3)

There are a number of studies that demonstrate the correlation between the Water Productivity Indicator and efficient water use.

For example, Arreguín-Cortés et al. (2004) present techniques for efficient water use at the household, industrial, municipal and basin levels, and conclude, on the basis of the evidence presented, that although there are more sophisticated techniques and equipment available, the correlation between water productivity and efficient water use remains. The actions are typically implemented in isolation, with only limited integration into broader programmes. This is contingent on a number of factors, and his final recommendation is that water efficiency programmes should be supported at the river basin level, with a comprehensive delineation of the roles and responsibilities of all water users.

Conversely, several authors have established a relationship between the water productivity indicator and various economic parameters. In particular, water is mainly investigated in two areas: firstly, in relation to agriculture, where the majority of consumption occurs; and secondly, in the analysis of wastewater, where it has a greater environmental impact.

Ibarra (2014) and Miracle (2006) provide detailed analysis of these two areas. Secondly, in the context of wastewater analysis, where it has a greater environmental impact.

In their study, Cruz León and Bielsa Callau (2001) cite specific references to illustrate their argument. Their focus is on the search efficiency, sustainable use of water resources and land management in the Zaragoza region. The authors highlight that improvements in efficiency are not limited to technological change in the narrow sense of substituting one irrigation technique for another.

In contrast to the aforementioned, they often relate to measures that do not necessitate the undertaking of costly investments. Instead, they pertain to the comprehension of hydric demand. Consequently, there is considerable scope for enhancement of the design and networks aimed at meeting the forecasting needs of users in the requisite amount and at the required time.

In the context of industrial economics, a study conducted by Cruz et al. (2003) examined the marginal productivity of water in the manufacturing industry within the Colombian context. The study's principal conclusion is that numerous industrial sectors, deemed water-intensive, have succeeded in significantly reducing their water access costs (abstraction, treatment, and distribution). Moreover, these sectors demonstrate a relatively low private marginal willingness to pay for the use of water as a raw material. A "WUF, Water Use Fee" that incorporates the private marginal willingness to pay for the use of water as an input could facilitate a more efficient distribution of this natural resource among the various industrial activities within the manufacturing sector. This is particularly relevant when one considers that the study found that the own price elasticity of water as a raw material is approximately -1.

Vargas Ovando (2015) employs a marginal factor productivity approach in order to determine the economic value of water within the context of the Chilean manufacturing industry. The aforementioned approach considers a number of variables, including the quantity of water, capital, labour, energy and intermediate materials, among others.

In the urban domain, Sánchez García and Blanco Jiménez (2012) investigate the potential of using tariffs to regulate water usage in urban centres. Their findings indicate that the existing pricing system has become inadequate in its ability to oversee water consumption. This necessitates a reassessment of pricing policy and the potential introduction of a novel tariff structure in Spain. This investigation connects the examination of water with the implementation of the WFD. This requires the implementation of pricing systems that recuperate the costs of water resources and the establishment of national pricing policies that contribute to achieving sustainable water use. Water tariffs should be employed as a means of regulating consumption, with the aim of promoting efficiency and sustainable utilisation of the resource.

- X1: Government Effectiveness (% country ranking)

As Zetland and Gasson (2012) observe, governance can influence the management of operators. Furthermore, it has been demonstrated that adequate public intervention is correlated with both the quality of the water supplied and the extent and condition of the water supply and sanitation network. Consequently, investment in infrastructure and governance would be found to be positively correlated. In particular, it can be reasonably argued that the dimension of governance that is most likely to influence the water sector is the regulatory quality of the states. Therefore, this will be the explanatory variable incorporated into the empirical model. The analysis will include data from a national source for the specified period, namely the WBWGI (Kaufmann et al., 2010).

Di Vaio et al. (2021) propose that collaboration, coordination, and stakeholder engagement are essential elements that should be incorporated into water governance models in order to effectively address the challenge of global sustainability.

- X2: Total water consumption (Millions of m^3)

In the econometric model developed by Colmenárez and Salazar (2018) for estimating domestic water production, the exogenous variables included are per capita consumption, population density, and the investment level made in potable water and wastewater.

Del Villar (2010) establishes the relationship between water prices and the demand for domestic use in Spain, taking into account not only consumption but also other variables such as the level of investment, the population growth rate, and per capita income.

In their study (Martín-Ortega et al., 2008), the authors characterised water usage within the Guadalquivir Demarcation area, applying the principles of the WFD. One key variable identified was the impact of agricultural water consumption on discharge.

Martínez and Goetz (2007) consider the specificities of the water markets in the irrigation area, with variables including operating costs, consumption in the area and the productivity of the farms.

In their study on energy efficiency and economic regulation in drinking water and sewerage services in Latin America and the Caribbean (Ferro & Lentini, 2015), the authors identify and analyse the conditioning factors of consumption in the final uses of water. This is done from the perspectives of both the supply and the demand of the resource, with particular emphasis on the price of water and the costs of treating waste generated.

- X3: R&D expenditure (millions of €)

Moro et al. (2018) performs a thorough panel data analysis comparing China and the EU, thereby corroborating previous studies which demonstrate the association between innovation in the water sector and water use efficiency.

The EU has promoted water-related research and development mainly through three initiatives: The EU framework programmes Horizon 2020 (H2020), LIFE+ Programme and "INTERREG, Programme and European Territorial Cooperation Programmes" have constituted the main vehicles for EU funding for water-related research and development. In the period studied (2014-2019), a total of 1,561 water-related projects were implemented. Funding for these initiatives was provided by a number of sources, including the Horizon 2020 programme, the LIFE+ programme, and the "INTERREG" programme, with a total budget of 1.3 billion, 800 million, and 1 billion euros, respectively. For instance, the ECWRTI, iMETland, REMEB and POWERSTEP projects represent pioneering efforts in wastewater treatment processes. Their objective is to recycle and reuse wastewater in industry and agriculture, reduce the operational and energy costs of wastewater treatment and increase the amount of energy that can be produced in sewage treatment plants. Other projects are similarly striving to enhance the efficacy and efficiency of water and energy use in irrigation systems within the agricultural sector, such as the MOSES and MASLOWATEN projects. The objective of the CENTAUR project is to reduce the risk and consequence of flooding in urban areas. The CYTO-WATER project has developed a novel technology platform for rapid microbial detection in industrial and environmental waters. Finally, SUBSOL is developing commercialised technologies for the use of sub-surface coastal water. REGROUND, on the other hand, is proposing a novel nano-geotechnology for the immobilisation of toxic metals in aquifers and river filtration sites.

-X4: Population density (people/km^2)

The distribution of water as a resource throughout Europe is not uniform. Moreover, the quality and quantity of this resource varies considerably across the continent. In Iceland, the average resident is allocated 600,000m^3 per year, while in Norway, the figure is 100,000m^3 per capita per year, and in Sweden and Finland, 20,000m^3. At the other extreme are Eastern European countries, such as Moldova and Ukraine, which have quantities of less than 4,000 m^3 per inhabitant per year, while in Southern Europe; Spain, Italy and Greece, with 3,000 m^3 per inhabitant per year, have even smaller endowments. Malta has a water endowment of only 100 m^3/inhabitant/year, in some cases derived from seawater desalination.

Xiaoming Liu et al. (2021) demonstrate a direct correlation between the consumption of water resources and population density in their comparative study of China's coastal and inland regions.

In Olmos Salvador (2018), both per capita GDP and population density were included as variables in an econometric model for determining residential water tariffs at the international level. In his 2016 study, Schreiber (2016) investigates the influence of population density on water usage, particularly in the context of municipal drought situations. Domestic economies account for approximately 12% of global water consumption (FAO, 2018).

