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Valeria Di Cosmo
Marie Hyland
Maria Llop

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Departament d'Economia
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Universitat Rovira i Virgili
Facultat d'Economia i Empresa
Avgda. de la Universitat, 1
43204 Reus
Tel.: +34 977 759 811
Fax: +34 977 300 661
Email: sde@urv.cat

CREIP
www.urv.cat/creip
Universitat Rovira i Virgili
Departament d'Economia
Avgda. de la Universitat, 1
43204 Reus
Tel.: +34 977 558 936
Email: creip@urv.cat

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Disentangling water usage in the European Union: A decomposition analysis

Valeria Di Cosmo[ab], Marie Hyland[ab], Maria Llop[c**]

[a] Economic and Social Research Institute, Dublin, Ireland

[b] Trinity College Dublin, Ireland

[c] Universitat Rovira i Virgili and CREIP, Reus, Barcelona, Spain. Corresponding author: maria.llop@urv.cat

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Abstract

The Water Framework Directive (WFD) defines common objectives for water resources throughout the European Union (EU). Given this general approach to water preservation and water policy, the objective of this paper is to analyse whether common patterns of water consumption exist within Europe. In particular, our study uses two methods to reveal the reasons behind sectoral water use in all EU countries. The first method is based on an accounting indicator that calculates the water intensity of an economy as the sum of sectoral water intensities. The second method is a subsystem input-output model that divides total water use into different income channels within the production system. The application uses data for the years 2005 and 2009 on water consumption in the production system of the 27 countries of the EU.

From our analysis it emerges that EU countries are characterized by very different patterns of water consumption. In particular water consumption by the agriculture sector is extremely high in Central/Eastern Europe, relative to the rest of Europe.

In most countries, the water used by the fuel, power and water sector is consumed to satisfy domestic final demand. However, our analysis shows that for some countries exports from this sector are an important driver of water consumption. Focusing on the agricultural sector, the decomposition analysis suggests that water usage in Mediterranean countries is mainly driven by final demand for, and exports of, agricultural products. In Central/Eastern Europe domestic final demand is the main driver of water consumption, but in this region the proportion of water use driven by demand for exports is increasing over time.

Given these heterogeneous water consumption patterns, our analysis suggests that Mediterranean and Central/Eastern European countries should adopt specific water policies in order to achieve efficient levels of water consumption in the European Union.

JEL codes: N5; C67

Keywords: Water use, Subsystem input–output model; Water intensity, European Union.

1. Introduction

The European Water Framework Directive (WFD) (2000/60EC) prescribes that "*Member States shall take account of the principle of recovery of the costs of water services, including environmental and resource costs, having regard to the economic analysis and in accordance in particular with the polluter pays principle*".[1] The idea behind this Directive is that water is a scarce commodity in Europe and has social, ecological and cultural values associated with it. If these values are to be taken into account, the price of water should reflect not only the scarcity and cost of use but also the externalities generated. Since these objectives are common to all European Union (EU) members, it is crucial to determine whether patterns of water usage are also common to the 27 EU countries and what the main drivers of water usage are in each state. Only in this way can the policies that encourage water saving schemes be successful at the European level.

The main aim of this paper is to identify the patterns of water usage in all the countries of the European Union, and to assess any changes to them over the course of the decade from 2000 to 2009. We wish to develop an overall picture of water consumption in Europe and to highlight any similar patterns in water intensity between European countries. We do so by looking at the sectoral water intensity of each country and by looking at the contribution of the water-intensive sectors to each country's total output. We then take the sectors which are, on average, the most water-intensive and check if there is an EU-wide pattern in terms of the drivers of water usage.

Our analysis is based on two different methods for analysing water consumption patterns. The first one adopts an accounting perspective and uses macro-indicators of both sectoral water use and sectoral production. This method allows us to identify the most water-intensive sectors in European countries, and the relative contribution of these sectors to each country's GDP. The second method is based on a subsystem input-output methodology, which reflects the different income channels that explain water consumption within the production system. Results from this part of the analysis highlight the shortcomings of focusing on a producer-pays definition of environmental responsibility by identifying the underlying drivers of water consumption.

The results in the paper show that European countries are characterized by very different water usage patterns, and that there has not been a notable convergence of these patterns over the period of our analysis. This is an important result which should be considered in the formulation of EU water policy in the future; when setting targets for water pricing and cost recovery at the European level, the heterogeneous patterns of water consumption across the EU should be taken into account.

Our study can be viewed as a starting-point by providing a picture of the situation regarding water usage in the production system of European countries. This information is of crucial importance to the definition and implementation of common water policies, given that these policies can only succeed if they take into account the specificities of each country to which they are applied. According to our results, different water measures should be applied in different EU countries if European water policy is to be successful in the preservation and sustainable use of water resources.

[1] The Directive is available here: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:327:0001:0072:EN:PDF

To date only a few multi-country analyses of water usage have been made. Moreover, to our knowledge, the literature does not contain a single complete analysis of sectoral water use for all EU countries. By examining water consumption patterns for all countries in the EU, across 35 production sectors, over the course of the 2000s, our study makes an important contribution to the international literature on virtual water consumption. Our analysis provides new and valuable information which could be useful in the process of defining and implementing a new common water policy in line with the EU's Water Framework Directive.

The rest of the paper is organised as follows. Section 2 gives a brief overview of the relevant literature. Section 3 describes the database used in the analysis and Section 4 presents the two methods used to decompose sectoral water usage. Section 5 contains the results of the empirical application to the 27 European countries. At the end of the paper we provide some concluding remarks.

2. Literature review

Several papers have used an input-output framework to analyse patterns of water consumption from a single-country perspective. For example, Lenzen and Foran (2001) constructed an input-output model based on multipliers for Australia. They found that the production of food to satisfy domestic demand accounted for 30% of water consumption and, similarly, exported goods accounted for 30% of water consumption. Their analysis also showed that Australia exported substantially more virtual water than it imported.

