THE ECONOMIC DEVELOPMENT EFFECTS ON FRESHWATER ABSTRACTION FROM THE EUROPEAN PERSPECTIVE

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A B S T R A C T

Water scarcity is a growing concern across the globe due to climate change and demands for increased economic development. This paper analyses the relationship between economic development and freshwater abstraction in order to investigate its European impact. The analysis focuses on a total of 19 European countries, including 18 EU member states and one candidate, from 2007 to 2018. Using a panel dataset, the impact of a diverse selection of indicators of economic development (per capita GDP, the Human Development Index - HDI, water productivity and volume of international trade) on freshwater abstraction, our analysis finds that all explanatory variables are significant for cross-country variations except for international trade. To maintain scope, the analysis is limited to economic-development indicators themselves, excluding the effects of climate change and the availability of water resources.

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Introduction

Although freshwater is a basic human right, it is still inaccessible to a significant share of the global population, with 2.5 billion lacking basic sanitation due to water scarcity and nearly one million annual deaths due to water pollution (Mekonnen, Hoekstra, 2016; WHO, 2021). Moreover, while freshwater resources account for only roughly 2% of all water on the planet, the high demand for them could lead to a 40% drop in the global water-supply by 2030 (Sachidananda *et al.,* 2016). Economic expansion, climate change, population growth, changes in land use and urban expansion are all both rapidly depleting water reserves and increasing water pollution levels (Roson, Damania 2017; Zhang *et al.,* 2017, Djuričin et al., 2016).

Many regions throughout the globe suffer from insufficient available water resources to meet demand (Hervás-Gámez, Delgado-Ramos, 2019). Over the last 50 years, global freshwater use have increased by more than 40% (Gerveni *et al.,* 2020). To exacerbate matters, climate may lead to more severe water scarcity. The impacts of climate-related risks to health, food security, water supply and economic growth are expected to increase with a global warming temperature shift of 1.5°C and intensify further at 2°C (Masson-Delmotte *et al.,* 2018). Water scarcity is of particular concern, along with other limited natural resources such as fertile land, with a variety of ecosystems significantly affecting human well-being (Dantas *et al.,* 2021).

As an important resource used in production, water is indispensable for socioeconomic development (Beecher, 2020), due to its direct and indirect contributions to economic activity across sectors (Distefanoa, Kellyb, 2017). Playing a fundamental role in the world economy, agriculture is one of the most vulnerable sectors to water scarcity (Musolino *et al.,* 2018), with most freshwater generally used for agricultural purposes, followed by industry and households (Wu *et al.* 2019). Water scarcity will also likely affect both industries and households due to electricity shortages from reduced hydroelectric energy production (Koch, Vögele, 2009). To address this issue, sustainability must entail financially feasible development that is able to maximize income by exploiting available water resources (Aznar-Sanchez *et al.,* 2018).

The relationship between economic development and water use has attracted increasing attention to become a common research topic. According to Aznar-Sanchez *et al.* (2018), the number of published articles examining the impact of economic development on water use has steadily increased over the past 30 years. From a systematic review and bibliometric analysis of a sample of 1022 published articles, 45% was found to have focused on the economic impact on water use, in which the majority of individual studies originated from the United States (23.5%), Australia (13.6%) and China (8.1%).

Although Europe as a whole is generally considered to possess sufficient water resources, water scarcity and droughts are an increasingly common and widespread phenomenon (Rey *et al.*, 2019). Except for Eastern Europe, annual renewable freshwater resources per capita have been declining over the last 30 years (European Environment Agency – EEA 2021). Water scarcity and droughts in Europe may currently affect over 100 million people and approximately one third of the European continent (Hervás-Gámez, Delgado-Ramos, 2019). It is calculated most European Mediterranean countries will have less freshwater by 2050 than was available in 1990 and at least 11% of the population of Europe will face water stress (Lavrnić *et al.,* 2017).