Chang et al. (2017) demonstrate that an increase in residential housing density is associated with a reduction in total municipal water use. Conversely, Ghavidelfar et al. (2018) demonstrate that per capita water consumption varies according to social class, challenging the underlying assumption of contemporary urban policy that densifying central city areas can result in significant savings in water use.

Sampson et al. (2022) propose that the efficiency gains in water use with increased density are not uniform and may be nonlinear, depending on the specific BT movements. The simulation outputs indicate that the greatest gains in water savings per unit change in DUUA can be achieved with short movements over the lowest density classes (e.g., LSF to a SSF).

Kim et al. (1998) examine the economic consequences of spatial integration within urban water service markets in Korea, applying the concept of economies of scale in terms of cost-effectiveness. It may be inferred from the results that changes in population density would have only a minimal effect on the potential for economies of scale.

-X5: Gross Domestic Product (Millions of € at current prices)

GDP and main components (output, expenditure and income); Gross Domestic Product at market prices expressed at Current prices, million euro. The national data taken directly from EUROSTAT expressed in millions of constant Euros for the year 2015 will be included. GDP at constant prices will be included in the model as a variable representing the degree of economic development.

Gross domestic product (GDP) is a metric that serves as a proxy for the level of economic activity in a given country. It is defined as the value of all goods and services produced, net of any goods or services utilised in their creation. The calculation of the annual growth rate of GDP volume allows for comparisons of the dynamics of economic development over time and between economies of different sizes, as well as for the analysis of the impact of various factors on the growth of an economy over time. In order to ascertain the growth rate of GDP in terms of volume, the GDP at current prices is valued in the prices of the previous year. The computed volume changes are then imposed on the level of a reference year. This methodology is known as a chain-linked series. Consequently, fluctuations in prices will not affect the calculated growth rate.

It should be noted that the income components of EUROSTAT GDP, as well as other income measures, are only available at current prices. This is due to the fact that pure monetary flows cannot be decomposed into price and volume components. Nevertheless, it is possible to convert these figures to real terms by applying an appropriate deflator. However, the data series on current prices are susceptible to inflationary effects. The relationship between water productivity and GDP has been explored by numerous authors, who have employed GDP at constant and current prices in an interchangeable manner. It follows that inflation is not considered an important factor in analysing this correlation. The study period from 2006-2015 did not include instances of deflation, or negative inflation, within the EU-28 countries. It may be concluded that the estimated prices for each country, expressed in local currency, were consistently higher than the constant price estimates in subsequent years, starting from the reference year. However, it is not currently possible to report the precise impact of this on each individual country.

The inverse U-shaped relationship between economic growth rate and relative water scarcity of a territory is quantified by Barbier (2004). This allows the optimal rate of water abstraction to be determined, which is defined by the maximum possible growth rate. His conclusion is that while current water consumption levels in many economies do not yet impede growth, there are a select few countries where even moderate or extreme water scarcity can have a markedly adverse impact on economic growth.

Orloci et al. (1985) conducted an empirical analysis of the correlation between per capita gross domestic product (GDP) and water usage for a sample of 50 countries over three distinct periods. The results indicate an initially positive correlation between the variables. This implies that, at the outset of economic growth, substantial quantities of water are required to elevate GDP. Consequently, access to water represents a limiting factor in the advancement of economic growth within developing countries. As a nation progresses to a higher stage of development, the relationship between per capita GDP and water use may weaken and potentially become negative.

This is due to the implementation of water-saving techniques in irrigation, as well as the scarcity of water resources.

In his study of the annual growth rate of per capita GDP (g) at constant prices (1990), Olmeda (2006) examines the relationship between economic growth and water, analysing the latter from an economic perspective.

The country's level of economic development may influence the productivity of its water resources through a number of interrelated mechanisms. In countries with a higher income, wages are typically higher, resulting in increased operational costs for the relevant parties. Moreover, it is anticipated that more advanced nations will allocate greater resources to technological advancement, infrastructure construction, and the maintenance of their water supply systems. Consequently, this will lead to an increase in costs. Additionally, another issue that could also be affected is the tariff system aimed at cost recovery and incentivising resource savings, which is more entrenched in economically developed environments.

-X6: Public water as a percentage of total water abstracted (%)

This variable is defined as a quotient that includes the total public water (WAT_PROC: Water abstraction for public water supply: Surface freshwater (Millions of cubic metres)) in its numerator and the total water abstracted (Annual freshwater abstraction by source and sector [env_wat_abs]. WAT_PROC, Total gross abstraction: Fresh surface water and groundwater (Million cubic metres) in the denominator.

This variable indicates the specific weight of the public sector with regard to water management. The application of the WFD suggests that the implementation of cost recovery principles, particularly the recovery of environmental costs, may positively impact water productivity. Accordingly, the proportion of supply, encompassing the fixed charge related to the provision of supply services and the variable amount contingent upon the quantity consumed, would exhibit a

Marín (2009) conducts a comprehensive comparison between public and privately managed projects, demonstrating that private management is more efficient with respect to water use efficiency than public management.

Pérard (2009) offers a comprehensive analysis of the economic discrepancies between the public and private sectors, with a focus on 45 countries belonging to the Organization for Economic Co-operation and Development. The author posits that the relative efficiency of one model over another is not always clear-cut; rather, the relative efficiency of one model over another is contingent upon a number of factors, including the cost of public funds, taxes and the influence exerted by private operators. Furthermore, the costs associated with privatisation implementation and the technical distinctions between the public and private sectors must be taken into account. It has been observed since 1990 that numerous national and local governments in developing countries have entered into contractual relationships with private companies with the intention of allowing them to operate or manage their water utilities under the auspices of the public-private partnership (PPP) model. The underlying assumption was that the private sector would enhance the performance of utilities by introducing new capital, raising the level of staff expertise and improving the cost-effectiveness and efficiency of operations.

In 1993, Lynk reached the conclusion that the privately owned water sector in the UK exhibited significantly higher levels of inefficiency than the publicly owned sector.

-X7: Total public water supplied to industrial activities and services (Millions of m^3)

The total volume of water supplied to the public via the municipal water supply system, including all NACE activities and households. The quantity of water is expressed in million cubic metres. The European Statistical Office (Eurostat) employs this indicator to gauge the quantity of water supplied and managed by public bodies, encompassing both industrial activities and households.

This variable indicates the extent to which public entities are involved in the provision of services related to the full water cycle. This indicator permits the identification of countries where water management is provided by public entities, as opposed to those where it is subcontracted by the administration to other private companies. Moreover, it permits the correlation between the impact of governmental management and the water used in economic activity associated with industrial and service activities.

Anwandter and Ozuna (2002) found that neither the decentralisation of water operations to municipal levels nor the establishment of an independent regulatory body had a positive effect on the efficiency of Mexican water utilities.

Wackerbauer (2009) pointed out that in Germany, the provision of water supply and sanitation services are considered to be core tasks of public services of general interest, with the responsibility for these services resting with the municipalities.

-X8: Percentage of population connected to the public service (%)

The term "access to drinking water" is defined as a connection to a water supply system (typically a piped system) that is accessible to the general public. All figures are presented as percentages of the resident population.

Access to potable water, sanitation (sewage) and wastewater treatment represent fundamental services that citizens of developed societies expect to receive in a modern context.
Of the countries for which data are available, only four (Estonia, Poland, Slovakia and Romania) have a population coverage of less than 90%. This does not imply that all segments of the populace lack access to potable water. Some may have access to it through alternative avenues, such as a private well. However, they remain unconnected to the broader supply network.

The incorporation of this variable into the model not only considers the implementation of the WFD, but also extends beyond this, as the UN itself is committed to ensuring access to safe and potable water. In accordance with SDG6, universal and equitable access to safe drinking water at an affordable price for all must be achieved by 2030.