Dietzenbacher and Velázquez (2007) used an input-output framework to analyse the consumption of water in the Andalusian production process. They also analysed how much virtual water – i.e. the amount of water used to produce goods and services, including the water used to satisfy intermediate demand – was embodied in trade. The Andalusian agricultural sector was responsible for 90% of direct water consumption, but contributed only 8% to the Gross Regional Product. Additionally, more than half of the final output of the agricultural sector was exported to the rest of Spain, the EU and the rest of the world. The authors highlighted that as Andalusia is a relatively arid region, their results contradicted the Hecksher-Ohlin theory which states that countries (or regions) should specialise in the production of goods that use inputs which are relatively abundant in that country/region.

Guan and Hubacek (2007) used a regional input-output model for eight regions in China to analyse patterns of regional trade and the flow of virtual water. They noted that while the northern part of China had only one-fifth of the water resources, it was supporting more than half of the population. The authors constructed two regional input-output tables for North and South China, and supplemented these with data on interregional trade flows. They noted that while northern China had fewer water resources, it was a net exporter of virtual water; they also noted that southern China was a net importer. These results are yet another contradiction of the Hecksher-Ohlin theory. The authors also stated that water scarcity in northern China is becoming a barrier to further economic development. To conclude, the authors remarked that direct and indirect water usage was not sufficiently taken into account in consumption and production decisions, which can lead to the unsustainable use of water resources.

Zhao et al. (2009) used an input-output framework to calculate the national water footprint for China, which illustrated the water used directly and indirectly to satisfy final demand, including demand for exports. The authors highlighted the advantage of using this national water footprint indicator as it matches the use of water, an import resource, to consumption, which may be a better tool for altering water consumption patterns. They also highlighted the importance of virtual water and noted that it should be imported from relatively water-abundant countries if water security is to be achieved.

International studies include Hoeskstra and Hung (2002), who calculated the flows of virtual water (although not within an input-output framework) in relation to crop trade between nations in the period 1995–1999 and found that the main virtual water exporters are the US, Canada, Thailand, Argentina and India, while Sri Lanka, Japan, the Netherlands and China are the main water importers. One shortcoming of this study is that it only takes crop production into account, and not the entire production system.

Within the input-output framework, an individual sector, or group of sectors, can be regarded as a subsystem which interacts with the other sectors. This approach isolates the relations of a limited number of activities from the whole system, and shows the particular patterns of individual units as part of the entire production sphere. The subsystems (economic) model was originally proposed by Sraffa (1960), Pasinetti (1973, 1988), Deprez (1990) and Scazzieri (1990) among others. Subsequently, this method was extended to the analysis of pollutant emissions.[2] However, as far as we are aware, the subsystem model has not been applied to water usage in the production system.

3. Data

The water use data and the input-output tables used in our analysis are from the World Input-Output Database (WIOD: www.wiod.org). This database contains Input-Output tables and environmental accounts (which include water usage) for 27 EU countries and 13 other countries in the world between 1995 and 2009. The Input-Output tables and the water use data are presented at a 35-sector level of aggregation.[3] While data are available for all years up until 2009, we have chosen to focus on 2000, 2005 and 2009 in our analysis. This allows us to analyse patterns of water use and economic activity that were not being affected by the current period of economic recession, and also to look at how these patterns have evolved over time. Furthermore, it covers the decade immediately after the adoption the EU's Directive establishing a framework for Community action in the field of water policy. Our analysis focuses on the 27 countries within the EU.[4] Input-output tables are expressed in current US$ terms, thus we adjust the 2000 and 2009 input-output tables so that they are expressed in real 2005 values. In order to inflate or deflate the I-O tables we use the

[2] See Alcántara (1995), Sánchez-Choliz and Duarte (2003), Alcántara and Padilla (2009), Cardenete and Fuentes (2011) and Butnar and Llop (2011) for applications to Spanish emissions; and Llop and Tol (2013) for an application to Irish emissions.
[3] See Timmer et al. (2012) for a list of the sectors and countries presented in this database.
[4] Croatia joined the EU in the summer of 2013, however, it is not included in our analysis as it is not covered by the WIOD database.

producer prices deflator[5] for the manufacturing sectors, the harmonised index of consumer prices[6] for the services sector, and the agricultural output price index[7] for the agricultural sector.

The water use data presented in the WIOD divides water use, in thousands of m^3, into blue, green and grey water. Blue water is water drawn from surface and ground water; green water is rainwater absorbed in soil; and grey water is water which is used to dilute pollutants. In our analysis we focus on the use of blue and green water (note however that green water is consumed only by the agricultural sector). In many countries a large portion of total grey water is consumed by private households. As we focus on the productive sectors of the economy, in our analysis we ignore the use of grey water.

There are a number of data caveats in the WIOD. Water use data for certain sectors is reported as zero even though it is unlikely that no water was used (for example, in the electricity, gas and water supply sector in both Malta and Cyprus). For the Electricity, Gas and Water Supply sector, the WIOD provides the water extracted by the water supply branch, which is then distributed throughout the rest of the economy. Details of the methodologies and data sources used to construct the economic tables and the environmental accounts can be found in Genty et al. (2012) and Timmer et al. (2012); in particular further data caveats are discussed by Timmer et al. (2012).

The WIOD gives input-output and water use tables for 35 productive sectors although the vast majority of water used in an economy is in fact concentrated in a small number of sectors. Thus, in our analysis we have chosen to focus on the sectors above the EU median in terms of water consumption; these are the Agriculture, Hunting, Forestry and Fishing sector; the Food, Beverages and Tobacco sector; the Chemicals and Chemical Products sector; and the Electricity, Gas and Water Supply sector (see Table 1). Together these sectors account for, on average, 99% of water used in production in the EU. The order of water intensity among the sectors, given in Table 1 below, does not change over the period of our analysis.

[5] http://epp.eurostat.ec.europa.eu/portal/page/portal/short_term_business_statistics/data/database. Data are missing for Ireland in the Eurostat series for years prior to 2005, therefore we use the wholesale price index published by Ireland's Central Statistics Office for these years. Furthermore, producer price deflators are missing for Portugal in all years, and thus we deflate the Portuguese I-O tables using the producer price deflator for Spain. Similarly data are missing for Slovakia in some years, and for these years we use the deflator for the Czech Republic.