Considering the critical nature of water scarcity, there is still a surprising research gap in assessing the impact of economic development on water in Europe. To address the gap, this paper investigates the impact of economic development on freshwater abstraction in Europe. Our analysis focuses on a total of 19 European countries, including 18 EU member states (Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, France, Hungary, Latvia, Lithuania, Malta, the Netherlands, Poland, Romania, Slovakia, Slovenia and Spain) and one candidate country (Serbia) from 2007 to 2018. Other European countries were not included as no data was readily available. To answer the main research question: "Does significant relationship between economic development and freshwater abstraction exist in the European countries selected?", a panel dataset was used that includes economic development indicators (per capita GDP, the Human Development Index - HDI, water productivity and volume of international trade) and freshwater abstraction according to source per capita - m^3 per capita.

Literature overview

Most literature examining the relationship between economic growth and the environment has focused on pollution as a function of income, which has led to criticism that such studies ignore the natural resource component of environmental quality (Arrow *et al.,* 1995). When it comes to studies examining use of natural resources, most have focused on deforestation (Culas, 2007), with only a few addressing other forms, including energy (Suri, Chapman, 1998) and water. These studies tend to equate resource use to pollution as an indicator of environmental quality.

Several characteristics distinguish natural resources from pollution in terms of their relationship to income, particularly for resources not generally traded internationally in large quantities such as water. These include: (1) limited supplies resulting in maximum amounts of use; (2) the role of natural endowments in influencing access to and demand for many resources; (3) unlike pollution which is an undesirable by-product of the production or consumption of other goods, natural resources generally yield a positive market price as goods; (4) the direct economic costs associated with the extraction and acquisition of resources; and (5) reduction is not necessarily desirable beyond a certain level (Katz, 2015).

There is a general consensus that water scarcity will likely increase significantly in the coming decades, causing problems for food security, environmental sustainability and economic development (Alcamo *et al.,* 2007; Hoekstra, 2014). Nevertheless, relatively little literature has addressed the relationship between income and water use at a state or national level. In the main, published studies provide evidence that national per capita water withdrawals appear to follow an inverted U or Environmental Kuznets

Curve (EKC) in relation to per capita income. In the early stages of economic growth, degradation and pollution increase, but do so only above a certain level of per capita income (as subject to the indicator); conversely, the trend reverses at high-income levels whereby economic growth leads to environmental improvement (Stern, 2004).

There is a general result of indicated EKCs when analysing water abstraction and its economic effects. Rock (1998) produced the first study on water income based on international cross-sectional data on water abstraction, finding per capita water withdrawal and consumption to follow an inverted-U path consistent with the EKC hypothesis. More importantly, however, is that Rock included explanatory variables other than income in his regression model - such as dummy variables for geographic regions, measures of agricultural water efficiency and trade openness. However, Gleick (2003) found no relationship between national per capita water withdrawals and income datasets. Goklany (2002) presented a qualitative assessment of water use, showing that per capita agricultural water withdrawal in the United States appears to have an inverted-U shape. Jia et al. (2006) also found an EKC for industrial water use for most OECD countries, with Bhattarai (2004) finding an EKC for irrigated land in tropical countries. Cole (2004) analysed the relationship between per capita water consumption and income using a panel data for 40 countries which confirmed a statistically significant inverted U-shaped relationship between water consumption and income. Furthermore, Barbier (2004) also found a concave relationship between growth and water use rates. Hoehn and Adanu (2008) tested an inverted-U relationship between water use and income using the International Hydrological Program (IHP) database with data from 32 countries for an interval of years of 1970, 1980 and 1990. Their dependent variable was water withdrawal and consumption, using the independent variables of: 1) economic size, 2) capital intensity, 3) trade openness, 4) income (and its squared term), 5) temperature (and its squared term), 6) precipitation and 7) climate dummies. Under a generalized least-squares estimation, capital intensity, trade openness and income all were indicated to potentially have negative effects on water use, while economic size tended to increase use which provides no support for an EKC.

The majority of existing quantitative studies on the water-income nexus have only incorporated income as an explanatory variable to assess the significance of correlation between water use and economic growth. Many additional variables have frequently been omitted from these reduced models intentionally because they were considered endogenous to economic growth. Therefore, analysts need to develop a comprehensive model that integrates all variables pertinent to isolating the effects of income (Katz, 2015).