A study by Benito et al. (2015) examines the comparative efficiency of the Spanish water sector, concluding that public sector utilities exhibit a higher level of productivity compared to those in the private sector.

-X9: Percentage of GDP associated to circular economy (%)

% GDP: Private investments, jobs and gross value added related to circular economy sectors. The indicator includes “Gross investment in tangible goods”, “Number of persons employed” and “Value added at factor costs” in the following three sectors: the recycling sector, repair and reuse sector and rental and leasing sector.

Frérot (2014) makes a connection between the principles of the circular economy in Europe and their impact on water efficiency. The return to economic growth, the preservation of the environment and the reduction of our dependence on raw materials and energy require a profound transformation of our production and consumer practices. It follows that this transformation will necessarily entail the adoption of the circular economy paradigm, which is defined as a model for the economic activity that sustains human life on a planet of finite resources, and in which the environmental, social and economic systems are in equilibrium. The optimal transformation, recovery and treatment of energy, waste and water are fundamental aspects of economic and environmental sustainability.

-X10: Percentage of environmental taxes (%)

The percentage of total tax revenues comprised of shares of environmental and labour taxes. The indicator quantifies the relative importance of environmental and labour taxes within the broader context of tax revenue, encompassing both direct taxes and social contributions. The term "environmental tax" is employed to describe a tax that has a specific negative impact on the environment, and whose tax base is a physical unit (or a proxy for one) of that impact. Environmental tax revenues are derived from four distinct tax types: energy taxes, which contribute approximately three-quarters of the total, transport taxes, which account for approximately one-fifth of the total, and pollution and resource taxes, which contribute approximately 4% of the total. In the context of taxation, the term "labor tax" is defined as all personal income taxes levied on labor income, encompassing both employed and non-employed individuals. This encompasses a diverse array of taxes, including those applied on both employees and employers, such as payroll taxes and social contributions, respectively.

The Directive places particular emphasis on the definition of environmental objectives (Art. 4 and Annex V), requiring Member States to achieve good ecological and chemical status in all surface waters, all groundwater and marine waters. Moreover, the Directive sets out the normative criteria for defining good chemical status of waters in terms of compliance with quality standards.

As Carles and García (2001) observed, "water is not a commercial good like any other" and therefore requires a different approach to its management. It is therefore important to "place the emphasis on the nature of water as an eco-social asset".

Munguía-López et al. (2019) demonstrate a positive relationship between water taxes and the optimisation of water consumption and increased aquifer recharge at a water treatment plant in the Sonoran Desert (Mexico).

3. Results

The econometric model utilised is a panel data analysis where Y represents water productivity, with i denoting the individual (EU country) and t signifying the observed period (year). Furthermore, other panel data are taken into consideration as a point of reference in order to gain a more comprehensive understanding of the subject matter under analysis. The following references have been consulted: Greene (2000), Wooldridge (2002), Torres-Reyna (2007), Beck (2001), Breitung and Das (2005). The panel data for the natural logarithms (LN) are taken for all variables in the model except for those variables that have already been defined as a percentage (%). This approach allows an elasticities analysis to be carried out.

3.1. Descriptive analysis of the main variables

Upon examination of the descriptive analysis of the principal dependent and independent variables, it becomes evident that the number of observations pertaining to each variable differs. In essence, the total number of observations (N) in each case does not reach the requisite 280. This may potentially constrain the applicability of certain multivariate techniques. Given the high degree of dispersion observed between the standard deviations of the dependent and independent variables, logarithmic transformations were applied to the latter, where possible, in order to normalise or reduce the dispersion. The resulting variables exhibited a more uniform standard deviation, thereby facilitating interpretation of the results and reducing the dispersion between standard deviations.

The graphs in Appendix 1 demonstrate considerable variability in productivity between countries, with no discernible evolution over time to determine a trend towards increasing water productivity. The absence of data in certain cases, either total (1: Austria, 9: Finland, 22: Portugal) or partial (2: Belgium, 8: Estonia, 10: France, 11: Germany, 14: Ireland, 18: Luxembourg, 27: Sweden), makes it challenging to draw generalisations about the European Union countries as a whole. The application of logarithms ensures that the data are treated uniformly due to the elimination of scale effects.

Table 1. Statistical description of the study variables.

Variable	Units	Average value	Standard Deviation		Min	Max	Obs	
Y: Water Productivity	(€/m³)	114.125	Global	180.012	5.200	1,017.900	N	189.00
			Enter	186.552	6.470	919.928	n	25.00
			Intra	20.050	9.397	212.097	T-bar	7.56
X1: Government Efectiveness	(% country ranking)	81.773	Global	12.780	44.075	100.00	N	280.00
			Enter	12.722	47.651	98.946	n	28.00
			Intra	2.339	74.152	91.768	T-bar	10.00
X2: Total Water Consumption	(Millions of m³)	5,277.964	Global	8,808.575	0.160	35,476.2	N	247.00
			Enter	9,843.178	77.469	33,322.45	n	28.00
			Intra	2,157.195	-11,053.42	14,442.75	T-bar	8.82
X3: R&D Expenditure	(Millons of €)	9,148.942	Global	16,283.39	31.253	88,781.82	N	280.00
			Enter	16,406.56	46.368	73,159.16	n	28.00
			Intra	2,157.873	-5,043.518	24,771.6	T-bar	10.00
X4: Population Density	(people /km²)	171.922	Global	245.128	17.300	1,408.4	N	280.00
			Enter	249.047	17.680	1,326.37	n	28.00
			Intra	8.019	129.852	253.9521	T-bar	10.00
X5: Gross Domestic Product	(Millons of € at 2015 current prices)	1,849.161	Global	5,286,747	5,386.1	3,44 exp 7	N	280.00
			Enter	4,697,630	11,174.02	2,51 exp 7	n	28.00
			Intra	2,567,844	-2,32exp-7	3,22 exp 7	T-bar	10.00
X6: Percentage of public water to total water abstracted	(%)	21.729	Global	12.212	1.799045	48.95259	N	180.00
			Enter	12.946	3.404095	48.1831	n	24.00
			Intra	2.281	13.81413	34.12986	T-bar	7.50
X7: Total public water supplied to industrial activities and services	(Millions of m³)	975.490	Global	1,327.252	24.74	5,533.4	N	157.00
			Enter	1,649.514	25.815	5,382.8	n	25.00
			Intra	100.698	336.7903	1,338.49	T-bar	6.28
X8: Total Public Water Supplied	(%)	92.011	Global	11.520	49.2	100	N	145.00
			Enter	10.350	57.47778	100	n	23.00
			Intra	1.640	83.73415	98.23415	T-bar	6.30
X9: Percentage of GPD associated to circular economy	(%)	0.942	Global	0.187	0.36	1.35	N	168.00
			Enter	0.188	0.405	1.21875	n	24.00
			Intra	0.077	0.655	1.246	T-bar	7.00
X10: Percentage of Environmental Taxes	(%)	7.394	Global	1.678	4.32	11.75	N	280.00
			Enter	1.569	4.459	10.145	n	28.00
			Intra	0.659	4.896571	9.458571	T-bar	10.00

3.2 Econometric interpretation of the model

The final model selected through the application of panel data with fixed effects is as shown below.

$$LY = 12{,}56618 + (0{,}0053926 * X1) - (0{,}2096545 * LX2) + (0{,}1398058 * LX3) - (1{,}735613 * LX4) + (0{,}120062 * X6) + (0{,}4596479 * LX7) + (0{,}03114292 * X8) - (0{,}0411553 * X10)$$

Table 2. Estimation results of the econometric fixed-effects model.