[6] http://epp.eurostat.ec.europa.eu/portal/page/portal/hicp/data/database.

[7] http://epp.eurostat.ec.europa.eu/portal/page/portal/agriculture/data/database.

Table 1: Distribution of sectoral water intensity (1000m³ per million USD): EU, 2000, 2005 and 2009[*]

Sector	Deciles
All other sectors	0.1
Other Non-Metallic Minerals	0.2
Textiles and Textile Products	0.3
Basic Metals and Fabricated Metal	0.4
Pulp, Paper, Paper, Printing and Publishing	**0.5**
Food, Beverages and Tobacco	0.6
Chemicals and Chemical Products	0.7
Electricity, Gas and Water Supply	0.8
Agriculture, Hunting, Forestry and Fishing	0.9

* Median in bold.

4. Methods

Our analysis can be divided into two parts: first, we use statistical indicators to quantify the importance of the sectoral water intensity for the economies of the EU-27 countries; second, we use an input-output decomposition analysis to find the main drivers of water usage for the sectors which have been identified as the most water intensive.

4.1. Water Intensity Indicator

Various methods can be used to calculate the water intensity of an economy. In what follows, we distinguish between those sectors that are above the median level of EU water intensity ($j = 1, \ldots, 4$) and the other sectors ($r = 5, \ldots, 35$). We also distinguish between the 27 EU countries ($C = 1, \ldots, 27$). So, we use the following calculation: [8]

$$\frac{W_C}{Y_C} = \sum_{j=1}^{4} \frac{W_{j,C}}{Y_{j,C}} \frac{Y_{j,C}}{Y_C} + \sum_{r=5}^{35} \frac{W_{r,C}}{Y_C} \qquad (1)$$

The first term in Equation (1) shows the water intensity in the C-th country considered: water consumption (W_C) per GDP (Y_C) as a function of water intensity per sector $\frac{W_{j,C}}{Y_{j,C}}$, where index j corresponds to the economic sectors identified previously; agriculture, food and beverages, chemicals and electricity, gas and water supply.

Also in Equation (1), the term $\frac{Y_{j,C}}{Y_C}$ measures how much the *j-th* sector contributes to the *C-th* country's GDP. Thus the indicator allows water intensity to be decomposed into sectoral water intensity and output intensity.

4.2. Input-Output Subsystem Decomposition

Having examined the water intensity of the EU countries, we then use the details of the production structure of each economy, as given in the national input-output tables, to decompose sectoral

[8] Mendiluce et al. (2010) proposed a similar method to measure energy intensity in the Spanish economy.

water use into different channels within the production system. Specifically, we use a subsystem input-output model to analyse the patterns of sectoral water consumption.

The subsystems approach considers an individual sector (or a group of sectors) as a particular unit that does not modify the main characteristics of the system of which it is a part. Taking into account that a subsystem responds to the notion of an individual sector or group of sectors that produce a specific commodity, an input-output table enables all sectors of production to be considered as different subsystems. In this paper we separately take into account four sectors of production and, for each one, we apply a subsystem division of its water use.[9] This analysis, which decomposes the water use of each sector into different sources, extends our knowledge about the water consumption within the production system.

The starting point of the subsystem representation consists of decomposing the *N* accounts of an input-output system into two categories (*M* and *S*), with 1, 2, …, *m* sectors belonging to *M* subsystem, and *m* + 1, …, *n*, belonging to the *S* subsystem. If these accounts are separated, the input-output representation can be written as follows:

$$\begin{pmatrix} A_{MM} & A_{MS} \\ A_{SM} & A_{SS} \end{pmatrix}\begin{pmatrix} x^M \\ x^S \end{pmatrix}+\begin{pmatrix} y^M \\ y^S \end{pmatrix}=\begin{pmatrix} x^M \\ x^S \end{pmatrix}, \qquad (2)$$

where the subscripts and superscripts denote the group of accounts *M* and *S*, respectively. In Equation (2), matrices *A* contain the technical input-output coefficients, the column vector $x=\begin{pmatrix} x^M \\ x^S \end{pmatrix}$ contains the sectoral production and the column vector $y=\begin{pmatrix} y^M \\ y^S \end{pmatrix}$ contains the final demand. From Equation (2), we can calculate sectoral production as $x=(I-A)^{-1}y=By$, where *B* is the Leontief inverse matrix. Using this definition, the model can be written as:

$$\left[\begin{pmatrix} A_{MM} & A_{MS} \\ A_{SM} & A_{SS} \end{pmatrix}\right]\begin{pmatrix} B_{MM} & B_{MS} \\ B_{SM} & B_{SS} \end{pmatrix}\begin{pmatrix} y^M \\ y^S \end{pmatrix}+\begin{pmatrix} y^M \\ y^S \end{pmatrix}=\begin{pmatrix} x^M \\ x^S \end{pmatrix}. \qquad (3)$$

Expression (3) contains the following two equations:[10]

$$A_{MM}B_{MM}\,y^M + A_{MM}B_{MS}\,y^S + A_{MS}B_{SM}\,y^M + A_{MS}B_{SS}\,y^S + y^M = x^M, \qquad (4)$$

$$A_{SS}B_{SM}\,y^M + A_{SS}B_{SS}\,y^S + A_{SM}B_{MM}\,y^M + A_{SM}B_{MS}\,y^S + y^S = x^S.$$

The two equations in (4) show the production of the *M* and *S* subsystems, respectively. Let us assume that we are interested in analysing the *S* subsystem. Then, the interpretation of Equation (4) is as follows: The first equation, which defines the total production of *M*, can be divided into two parts. The first, $A_{MM}B_{MS}\,y^S + A_{MS}B_{SS}\,y^S$, shows the effects of the final demand of the *S* subsystem on the production of *M* and we can regard it as an *external component*. The remaining elements in

[9] Specifically, we will consider the four activities that show a level of water intensity above the EU median (see Table 1).