Trade openness is an indicator of the water-trade nexus, whose work began with the observation that trade can “save” the importing country’s local water resources (Allan, 1993). The introduction of the concept of virtual water (VW) has been used to account for the water contained in traded goods outside national borders but excludes domestic consumption. It has led to extensive work on trade-based global water savings (GWS) (Chapagain *et al.,* 2006). Hoekstra and Chapagain (2007) transformed the VW concept into a water footprint (WF) to indicate the amount of water required to produce either a product or service. Through another application of VW, Chapagain and Hoekstra (2008) indicated that international trade in crops accounts for 61% of global VW trade, with trade in livestock and livestock products representing 17% and trade in industrial products making up 22%. In total, 16% of the water used in the world for agricultural and industrial production is exported as VW.

Trade liberalization itself, however, has varied but beneficial effects on water scarcity. Dang *et al.* (2016) presented a theoretical model of trade and domestic water resources that demonstrates the conditions under which trade liberalization affects water use. Reimer (2014) also demonstrated that trade liberalization could be neutral from a water-resource perspective as well as improve welfare and allow markets to better cope with shocks. Moreover, Berrittella *et al.* (2008) showed the effects of trade liberalization to likely be non-linear – i.e., reducing water use in water-scarce countries while increasing it in water-rich countries. Further to this finding, Liu *et al*. (2014) concluded that international trade buffers the impact of projected future irrigation shortages. Ultimately, Konar *et al.* (2016) found that free trade under a changing climate may also lead to higher GWS. Nevertheless, Hoekstra (2009) suggested that the export of water-intensive goods does increase water consumption and water scarcity in the exporting country.

Water productivity (WP) is the physical or economic output per unit of water use (Cai, Rosegrant, 2003). It indicates economic output generated per m^3 of freshwater withdrawn (in EUR per m3 or PPS per m3). Physical WP is the ratio between agricultural production by mass with the amount of water consumed, whereas the monetary value generated per unit of water consumed determines economic WP (Brauman, 2013; Ali, Talukder, 2008). It is found that growing more food with less water may help achieve more agricultural benefits (Molden, 2010). WP itself reflects the ability to produce more food and higher income, while also improving livelihoods and increasing environmental benefits at a lower social and environmental cost per unit of water consumed. Such outcomes of correlated increased WP and reduced water consumption have been confirmed over multiple studies (Zheng *et al.,* 2018; Kresovic *et al,*. 2014; Fraiture, Wichelns, 2010). In addition, higher WP may reduce the need for additional water resources (Rosegrant *et al.,* 2002). In industrialized countries, the gains from high WP are limited (Viala, 2008). Provided that the water is used efficiently, improved WP in agriculture allows for more water to be available for other competing sectors (Descheemaeker *et al*., 2013). Therefore, increasing water productivity is an important response to decreased water scarcity, including the maintaining of sufficient water levels in rivers to maintain ecosystems and meet the growing needs of both urban areas and industry (Hengsdijk *et al,*. 2006).

Finally, as a summary measure of human development taking into account average performance in key dimensions (a long and healthy life, knowledge and an adequate standard of living) (UNDP 2021), the HDI may be used to measure these variables to indicate a country's ability to adapt to water stress (Brown and Matlock 2011). Lawrence et al. (2002) found a strong positive correlation between the HDI and water capacity. In support, Sušnik and Zaag (2017) also found a strong positive correlation between access to clean water (as a percentage of the total population) and the HDI. Desai (1995) claims that whether a country withdraws 20% or 60% of its internal water resources annually depends strongly on the geophysical conditions but has virtually no direct impact on human development.

To the best of the authors' knowledge, a panel-data empirical analysis on the impact of economic development on freshwater abstraction has yet to be carried out for European countries, apart for research for Spain and France.