Number of observations		Number of groups	R^2	R^2 intra	R^2 global
105		17	0.7501	0.0569	0.0682
Sigma_u	**Sigma_e**	**rho**	**corr(u_i, Xb)**	**F test (16, 80)**	**Prob>F**
2.0038387	0.070	0.998	- 0.882	56.81	0
Variable (1)	**Coefficient**	**t-ratios**	**P> (t)**	**[95% Confidence Interval]**	
Constant	12.566	1.76	0.082	-0.001	0.011
X1	0.005	- 4.39	-	-0.305	- 0.115
LX2	- 0.210	3.04	0.003	0.048	0.231
LX3	0.140	- 3.80	-	-2.645	-0.826
LX4	- 1.735	2.16	0.034	-0.001	0.023
X6	0.012	- 2.49	0.015	-0.823	-0.092
LX7	- 0.460	2.69	0.009	0.008	0.055
X8	0.031	- 2.00	0.049	-0.082	- 0.0002
X10	- 0.041	5.10	-	7.663	17.472

The data pertaining to the variables X5 (Gross Domestic Product) and X9 (Percentage of GDP associated with the circular economy) have been excluded from the model due to their lack of statistical significance. In the first instance, it is posited that there is an issue of collinearity with other variables of an economic nature that are more closely related to water use. These include variables representing consumption, such as that indicated in the model by X2 (Total Water Consumption). In the second case, with regard to the concept of the circular economy, it could be postulated that since it encompasses a multitude of factors that are not directly related to water, this variable may be regarded as an indication of sustainability. However, it is not significant. The exclusion of these variables allows for the creation of a fully specified panel data model with fixed effects. All of the variables were found to be significant individually, with their respective p-value falling below a threshold of 0.05. Furthermore, the joint significance of these variables was also confirmed, with the Prob > F value falling below 0.05.

At the level of econometrics, the final model selected is a fixed-effects panel, as indicated by the results of the Hausmann Test. It does not incorporate temporal effects, and heteroscedasticity and first-order serial autocorrelation are present. However, these issues are alleviated to some extent when applying the feasible generalized least squares (FGLS) method. In other cases, authors calculate these statistics with the aim of validating their models. For instance, Im et al. (2003) and

Blackburne and Frank (2007), along with Hadri (2000), have provided examples of this approach.

The implementation of the distinct examinations has yielded the following results:

- The prevalence of the panel data model versus OLS: random effects are relevant and it is preferable to use the estimate of random effects instead of the one grouped according to the result of the application of the Breusch-Pagan La-grange multiplier test (LM)).
- The prevalence of fixed effects over random effects according to the result of the Hausmann Test considering the different panel data models, with fixed effects and random effects.
- the non-existence of temporary fixed effects according to the result of the Test-parm test

Our study is located in the so-called micro panels. That implies:

- The impossibility of carrying out the evaluation of transversal dependency neither by applying the Pesaran CD Test nor by Breusch-Pagan due to insufficient observations.
- the presence of heteroscedasticity, either between countries or over time.
- The possibility of applying non-robust models such as the panel of fixed effects according to the negative result after applying the robustness test.
- The presence of first order or serial autocorrelation, which is resolved more efficiently with Feasible Generalized Least Squares (FGLS).

3.3 Economic interpretation of the model signs

It is important to note that the final model selected allows an analysis of elasticity, rather than the direct impact of independent variables on the dependent variable. Therefore, variables must be ordered according to their contribution to the final model. In this context, the most significant variables are those that contribute the most to population density, public water consumed in industrial and service activities, total consumption, percentage of public water, percentage of environmental taxes, percentage of the population connected, and governance. The effects of agglomeration and consumption economies are particularly pronounced at the industrial and service levels, as well as at the aggregate level. All of these factors contribute to economic development, although not in accordance with the guidelines set by the WFD, which occupy a subordinate position. Nevertheless, they are of significant importance within the model.

Four variables have been identified as having a positive impact on the efficient use of water. These are presented in order of importance based on the highest coefficient they present in the model. The variables that have the greatest positive impact on the efficient use of water are research and development expenditure, the percentage of public water, the percentage of the population connected to the water supply, and governance. These variables are presented in the WFD guidelines, based on the objective of modernising facilities, implementing public control of the resource, guaranteeing access to the population and encouraging public interest in influencing EU policies. There are also four variables that have a negative impact on water productivity, which are, in order of importance: population density, public water supplied to industrial and service activities, total consumption and the percentage of environmental taxes. It shows that as the use of the resource increases, its efficiency decreases, but it also proves that a purely punitive policy does not solve the situation.

The presence of greater population density is associated with lower levels of economic productivity. This is a more nuanced phenomenon to analyse, as while greater population density may facilitate a more concentrated water supply, it may also lead to greater water contamination. The so-called agglomeration diseconomies, whereby the benefits of increased density are outstripped by the negative effects, must be considered.

A greater total volume of public water supplied to industrial activities and services is associated with lower productivity. This implies that, for water productivity to be high, it is not necessary for water management to be high; private management is more productive. This outcome would be the inverse of the previous one, yet it could yield a parallel conclusion. In developed countries where water consumption is higher due to higher rates of growth, increased industrial activity, and a greater number of cities, the engines of the economy itself are set in motion, leading to a more efficient use of the resource without the need for further public intervention.

The consumption of greater quantities of water is associated with a reduction in productivity. In more affluent nations, there is greater utilisation of water for the fulfilment of all productive requirements, thus maintaining a stable economic status. In addition to its use in the agricultural sector, water is also employed at an industrial level. Furthermore, the creation of urban settlements in this type of economic system also results in greater water consumption, making the efficient utilisation of the resource challenging.

It can be reasonably assumed that increased investment in research and development (R&D) will lead to an enhancement of overall productivity levels. This indicates the necessity for the continued enhancement of investments in technologies that reduce the consumption of water.
A reduction in the level of environmental taxation is conducive to an increase in overall productivity. These findings demonstrate that an ambitious taxation strategy is not as effective as a targeted subsidy approach.

A greater proportion of the population connected to public services will result in increased productivity. This conclusion aligns with one of the objectives of the WFD, which aims to ensure the supply to the population.

The proportion of public water abstracted is positively correlated with productivity levels. In general, public water management has precedence over private water management. This is a common occurrence in economies that are not particularly sustainability-oriented.

The implementation of more robust governance mechanisms is conducive to enhanced water productivity. This outcome is in close alignment with the objectives of the WFD, which demonstrates the effectiveness of the OECD Water Governance programme in improving water resource efficiency. This is achieved by employing appropriate policy interventions to manage this vital natural resource.

The GDP, when subjected to a correlation analysis, has been observed to exhibit collinearity with variables of an economic nature that have been demonstrated to exert a more pronounced influence. Among these, variables such as consumption have emerged as particularly noteworthy due to their direct bearing on water utilisation.

The circular economy is a concept that encompasses a multitude of factors not directly related to water. While it could be interpreted as an indication of sustainability if this variable were significant, it has been discarded due to its lack of significance compared to the other variables.

4. Discussion

As discussed in the previous section, all the variables in the final model are individually and jointly significant in the fixed effects model under consideration.

A parsed analysis of the variables seeking for the individual effect, which has strictly economic variables and the variables associated with the application of public policies predicted by the "WFD", has shown that water productivity is better explained by purely economic variables than by variables related to the "WFD".

According to the model, R&D expenditure, the percentage of public water, the percentage of population connected and the governance index are relevant and have a positive impact on water use efficiency, highlighting the need to modernise facilities, implement public control of the resource, guarantee access to the population and encourage citizens' interest to influence EU policies. In turn, population density, public water supplied to industrial and service activities, total consumption and the share of environmental taxes have a negative impact on water productivity, showing that as water use increases, water efficiency decreases, but also that a purely punitive policy does not solve the situation.