[10] The literature on input-output subsystems usually assumes that the final demand in one subsystem is zero and, accordingly, this subsystem is thought to only produce for the intermediate demand (see, for instance, Alcántara and Padilla (2009)). Unlike other similar studies, expression (4) captures all the income relations within the production system.

the first equation of (4), $A_{MM} B_{MM} y^{M} + A_{MS} B_{SM} y^{M} + y^{M}$ show the production of *M* needed to cover its final demand.[11]

The left-hand side of the second equation in expression (4) can be divided into different components that convey different economic meaning. The term $A_{SS} B_{SM} y^{M} + A_{SM} B_{MM} y^{M}$ shows the production of *S* required to cover the final demand of *M* or the *induced component*. The term $A_{SS} B_{SS} y^{S} + A_{SM} B_{MS} y^{S}$ is interpreted as an *internal component* that shows effects that both end in *S* and start from *S*. Finally, the last component, y^{S}, is the final demand for the *S* subsystem and can be divided into exports final demand (y_{X}^{S}) and domestic final demand (y_{D}^{S}):[12] $y^{S} = y_{X}^{S} + y_{D}^{S}$.

To transform Equation (4) into a water-use model, we use the diagonal matrices W^{M} and W^{S} that contain in the main diagonal the water-use coefficients, calculated as the water used (in physical units) per unit of total production in the *M* and *S* subsystems, respectively. The water-use associated with the components of the *S* subsystem is equal to:

$$EC_{S} = W^{M} (A_{MM} B_{MS} + A_{MS} B_{SS}) y^{S}$$

$$INC_{S} = W^{S} (A_{SS} B_{SM} + A_{SM} B_{MM}) y^{M}$$

$$ITC_{S} = W^{S} (A_{SS} B_{SS} + A_{SM} B_{MS}) y^{S}$$

$$EXC_{S} = W^{S} y_{X}^{S}$$

$$DC_{S} = W^{S} y_{D}^{S}$$

These expressions show the water use explained by the external component (EC_S) – the water used in subsystem *M* due to demand for *S*; the induced component (INC_S) – the water used in subsystem *S* due to demand for *M*; the internal component (ITC_S) – the water used in subsystem *S* due to demand for *S*; the export level component (EXC_S) – the direct water use due to foreign demand for *S;* and the domestic final demand component (DC_S). The total (direct and indirect) water use (TW_S) of the *S* subsystem can then be calculated as:

$$TW_{S} = EC_{S} + INC_{S} + ITC_{S} + EXC_{S} + DC_{S}$$

$$= W^{M} \left(A_{MM} B_{MS} + A_{MS} B_{SS} \right) y^{S} + W^{S} \left(A_{SS} B_{SM} + A_{SM} B_{MM} \right) y^{M} \quad (5)$$

external induced

[11] Note that if we are interested in the *S* subsystem, this part of the *M* production can be avoided.

[12] The domestic final demand includes sectoral private consumption, public consumption and investment.

$$+W^S(A_{SS}B_{SS}+A_{SM}B_{MS})y^S+W^S(y_D^S+y_X^S)$$

internal demand(sum of domestic and export)

5. Results

The main aim of our study is to investigate whether a common pattern emerges in the water consumption of the EU 27 countries, and to analyse what changes have taken place in these patterns from 2000 to 2009. As the WFD defines common criteria to evaluate the water consumption in different countries and suggests the application of economic analysis to quantify the prices and the costs associated with water usage, an analysis of water intensity in different sectors and the drivers of water usage in the water-intensive sectors for all EU member states is an important step in helping policy-makers to understand whether common incentives to encourage the efficient consumption of water will have parallel effects in all EU countries.

Analysis of the water intensity indicators shows that water intensity is heterogeneous at a national level, but homogeneous over time. In particular, the water used in agriculture is particularly high for Central/Eastern European countries, such as Romania, Lithuania, Bulgaria and Hungary. Moreover, the water used in the electricity, gas and water supply sector in countries with nuclear power plants (Sweden, France, and Romania) is higher than in other countries.

To analyse more homogeneous trends in water use, we divide our sample into different sub-regions to identify common patterns of water consumption within them.[13] This leads us to identify three main regions within our sample: the area which we refer to as "Northern Europe" is comprised of Great Britain, Ireland, Germany, France, Sweden, Austria, Belgium, Finland, Luxembourg, the Netherlands and Denmark; the "Mediterranean" region is comprised of Spain, Italy, Cyprus, Greece, Malta and Portugal; finally "Central/Eastern Europe" refers to Estonia, Slovakia, Slovenia, Poland, Romania, Bulgaria, the Czech Republic, Hungary, Latvia and Lithuania. Water consumption within each group exhibits broadly similar patterns; however, our results show a general heterogeneity of water consumption within the EU as a whole.

5.1 Water Intensity

Our aggregate water intensity indicator is comprised of two separate indicators; sectoral water intensity (WI), defined as sectoral water use in country *i,* divided by total output of country *i;* and sectoral output intensity (YI), defined as sectoral output of country *i,* divided by total output of country *i*.

In many sectors direct water consumption is low, therefore, in our analysis we focus on those sectors that are relatively water intensive. We consider the four sectors in which water use is above the European average level, and we analyse the water and output intensities of these sectors in the macro-regions identified before (Tables 2-5).

[13] Results for all the EU countries are available by the authors upon request.

Table 2: Water Intensity (WI) and Output Intensity (YI), Agricultural, Hunting, Forestry & Fishing sector

	Water Intensity (1000m3 per million $)			Average	*Output Intensity*			Average
	2000	2005	2009	(2000-2009)	2000	2005	2009	(2000-2009)
Northern	15.11	9.84	9.25	11.40	0.019	0.016	0.016	0.017
Mediterranean	**43.94**	**24.00**	**20.04**	29.32	**0.035**	**0.028**	**0.025**	0.029
Central/Eastern	**180.26**	**127.41**	**114.24**	140.64	**0.058**	**0.049**	**0.043**	0.050
EU average	26.66	18.60	17.89	21.05	0.022	0.019	0.019	0.020

Note: Figures in bold are those which are above the EU average for this sector.