Materials and methods

In this paper, the following panel model specification was applied for estimation:

$$fw_{i,t} = x'_{i,t}\beta + u_{i,t}, \quad i = 1, \dots N, \; t = 1, \dots T \tag{1}$$

where $fw_{i,t}$ is the total freshwater abstraction by source per capita - m³ per capita in country *i* at time *t*, $x'_{i,t}$ is a vector of explanatory variables and $u_{i,t}u_{i,t}$ is a disturbance term. The total freshwater abstraction includes water withdrawn permanently or temporarily from a freshwater source. Mine and drainage water, as well as that abstracted from precipitation, are included, while water used for hydropower generation (in-situ use) is excluded (Eurostat).

Following the discussion in the research background, the explanatory variables include:

$gdp\_pc_{i,t}gdp\_pc_{i,t}gdp\_pc_{i,t}$ – GDP per capita in current USD

$trade_{i,t}$ - international trade (sum of import and export) as a percentage of GDP

$wp_{i,t}$ - water productivity, measured as economic output produced per m³ of freshwater abstracted, in constant 2010 EUR at 2010 exchange rates

$hdi_{i,t}$ – Human Development Index

We estimate the empirical model using an unbalanced panel dataset for 19 European countries, comprised of 18 EU Member States and one candidate country, from 2007 to 2018. Several datasets were combined to estimate the impact of economic development on freshwater withdrawals. The data on GDP per capita and international trade were obtained from the World Bank's WDI database, while the data on the Human Development Index were retrieved from the UNDP. The data on freshwater and water productivity come from the Eurostat database. The incompleteness of cross-country data on freshwater and water productivity limited the selection of countries to 19 for which at least ¾ of the observations are available within the timeframe observed to prevent major imbalances in the panel dataset. Ultimately, 221 observations were included.

In the estimation, typical problems were taken into account that characterize the econometric estimation of panel models and that reduce the efficiency of basic OLS estimation, such as panel heterogeneity and cross-sectional dependence, as well as the correlation and heteroscedasticity of residuals. The assumption of panel heterogeneity implies that the disturbance term $u_{i,t}$ consists of the time-invariant individual effect of country v_i and IID random error $\varepsilon_{i,t}$, $u_{i,t} = v_i + \varepsilon_{i,t}$. The presence of cross-sectional dependence, correlation and heteroscedasticity necessitates the covariance matrix of the residuals $E[uu']$ to be a block matrix:

$$\Omega_{uu} = \begin{bmatrix} {\sigma_1}^2\Omega_{11} & \dots & \sigma_{1N}\Omega_{1N} \\ \dots & \ddots & \dots \\ \sigma_{N1}\Omega_{N1} & \dots & {\sigma_N}^2\Omega_{NN} \end{bmatrix}$$

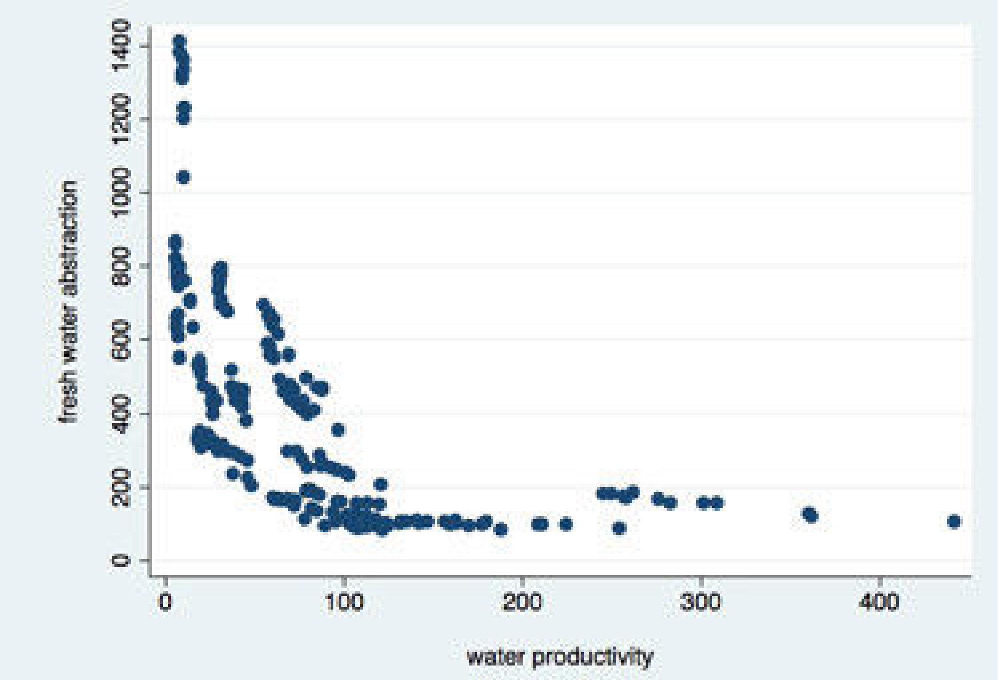
where σ_i^2 is the heteroskedastic variance of the disturbances, Ω_{ii} is a matrix of autocorrelations, and $\sigma_{ij}\Omega_{\mathrm{ij}}$ is a matrix of cross-sectional correlations. Since basic OLS estimation requires the assumptions that all σ_i^2 are equal, all Ω_{ii} are identical matrices and all $\sigma_{ij}\Omega_{\mathrm{ij}}$ are zeros, it is clear that neglecting these aspects may lead to unreliable estimates if the OLS is applied without the appropriate corrections.