Some of the UE-28 more developed countries, such as Denmark, Finland, and the United Kingdom, have higher levels of water use efficiency, i.e., higher water productivity values. Denmark, the 40th largest economy by GDP, is a modern economy with a high-tech agricultural sector, world-leading companies in pharmaceuticals, shipping, and renewable energy, and a high dependence on foreign trade. Finland is the 48th largest economy by GDP, and has a highly industrialised economy, based on large forest resources and high levels of capital investment. It now has one of the most technologically advanced economies in the world, although it was basically agrarian 50 years ago. The UK economy is the sixth largest in the world, in terms of market exchange rates, and the second largest in Europe. Its economy is considered to be highly developed and service sector-oriented. The effect of agglomeration economies and consumption at the total level and in industrial and service activities, all of which are variables that participate in the development of the economy, promote the highest water productivity indexes. Netherlands, France, Ireland and Germany are other examples of highest water productivity values.

Population density affects the water productivity index in particularly small countries such as Belgium, Malta, Cyprus, and Luxembourg, providing better water productivity indexes.

Governance has come last. It is a fairly modern concept that should be promoted. The notion of public policies "in the form of governance" calls for a state that is present and a society that participates, fostering public governors and administrators in dialogue with private leaders (business and civil) and with citizens who do not belong to any sector. The 2010-2014 situation of budgetary austerity should not be a brake on the development of actions within the framework of public policy evaluation, since this should be understood as an investment and not as a cost. Therefore, in 2016, the Euro area economy was still on deflationary dangers, the insight of both the public and policymakers as to the necessity of a macroeconomic policy change increased. The calls for a more expansionary fiscal stance, above all for a boost to public – or publically supported – investment, become louder, with the Investment for Europe Plan (Juncker-Plan) as the most prominent official policy reaction and previous initiatives – as the introduction of the so-called 'investment clause' under the Stability and Growth Pact (SGP) – to support and protect public investment. However, those initiatives failed, and public investment in the Euro area has decreased substantially since the onset of the crisis. In the periphery countries, public investment expenditures shrunk dramatically as a result of the austerity policies imposed on those member states. And despite all efforts, growth forecasts for the euro area was stagnating since summer 2014. The COVID-19 pandemic led to a sharp economic collapse in the Eurozone in 2020 and forced the authorities in these countries to employ Keynesian methods to sustain the economy. As a result of the severe recession and the temporary emergency measures taken, public finances in the member states suffered significantly. The mutually reinforcing effects of the Eurozone's fiscal policy and monetary policy were crucial for mitigating the effects of the COVID-19 crisis in its countries and supporting the economic recovery thereof in 2021–2022. The rapid development of the crisis has revealed the difficulties in the application of fiscal policy assessment indicators. Changes in the surveillance should lead to improved regulatory clarity and reduced regulatory complexity.

There is a local effect associated, on the one hand, with the climate and, on the other hand, with the origin of the water. It is important to bear in mind that water productivity also depends on water quality and that water is a common element that is transferred from one country to another through the different river basins.

Northern European countries have a greater water catchment capacity due to their climatic conditions and less water use in agriculture because they are more developed economies that are more focused on the secondary and tertiary sectors than on the primary sector. Water stress in these areas is much lower than in southern European countries, where the opposite is true.

Countries where specific policies associated with the WFD have been applied more intensively, such as the Czech Republic, Hungary, Bulgaria, Poland, Romania, Slovakia, and Lithuania, (the majority of them belonging to the Danube and Rhine river basin) are in the last positions but are in any case significant within the model. It is also no coincidence that these countries are geographically located mostly in south-eastern Europe. Again, there are both climatological and sustainable awareness reasons for this.

Although it has not been possible to observe a temporal evolution, it is important to note that the initial information was derived from a micro-panel comprising data from 10 years of time. In order to perform the requisite analysis on this variable, it is essential that the calculation program in question has access to a minimum dataset of at least 25 years.

5. Conclusions

Water productivity in the EU-28 depends mainly on purely macroeconomic variables such as population density, water consumption, environmental taxes, and government efficiency.

Some authors have previously demonstrated these direct dependencies between water productivity and specific variables in various areas of water use. These include agriculture (Martínez and Goetz, 2007), industry (Cruz et al., 2003; Vargas Ovando, 2015), services (Del Villar, 2010), and urban consumption (Kim et al., 1998, Sampson et al., 2022). However, this study presents a comprehensive analysis of these variables, incorporating harmonised data for the EU-28. In its dummy application, the distribution by country allows the econometric model to be correlated geographically. The country analysis has highlighted the differences between rich and poor economies and their location between northern and southern Europe. Global economic drivers, as well as climatic conditions and the quality of the water to be used, could explain these indices.

In their respective works, Marin (2009) and Pérard (2009) examine the distinctions between public and privately managed water resources. At the European level, Lynk (1993) focuses on the United Kingdom, Wackerbauer (2009) on Germany, and Benito et al. (2015) on Spain. The studies in question are local in scope and focus on a single variable, whereas our model is based on the analysis of a global indicator, namely water productivity. The model has demonstrated that water productivity is contingent upon variables that can be linked to the implementation of the WFD. These include total public water supply, environmental taxes, population connected to public services, and public water to total abstraction. A relationship can be established between the application of a public policy, such as the WFD, and an objective indicator, such as water productivity. It is challenging to translate the efficacy of public economic policies into an economic indicator, given that their effects frequently depend on numerous correlated variables. The effectiveness of the implementation of the WFD can be assessed both geographically and in aggregate using the objective indicator of water productivity in the EU-28.

The application of the WFD has had an impact on the efficient use of water, and this is an indication that the application of this public policy model to this natural resource has been effective. However, the economic drivers themselves have had a greater impact on the efficient use of water than the application of the public policy itself - the implementation of the WFD has been more strongly promoted where it was most needed. The implementation of the guidelines set by the WFD has not yet led to a direct improvement in the water productivity indices.

Some authors, such as Sánchez García and Blanco Jiménez (2012) and Munguía-López et al. (2019), correlate price with water consumption. This would have been a macroeconomic variable to include in the model if EUROSTAT had harmonised data on water prices in Europe. However, the actors involved in the water cycle apply water prices locally and in a relatively arbitrary manner. This is one of the reasons why it is difficult to have public policies in place that have an impact on the overall results.

One of the main lines of action of the WFD is based on the water cost recovery policy. However, it has not been possible to correlate or link it to any of the variables of the established econometric model. The new public policies in the water sector should have objective indicators, based on harmonised macro-economic indices in the EU-28, which would make it possible to determine their effectiveness.

Water quality as a variable was not included in the model. It was not possible to determine the effect of river basin management in the different countries. Given that recovery costs include a large part of wastewater treatment costs, this variable is very important. It is important to know not only where water use is most efficient but also where water use efficiency is most needed. It is necessary to determine where it is appropriate to focus public water policy efforts so that more efficient water use takes place where water stress is greatest.

It is quite possible that in the future, we will be able to carry out a new analysis of the application of the WFD, but at the moment, there is not enough information to attribute some of the measures taken to productivity.

Likewise, it is necessary to broaden the study of water from a perspective that goes beyond the efficient use of the resource and considers the impact on the environment.

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Appendix 1

The following figures present the data of the different study variables on which the model is based. These ad hoc data were provided by the EU-28 countries for the period from 2006 to 2015.