We find that in Northern European countries, most sectors are below the EU average level of water usage relative to total economic output. However, there are some exceptions: in France the water usage relative to output is above average in all sectors, and in Sweden, Austria and Finland water intensity is above average in the Electricity, Gas and Water supply sector. In some of these countries (for example, Sweden, Finland and France), the high levels of water intensity in the Electricity, Gas and Water supply sector may be due to the use of nuclear power in electricity generation (European Union, 2012), which requires the use of significant amounts of water to cool the nuclear reactors and produce steam (EPA, 2012).

However, Table 2 shows that in the agricultural sector, water and the output intensity in Northern European countries is, on average, well below the average for the EU as a whole.

A very different pattern of water intensity can be seen in the Mediterranean and Central/Eastern European countries. Countries in these regions have much higher levels of water intensity in the agriculture, hunting, forestry and fishing sector than in the Northern European countries. This result might be seen as surprising because, as mentioned above, the measure of water use in our analysis includes rain water absorbed from soil. However, it should be noted that Mediterranean countries generally use a vast amount of blue water in agriculture, given their arid climate.

The water intensity indicator shows a declining pattern of water intensity for almost all countries between 2000 and 2009. However the greatest percentage change is registered by the Central/Eastern EU countries. This is generally associated with a reduction of the relative economic importance of the agriculture sector. However, the output intensity of the agriculture sector remains high in these countries and is above the European average level in all years.

Countries in which the decrease in the water intensity is most notable include Slovakia, the Czech Republic and Cyprus. In Slovakia the water intensity of the agricultural sector almost halved over the period of the analysis, at an average rate of decrease of approximately 18% per annum. The average annual decline was 11% and 10% in Cyprus and the Czech Republic respectively. While these declines were accompanied by decreases in the economic importance of the agriculture sector for these countries, the declining water intensities are greater than can be explained by falling output intensity alone; suggesting that water use in agriculture has seen efficiency improvements.

Table 3: Water Intensity (WI) and Output Intensity (YI), Electricity, Gas and Water Supply sector

	Water Intensity (1000m3 per million $)	Average	*Output Intensity*	Average

	2000	2005	2009	(2000-2009)	2000	2005	2009	(2000-2009)
Northern	**8.36**	**5.07**	**4.61**	6.01	0.019	0.023	0.026	0.023
Mediterranean	4.25	1.86	2.30	2.80	**0.026**	**0.031**	**0.037**	0.031
Central/Eastern	**12.53**	**9.73**	**7.25**	9.84	**0.044**	**0.042**	**0.049**	0.045
EU average	4.89	2.90	2.86	3.55	0.023	0.027	0.031	0.027

Note: Figures in bold are those which are above the EU average for this sector.

Turning next to the electricity, gas and water supply sector it is important to note that, as mentioned above, high water intensity in this sector in some countries may be associated with the presence of nuclear power plants. The pattern of overall decline in water and output intensities that we identified in the agricultural sector is not seen the electricity, gas and water supply sector. Northern countries show higher values of the water intensity indicator in this sector than the European mean, whereas Mediterranean countries are characterized by values of water usage in this sector lower than the other countries.

Finally, all regions have experienced an increase in the output intensity of this sector, but this has been accompanied by a decrease in the water intensity of the sector on average in Northern and, in particular, Central/Eastern European countries.

Table 4: Water Intensity (WI) and Output Intensity (YI), Chemicals and Chemical Products sector

	Water Intensity (1000m3 per million $)			Average	*Output Intensity*			Average
	2000	2005	2009	(2000-2009)	2000	2005	2009	(2000-2009)
Northern	0.105	0.080	0.075	0.086	**0.034**	**0.033**	**0.034**	0.034
Mediterranean	0.038	0.025	0.022	0.028	0.017	0.016	0.017	0.017
Central/Eastern	**0.310**	**0.226**	**0.239**	0.259	0.022	0.020	0.020	0.021
EU average	0.15	0.12	0.11	0.13	0.030	0.029	0.027	0.029

Note: Figures in bold are those which are above the EU average for this sector.

The overall level of water intensity is quite low in the chemicals sector and clear patterns within the regions, both in terms of levels and changes over time, are less clear here. What can be seen is that in Northern Europe the contribution of this sector to economic output is generally above the EU average level, but in some countries in Central/Eastern Europe this sector is also economically important, (most notably in Slovenia).

Table 5: Water Intensity (WI) and Output Intensity (YI), Food, Beverages and Tobacco sector

	Water Intensity (1000m3 per million $)			Average	*Output Intensity*			Average
	2000	2005	2009	(2000-2009)	2000	2005	2009	(2000-2009)
Northern	0.056	0.040	0.037	0.044	0.039	0.035	0.034	0.036
Mediterranean	0.030	0.021	0.019	0.023	0.041	**0.047**	**0.043**	0.043
Central/Eastern	**0.364**	**0.298**	**0.248**	0.303	**0.039**	**0.052**	**0.050**	0.047
EU average	0.09	0.06	0.06	0.07	0.041	0.039	0.038	0.039

Note: Figures in bold are those which are above the EU average for this sector.

The food, beverages and tobacco sector generally has a very low level of water intensity in all countries; however, it is above average in most Central/Eastern European countries. For the vast majority of countries, the water intensity of this sector is declining over time, often accompanied by a decreasing level of economic importance. The output intensity of this sector is also generally highest in Central/Eastern Europe. Similar to the agriculture and utilities sectors, an increase in the efficiency with which water is consumed in this sector is particularly notable in Slovakia, although in this case the decline in output intensity is also relatively large.