Finally, an additional econometric problem that particularly relates to the specification of the model has been taken into consideration; namely, water productivity is most likely endogenous to water extraction. This arises from water productivity being calculated as economic output per m^3 of freshwater withdrawn, which in turn implies a likely simultaneity of freshwater withdrawn per capita and water productivity. Similar to other econometric problems, the presence of endogeneity in the model reduces the reliability of a simple OLS estimation.

Therefore, tests were first performed for cross-sectional dependence, correlation and heteroscedasticity to check whether these problems are relevant to the model, as well as the Hausman test to decide whether we should use a fixed or random effects estimator. Thereafter, to address all the econometric issues discussed as well as check the robustness of the estimation results, the model was evaluated using several estimators as proposed in the literature.

Before estimating the model, a graphic examination using scatter plots was performed on the relationships between the dependent variable and each explanatory variable to check whether all relationships are linear. Since the scatterplot of freshwater abstraction and water productivity indicates the presence of very strong non-linear relationships between these two variables, as shown in Figure 1 in the Appendix, the squared value of water productivity as an explanatory variable was also included.

Figure 1. The relation between freshwater abstraction and water productivity



Source: Authors

Results

To test for the presence of cross-sectional dependence, correlation and heteroskedasticity of the residuals, the following residual tests were applied:

- Heteroskedasticity: the Modified Wald test for heteroskedasticity (Greene, 2000). Under the null that all residual variances of all panels are equal, the Modified Wald test statistics is Chi-squared distributed.
- Autocorrelation: the Wooldridge test for serial correlation in panel data (Wooldridge, 2002). Under the null that the residuals within the panel are not autocorrelated at the first lag, the Wooldridge test statistics is F distributed.
- Cross-sectional dependence: Pesaran's test of cross-sectional independence (Pesaran, 2004). Under the null that the residuals are not cross-sectional dependent, the Pesaran test statistics is z distributed.

The results of testing, presented in Table 1, clearly reject nulls in all three tests applied, thereby implying that issues of cross-sectional dependence, correlation and heteroskedasticity of the residuals should not be neglected in model estimation.

Table 1. Residual tests

Test	Statistics	P-value
Modified Wald test for heteroskedasticity	chi2 (19) = 12674.61	0.0000
Wooldridge test for serial correlation in panel data	F(1, 18) = 102.165	0.0000
Pesaran's test of cross sectional independence	z = 7.748	0.0000

Source: Authors

Further, the Hausman specification test (Hausman, 1978) was performed to test null that the Random Effect (RE) estimator is efficient against the alternative of the RE as inconsistent. The computed Hausman statistics (chi2(3) = 8.8, P-value= 0.032) suggest the rejection of null, making Fixed Effects estimation more appropriate.