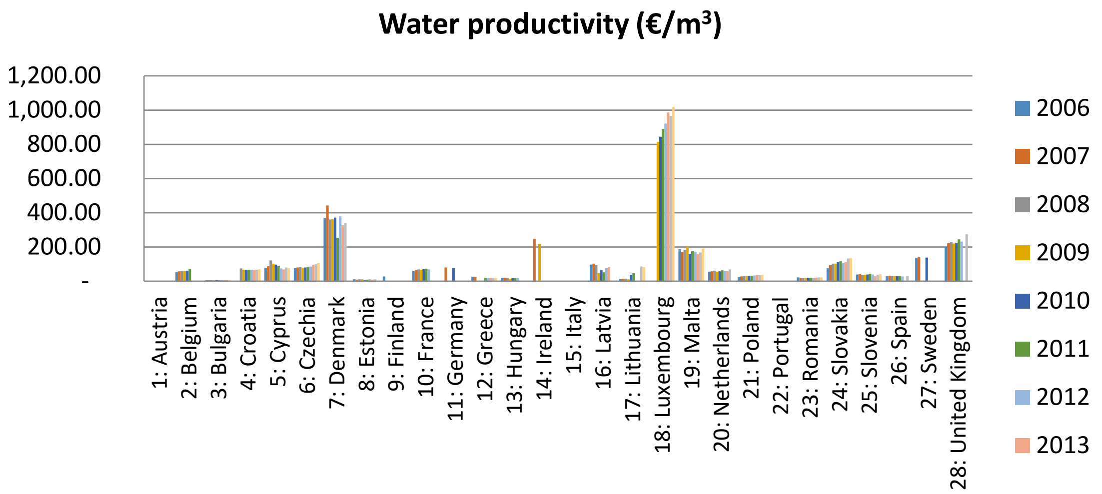

Figure 1. Water productivity. *Note*: This variable represents the quantity of economic output produced for a specific quantity of water collected. The variable measures the efficiency of water use. The total quantity of water extracted encompasses all sources of water withdrawal, encompassing both fresh water and water that has been reused, either temporarily or indefinitely. The data also includes water used in mining and water that has been extracted from the ground, as well as rainwater harvesting. Notwithstanding the aforementioned considerations, the quantity of water employed by hydroelectric power stations for the generation of electricity is to be excluded.

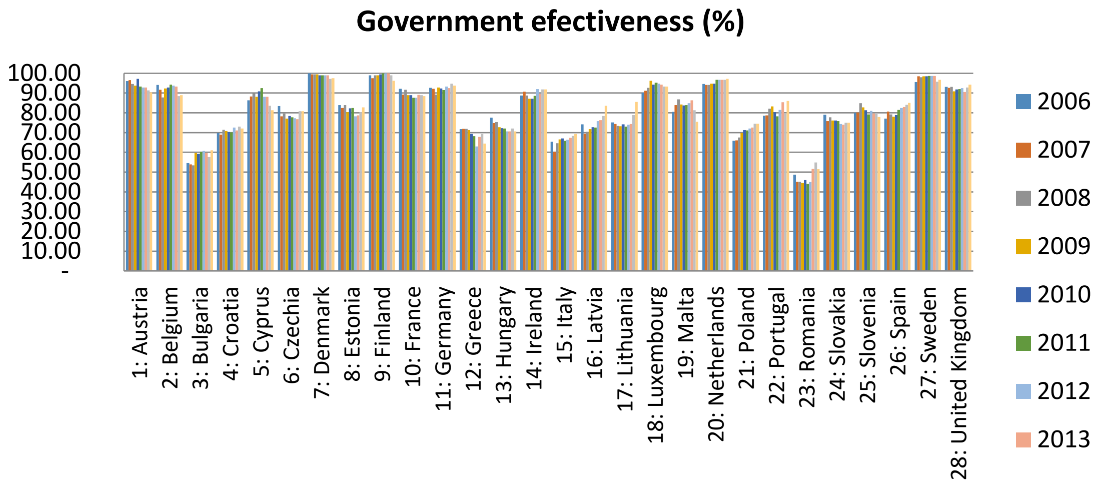

Figure 2. Government effectiveness. *Note:* The concept of government effectiveness is defined by the perception of the quality of public services, the quality of civil services and the degree of independence from political pressures, the quality of policy formulation and implementation, and the credibility of politicians' actions, in terms of their alignment with the implementation of their respective policies. A percentile is distributed across all countries worldwide, with a range from 0, representing the lowest level, to 100, representing the highest level.

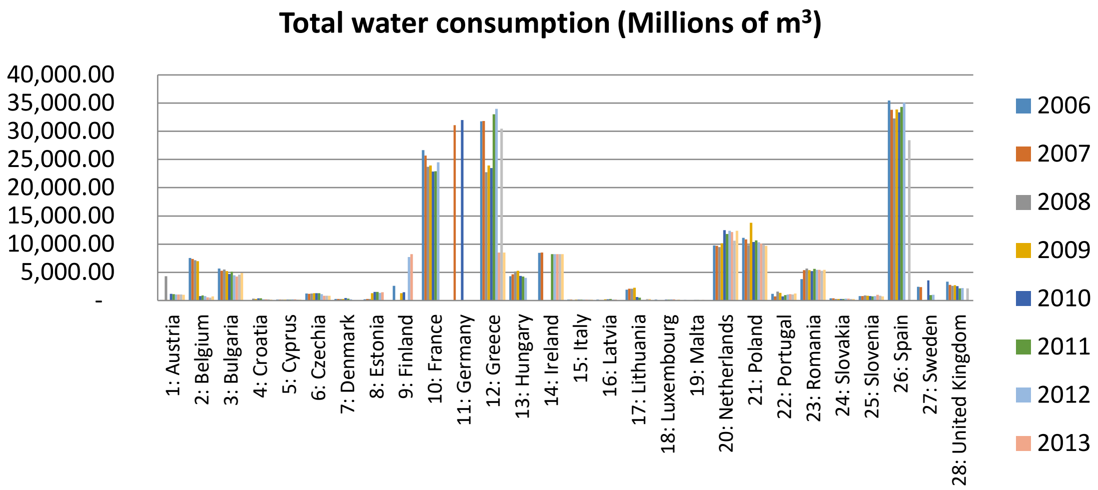

Figure 3. Total water consumption. *Note*: The indicator encompasses the total consumption of water utilized across a multitude of sectors. These include agriculture, industry, mining, service, and domestic use. The indicator quantifies the total volume of water consumed, expressed as millions of cubic metres of surface water and groundwater, in all of these sectors.

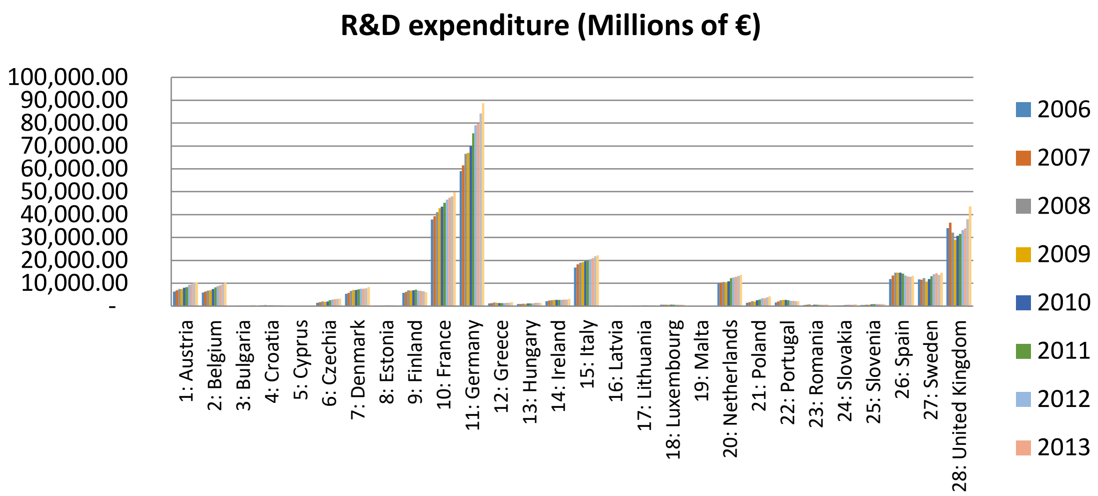

Figure 4. R&D expenditure. *Note:* EUROSTAT collates data related to expenditure on research and development, expressed in millions of euros at 2005 prices. At the level of research and development, the segment of companies related to water comprises technology and component companies that provide services and products to infrastructures.