Looking at the overall patterns of water intensity and output intensity we can conclude the following: In 2009, in all the countries in Central/Eastern EU, the contribution of the agricultural sector to total output is above the EU average of 1.91% and in some countries it is well above the EU average (e.g. Bulgaria: 8.8% and Romania: 9.1%). Our results also show that these countries use water at levels that are higher than can be explained by the relative economic importance of these sectors. In both Mediterranean and Central/Eastern EU countries, water use in the chemicals and chemical products sector is below the EU average. On the other hand, in a number of the Central/Eastern European countries, the electricity, gas and water supply sector consumes water at a level which is above the EU average. Again this may be due the electricity generation mix in these countries, many of which use nuclear and hydro power (European Union, 2012). Finally, with the exception of agricultural sector, in which the water intensity has been significantly reduced between 2000 and 2009, in all the other sectors levels of water intensity have not shown clear patterns of change over this period.

5.2 Subsystem Decomposition of Water Usage

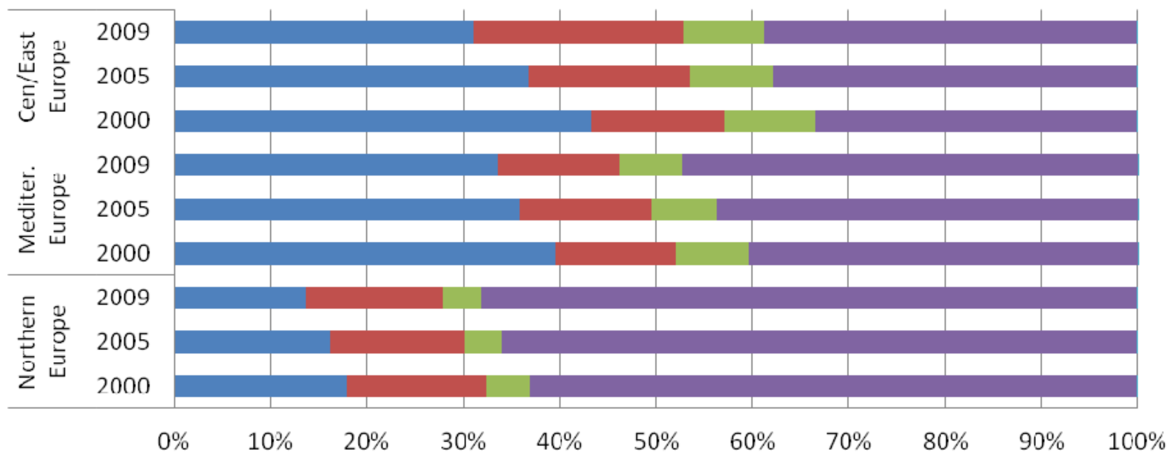
Having examined the general patterns of sectoral water intensity and output intensity in the EU countries, we now run an input-output subsystem decomposition analysis in order to get a better understanding of what is driving water use in the different sectors and countries. The decomposition is run for 2000, 2005 and 2009 to examine what changes, if any, have taken place in the drivers of water use over this decade.

As shown in Table 1, we will focus on the four sectors whose water intensity (expressed as 1000m^3/million$) is above the median level. While Section 5.1 illustrates that some significant changes have taken place in the levels of water intensity, and the relative economic importance of the water-intensive sectors from 2000 to 2005 and from 2005 to 2009, particularly in agriculture, this section shows that in general, the drivers of water usage have remained relatively stable over time.

5.2.1 Agriculture, Hunting, Forestry and Fishing

The average water intensity of this sector decreased in all three regions from 2000 to 2005 and from 2005 to 2009; from 15.1 to 9.8 and then to 9.2 1000m^3 per million$ on average in Northern Europe; from 43.9 to 24.0 and then to 20.0 1000m^3 per million$ in Mediterranean Europe; and from 180.3 to 127.4 to 114.2 1000m^3 per million$ in Central/Eastern Europe. However, in most of the regions there have been few changes in the drivers of water usage, as shown by Figure 1 below.

Figure 1: Decomposition of water use in the Agricultural, Hunting, Forestry & Fishing sector: 2000, 2005 and 2009



	Northern Europe			Mediter. Europe			Cen/East Europe		
	2000	2005	2009	2000	2005	2009	2000	2005	2009
DOMESTIC	17.9%	16.2%	13.6%	39.5%	35.8%	33.7%	43.2%	36.7%	31.1%
EXPORT	14.4%	13.9%	14.3%	12.5%	13.8%	12.5%	13.9%	16.9%	21.7%
INTERNAL	4.6%	4.0%	3.9%	7.5%	6.7%	6.5%	9.5%	8.5%	8.5%
INDUCED	63.0%	65.9%	68.1%	40.4%	43.8%	47.3%	33.2%	37.8%	38.6%
EXTERNAL	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%

Figure 1 shows that in both Central/Eastern and Mediterranean Europe, a large proportion of the water used in the agricultural sector is driven by demand for final produce from this sector; this is due to both domestic and overseas demand for agricultural products. In Northern Europe, however, this sector has a large induced component, indicating that the output of this sector is further processed before being sold onto consumers as final produce. A large induced component reveals that while this sector is a large consumer of water, this consumption is being driven by demand for goods produced by other sectors of the economy.

Turning to the temporal aspect of our analysis, the most notable change in the drivers of water consumption revealed by the decomposition took place in the Central/Eastern EU region. Here the proportion of water used in the agricultural sector which was driven by the demand for exports increased by 3 percentage points from 2000 to 2005, and by a further 4.8 percentage points from 2005 to 2009. In 2005, approximately 17% of the water used in the agricultural sector in this region was due to demand from abroad; this increased to 22% in 2009. This figure is significantly larger than the proportion of water used for exports in this sector in Northern and Mediterranean Europe where the proportions for 2009 were 14.3% and 12.5% respectively - close to their respective values in 2000 and in 2005. The increase in the consumption of water to satisfy the demand for exported agricultural produce in Central/Eastern Europe was accompanied by an almost equal decrease in the consumption of water driven by demand for domestically-consumed agricultural products; indicating that this sector has become increasingly export-orientated over the course of the decade.