It is typical to address endogeneity through using an estimator based on the instrumental variable approach (IV). However, in order to achieve a more efficient estimation with an IV estimator compared to OLS, the instruments must be sufficiently adequate / relevant (i.e., correlated with the instrumented variables) and valid (i.e., not correlated with the disturbance term). If there is no clear choice of instruments from the explanatory variables, the first lags of the explanatory ones may be used, as they are not correlated with contemporaneous disturbances but likely with the current values of the instrumented explanatory variables. For our research, the linear and quadratic terms of water productivity are instrumented by both their own first lags and those of the other explanatory variables. The validity of the instruments is tested using the Kleibergen-Paap rk Wald F test (Kleibergen, Paap, 2006) and the Hansen J test (Hansen et al., 1996). The Kleibergen-Paap rk Wald F test of weak identification indicates whether the instruments are relevant, whereas the Hansen J test indicates instrument validity. The calculated values of the two statistics and the respective critical values confirm the instruments to be appropriate.

Since the results of the residual test clearly indicate the presence of cross-sectional dependence, correlation and heteroskedasticity, three different estimators are used for the model (including the squared water productivity). Firstly, the Fixed Effects (FE) estimator, as implied by the Hausman test, is applied to control for individual effects. However, since the FE estimator is essentially an OLS estimator applied to data transformed by removing fixed effects, it is not robust for cross-sectional dependence, correlation and heteroskedasticity. Two additional estimators, therefore, are also applied: Feasible Generalized Least Squares (GLS) and Panel-Corrected Standard Errors (PCSE) - both of which are robust to cross-sectional dependence, correlation and heteroskedasticity. Finally, Two-Stage LS estimators are also applied to deal with the endogeneity arising from the simultaneous dependence between water productivity and freshwater withdrawals. The results of the estimations are presented in Table 2.

Table 2. The model's estimation results

	FE	FGLS	PCSE	IV TSLS
wp	-6.3817***	-5.3583***	-6.1680***	-6.1594***
	(0.4519)	(0.3732)	(0.6814)	(1.0247)
wp_sq	0.0095***	0.0089***	0.0099***	0.00972***
	(0.0008)	(0.0009)	(0.0013)	(0.0020)
hdi	1589.6417***	863.0137***	996.6999*	1697.968**
	(393.4906)	(279.8742)	(545.0999)	(823.9513)
gdp_pc	0.0065***	0.0033***	0.0048***	0.0063***
	(0.0017)	(0.0007)	(0.0016)	(0.0017)
trade	-0.5761	0.2067	0.3461	-0.4793
	(0.3649)	(0.1461)	(0.2246)	(0 .8081)
_cons	-658.5154**	-127.6685	-205.8569	
	(303.7843)	(228.7309)	(435.2034)	
No. of Obs.	221	221	221	202
R-Squared	0.56		0.65	0.55

Dependent variable: Freshwater
Fixed effects are removed in IV TSLS estimation
*Levels of significance: * p<0.1, ** p<0.05, *** p<0.01*
R-Squared is not possible to compute for FGLS

Apart from international trade, the estimation results clearly demonstrate all explanatory variables to be significant in explaining cross-country variation in freshwater. The estimated relationship between water productivity and freshwater is non-linear, as indicated by the scatter plot, which is a highly robust result in terms of the significance, direction and magnitude of the estimated regression coefficients. A one-unit change in water productivity leads to a per capita decrease in freshwater withdrawal between 5.4 and 6.4 m^3; nonetheless, this negative linear effect is partially offset by the positive non-linear effects. The estimated impact of the HDI on freshwater is both positive and significant, suggesting better living standards coincide with an increased ability to extract more freshwater. Still, the magnitude of this effect cannot be accurately assessed due to the considerable variation in the estimated regression coefficients with respect to the estimators used. Finally, the estimation results also indicate a positive and robust influence of GDP per capita on freshwater intake. Accordingly, a change in GDP per capita of USD 1000 leads to a corresponding change in the freshwater intake of between 3.3 and 6.5 m^3. |In sum, the explanatory power of the model may be considered satisfactory as it is estimated at 56%, 65% and 55% for IV, FE and PCSE regression, respectively. (Note: It is not possible to estimate the R-squared when FGLS is applied.)