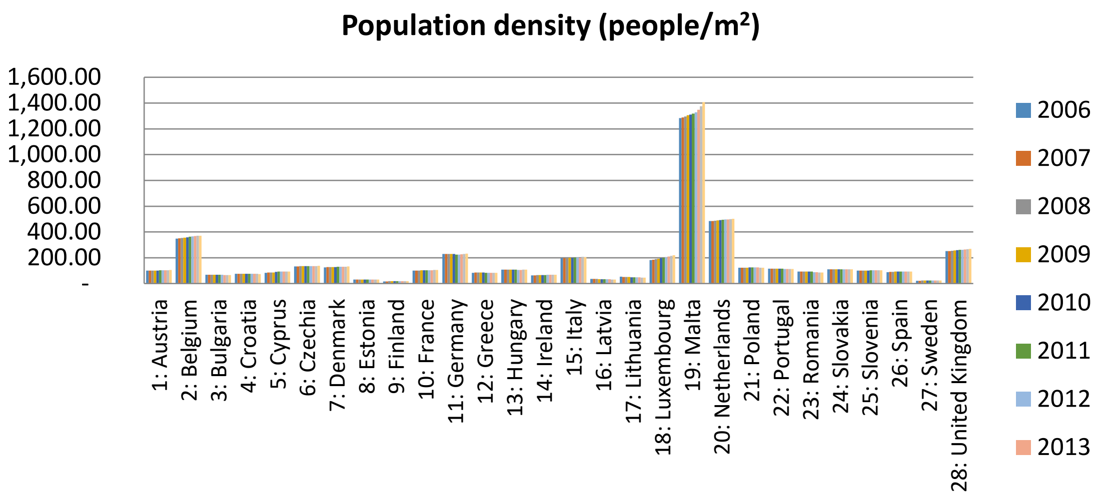

Figure 5. Population density. *Note:* The population density of a given country has been calculated by dividing the number of inhabitants by the country's area in square kilometres, as provided by the EUROSTAT database. Conversely, this constrains the length of the network for a given population, which may be linked to the costs associated with its construction and maintenance. Consequently, a positive correlation between productivity and population density would be anticipated.

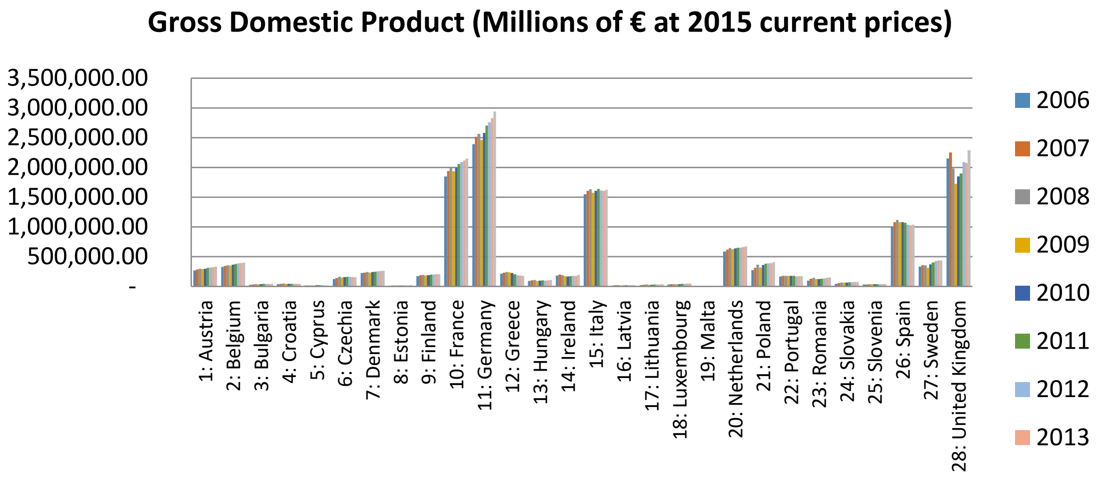

Figure 6. Gross Domestic Product.

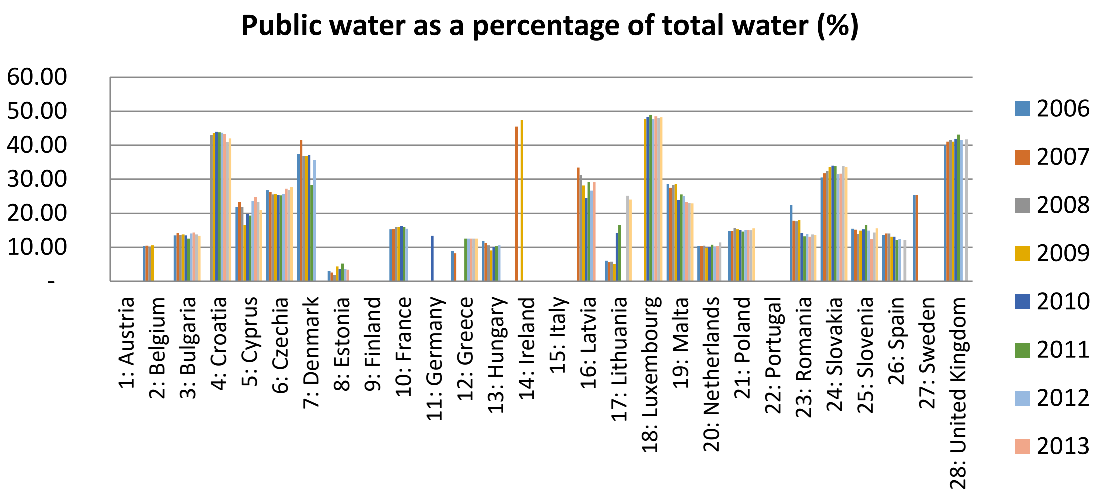

Figure 7. % Public water. *Note:* This variable indicates the proportionate importance of public control activity in the context of various services related to the integrated water cycle. It differentiates between countries where the management of water is carried out by public entities, those where it is subcontracted by the administration to other entities of a private nature and how this management affects the water used in the economic activities related to industrial activities and services. Furthermore, this differentiation allows us to ascertain the impact this difference in management has on water productivity.