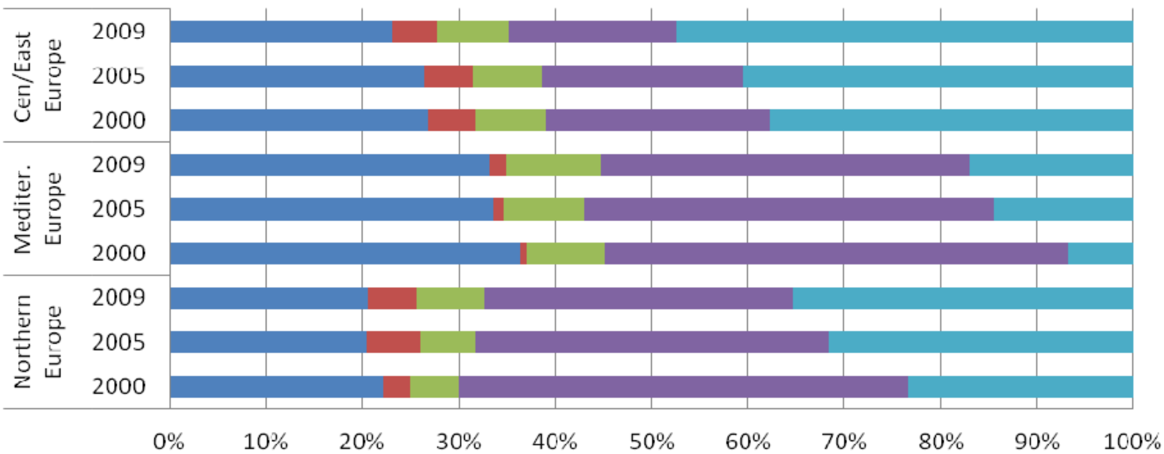
5.2.2 Electricity, Gas and Water Supply

The electricity, gas and water supply sector is the second most water-intensive in all regions. As mentioned in Section 5.1 above, the average water intensity of this sector decreased from 2000 to

2005 and from 2005 to 2009 in Northern and Central/Eastern Europe; from 8.4 to 5.1 to 4.6 1000m^3 per million$ in Northern Europe and from 12.5 to 9.7 to 7.3 1000m^3 per million$ in Central/Eastern Europe. In Mediterranean Europe,[14] on the other hand, while the water intensity of this sector fell from 2000 to 2005 (from 4.3 to 1.9 1000m^3 per million$) it subsequently increased from 1.9 to 2.3 1000m^3 per million$ between 2005 and 2009, which remains low however relative to the other regions.

As Figure 2 below shows, there are some notable differences in the drivers of water usage in this sector in the three broad regions. In Northern and Mediterranean Europe, the induced component is generally the main driver of water usage, followed by the final demand component (i.e. the sum of domestic final demand and exports). The pattern is somewhat different in Central/Eastern Europe where the final demand component is the largest, followed by the induced component.

Figure 2: Decomposition of water use in the Electricity, Gas & Water Supply sector: 2000, 2005 and 2009



	Northern Europe			Mediter. Europe			Cen/East Europe		
	2000	2005	2009	2000	2005	2009	2000	2005	2009
DOMESTIC	22.2%	20.5%	20.6%	36.4%	33.5%	33.1%	26.8%	26.4%	23.0%
EXPORT	2.8%	5.5%	5.0%	0.7%	1.2%	1.8%	5.0%	5.1%	4.7%
INTERNAL	5.0%	5.8%	7.1%	8.0%	8.2%	9.9%	7.2%	7.1%	7.5%
INDUCED	46.7%	36.7%	32.0%	48.2%	42.6%	38.3%	23.3%	20.8%	17.4%
EXTERNAL	23.4%	31.6%	35.3%	6.7%	14.5%	16.9%	37.7%	40.6%	47.4%

Figure 2 shows that in Northern Europe the induced component fell significant over the period of our analysis; by 10 percentage points from 2000 to 2005 and by a further 4.7 percentage points from 2005 to 2009, indicating that this sector is now using less water to satisfy demand for intermediate inputs used in other sectors. This result is also seen in Central/Eastern Europe and Mediterranean Europe, where the induced component fell by 9.9 and 5.9 percentage points respectively over the course of the decade. Furthermore, in Central/Eastern Europe the internal final demand component fell by 3.8 percentage points from 2000 to 2009, while the external component increased by 9.7 percentage points. This shows that in Central/Eastern Europe, the direct water use by this sector is

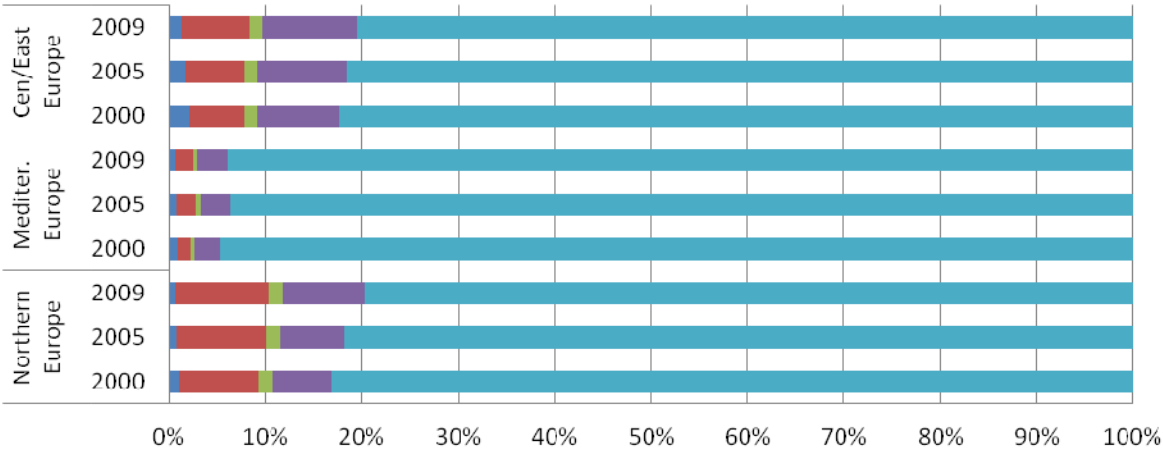
[14] Note that data on water use in the Electricity, Gas and Water Supply sector is incomplete for Malta and Cyprus, and thus these countries are excluded from any analyses of this sector.

falling and it is driving more water use in other sectors. Indeed the external component has increased over time in all regions.