Discussions

Confirming others' results (El Khanji, Hudson, 2016), our estimation results indicate a significant positive impact of economic growth on water consumption, which suggests development to be likely influenced by water-resource management. As a country grows in wealth, it tends to use water more intensively – especially for non-agricultural purposes. Yet, since the existence of the inverted U relationship between water use and economic growth according to the EKC theory was not the subject of our analysis, our conclusions may only echo those already found in the literature showing trends change in favour of improving environmental conditions when economic growth is high.

When considering the relationship between trade openness and water use, the breadth of research has produced varied results. While some studies have argued for trade openness as a significant factor for water conservation (Hoehn, Adanu, 2008), others have yielded either neutral effects (Reimer, 2014) or a non-linear correlation between the two variables (Berrittella *et al.,* 2008). One possible reason could be the structure of the individual countries researched.

Regarding the relationship between water productivity and water use, our result is consistent with other studies in the literature which also concluded that increasing water productivity reduces per capita water withdrawals (Zheng *et al.,* 2018; Kresovic *et al,.* 2014). The non-linear negative relationship between water productivity and water withdrawal suggests that the rates of decline in water withdrawal have the potential to lower with additional growth in water productivity. The finding that the decline in water withdrawal weakens as water productivity increases is consistent with the conclusion of Viala (2008). There is the potential to increase physical and economic water productivity, but it would require policies and actions that take into account the complexity of achieving these gains. Moreover, the areas posed to benefit from the highest potential gains in improved WP are those which have extremely low yields and which rely on rain-fed agricultural systems.

Our research finding of a strong positive correlation between the HDI and freshwater use also confirms the conclusions of Lawrence *et al.* (2002). Our results, however, differ from the findings of Neumayer (2001), Sušnik and Zaag (2017), who all concluded there to be no direct correlation between resource exploitation and environmental degradation with human development.

Conclusion

Using country-level panel data from 19 European countries from 2007 to 2018, this paper has examined the relationship between its selected indicators of economic development (GDP per capita, the Human Development Index - HDI, water productivity and volume of international trade) and freshwater abstraction. With the exception of the volume of international trade, our analysis confirms research elsewhere in the literature and indicates all explanatory variables to be significant in explaining cross-country variation in freshwater abstraction.

According to Eurostat methodology, the main issue associated with using total freshwater abstraction as an indicator of water consumption is that it fails to distinguish between freshwater abstraction from surface and groundwater. Since the Eurostat database for water abstraction statistics aggregates nationally, it does not account for regional and seasonal changes throughout the year for areas which may be under the influence river basins, which may suffer from varying degrees of water scarcity in summer, or which may experience drastic contrasts in temperature. The indicator also does not distinguish between abstracted water that is returned to the catchment after use and appropriate treatment or when it is used for irrigation purposes and undergoes natural evaporation. For a more detailed analysis, separate data on water abstraction from groundwater, surface water and regional allocation should be considered, but these data are not readily available.

Furthermore, as the impact of climate change has not been assessed here; rather, our analysis is limited solely to economic development indicators. An important extension of this study would be to consider the impact of climate change on water abstraction, especially within a country or countries facing moderate or severe water scarcity.

Bearing in mind the impact of economic development on water abstraction, European countries must learn to adapt to any and all successful water conservation strategies. Economic and population growth, cultural challenges, changes in trade controls and the responses throughout the industrial sector to water scarcity shall all be the main factors influencing the future of water demand (Ercin, Hoekstra 2016). One possible solution is to reduce water demand by increasing water prices (Lavrnić *et al.,* 2017). In addition, the reuse of wastewater can be a suitable strategy to prevent further problems with water demand (Tchobanoglous, 2021). Technological changes in the productivity of water use could significantly slow down the increase in water withdrawals in all sectors (Alcamo *et al.*, 2007). These measures may also all have impact on freshwater abstraction to economic development as has been presented here.

This paper is a starting point to better understand the relationship between economic development and water abstraction in Europe. Further research should examine economic-development forecasts as well as the measures used to reduce freshwater abstraction by country. This paper may assist national decision-makers in Europe to identify priorities and further measures to provide sufficient freshwater of adequate quantity and quality for all.

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Conflict of interests

The authors declare no conflict of interest.

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