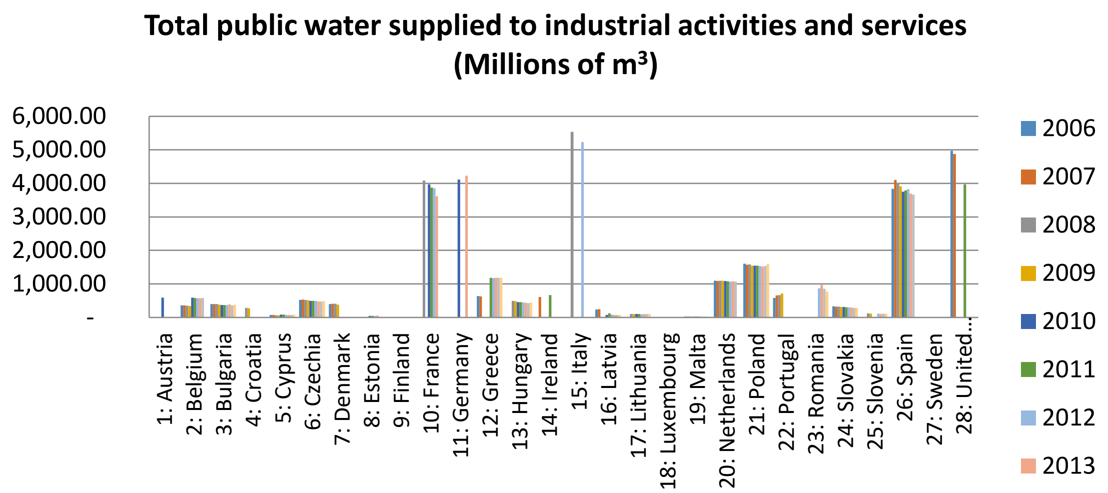

Figure 8. Public water to industrial activities & services. *Note:* EUROSTAT employs this indicator to quantify the water resources managed and supplied by public entities, encompassing all industrial and domestic activities.

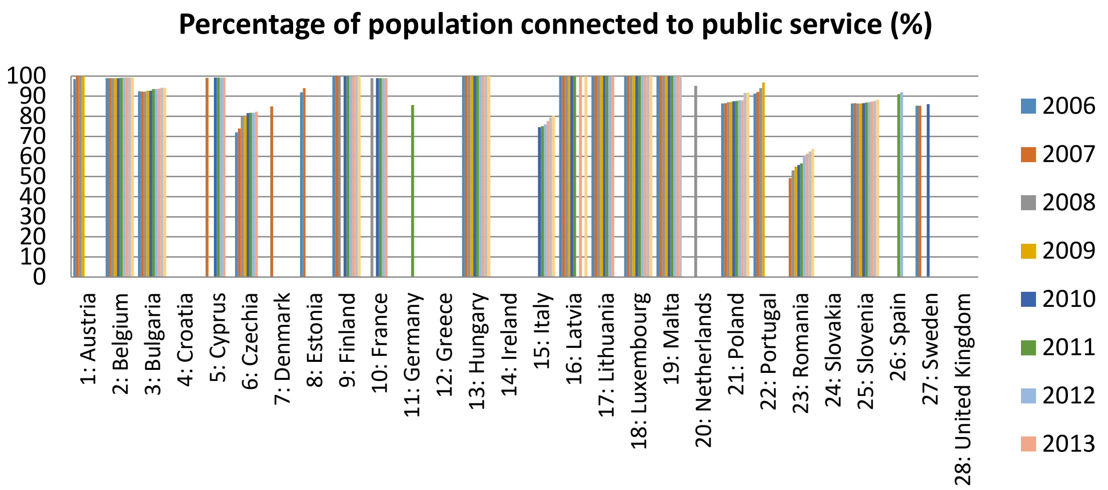

Figure 9. % Population connected to WWT. *Note:* The EUROSTAT indicator is employed to ascertain the degree to which the population has access to drinking water, taking into consideration the extent of access to the public service network. The data presented represents the percentage of the resident population that is connected to the public water supply network.

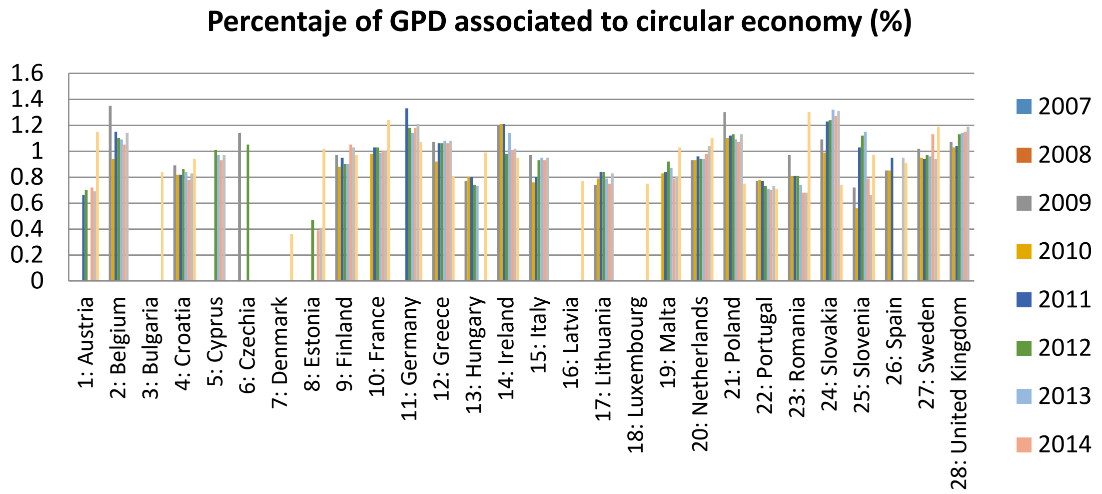

Figure 10. % GDP to circular economy. *Note:* This variable represents the percentage of GDP associated with the circular economy, encompassing both private investment and jobs, as well as the GDP generated within sectors directly or indirectly linked to the circular economy. The indicator encompasses substantial financial investments in tangible products, the size of the employed workforce and the value added to assets in sectors pertaining to recycling, reuse, rental and leasing. The NACE classification of sectors has been used to define these sectors as being related to the circular economy, with investments in tangible goods calculated to have been made for more than one year. The number of employees has also been considered, expressed as a percentage of the total employees in each country, in order to provide a more detailed picture of the sectors involved.

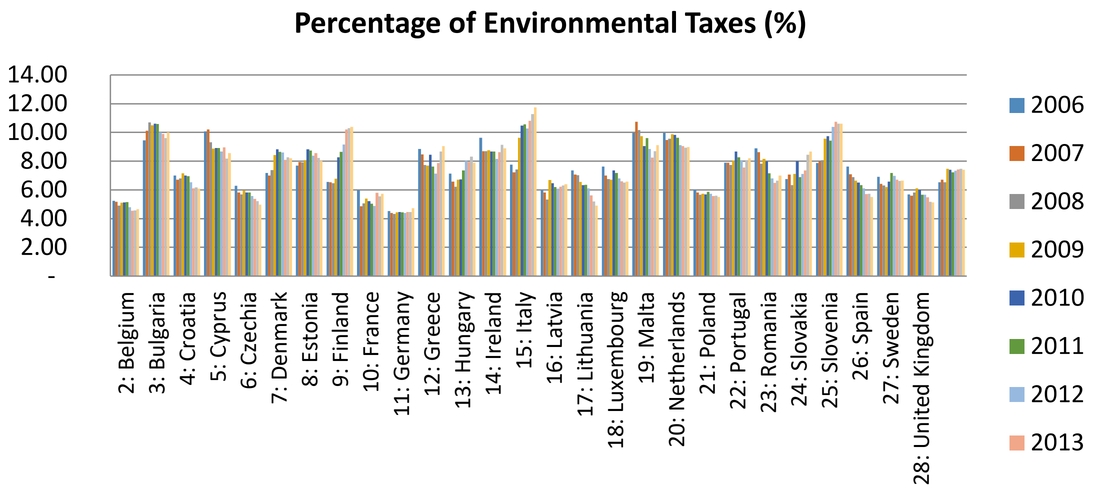

Figure 11. % Environmental Taxes Graphic. *Note:* This indicator measures both defined environmental taxes and rates associated with environmental fines, with the latter being primarily related to energy, transportation and atmospheric environmental issues. Additionally, it encompasses taxes associated with workers as social contributions for environmental conservation.