5.2.3 Chemical and Chemical Produce

In this sector the external component dominates, as illustrated by Figure 3. The final demand component is largest in Northern Europe, where much of the water used by this sector is driven by the demand for its output from overseas consumers. Direct consumption of water by this sector is lowest in the Mediterranean region in all years. As can be seen from Figure 3, the drivers of water use in this sector have remained relatively stable from 2000 to 2009.

Figure 3: Decomposition of water use in the Chemicals & Chemical Produce sector: 2000, 2005 and 2009



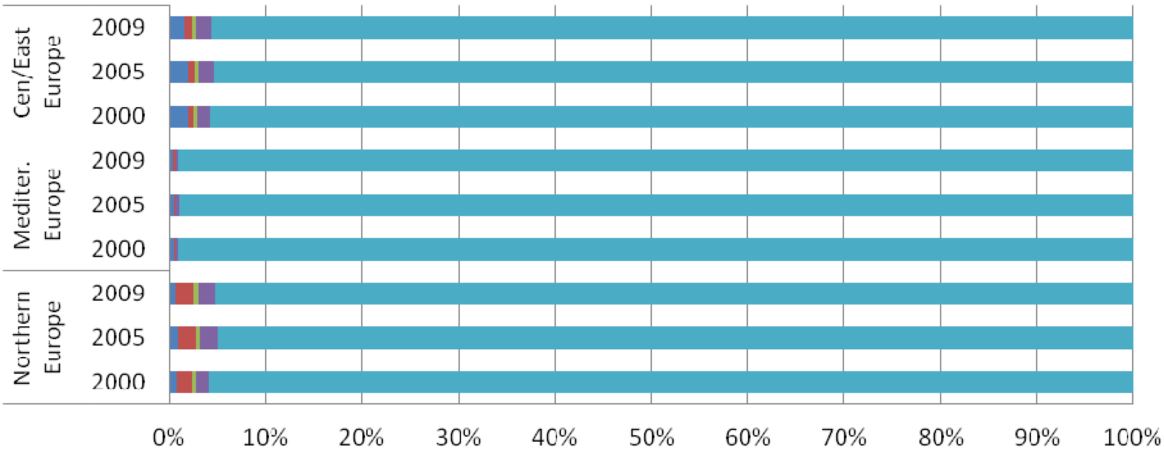
	Northern Europe			Mediter. Europe			Cen/East Europe		
	2000	2005	2009	2000	2005	2009	2000	2005	2009
DOMESTIC	1.1%	0.9%	0.7%	0.9%	0.9%	0.7%	2.1%	1.8%	1.4%
EXPORT	8.1%	9.1%	9.6%	1.4%	1.9%	1.8%	5.7%	6.1%	7.0%
INTERNAL	1.5%	1.5%	1.6%	0.4%	0.5%	0.4%	1.3%	1.3%	1.3%
INDUCED	6.1%	6.6%	8.4%	2.6%	3.1%	3.2%	8.5%	9.3%	9.8%
EXTERNAL	83.2%	81.8%	79.7%	94.7%	93.6%	93.9%	82.3%	81.5%	80.5%

In Northern Europe, the induced component has increased by 2.3 percentage points from 2000 to 2009, indicating that more water is now being used in this sector to satisfy the demand for intermediate goods from other sectors. However, in general the results of the decomposition have changed little over time.

5.2.4 Food, Beverages and Tobacco

This is another sector in which the direct use of water is low relative to the other sectors. The results of the subsystem decomposition reveal that water use is dominated by the external component in all countries and regions, indicating that this sector is large driver of water use, but uses little directly. In general, the food, beverages and tobacco sector is a significant driver of water use in the agricultural sector.

Figure 4: Decomposition of water use in the Food, Beverages & Tobacco sector: 2000, 2005 and 2009



	Northern Europe			Mediter. Europe			Cen/East Europe		
	2000	2005	2009	2000	2005	2009	2000	2005	2009
DOMESTIC	0.9%	0.9%	0.7%	0.4%	0.4%	0.4%	2.0%	2.0%	1.6%
EXPORT	1.5%	1.8%	1.9%	0.1%	0.1%	0.2%	0.5%	0.6%	0.8%
INTERNAL	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.4%	0.4%	0.4%
INDUCED	1.4%	1.9%	1.9%	0.3%	0.4%	0.4%	1.4%	1.6%	1.7%
EXTERNAL	95.8%	94.9%	95.1%	99.0%	98.9%	99.0%	95.7%	95.4%	95.6%

The direct water consumption by this sector is lowest in Mediterranean Europe, but is also very low in the two other regions analysed. Figure 4 shows that the drivers of water consumption have not changed notably from 2000 to 2009.

Conclusions

The Water Framework Directive defines common objectives for water preservation across the European Union. Given this general approach to European water management, a common water policy can only succeed in its objectives if patterns of water use are parallel in all EU countries. Our paper addresses this point. Specifically, we analyse the patterns that explain water consumption in the production system of all EU members, and look at how these patterns have changed over time.

Our results highlight that the most water-intensive sectors in Europe are agriculture; food and beverages; chemical products and electricity, gas and water supply. However, the amount of water used in these sectors varies quite substantially across EU countries. The indicator used also shows different water intensities in the three European regions considered.

The subsystem model shows that for most countries in Northern and Mediterranean Europe, the majority of water used by the electricity, gas and water supply sector is accounted for by the induced component. This shows that while this sector is a large consumer of water resources in these regions, the consumption is largely driven by demand from other sectors for water-intensive inputs. This raises the question of whether water should be charged on the basis of a producer-pays or a consumer-pays principle in these countries.

Our results show that agriculture is the most water-intensive sector in all three regions but the level of water intensity is highest by far in Central/Eastern Europe, followed by Mediterranean European countries. Additionally, the contribution of the agricultural sector to total output differs noticeably between the three regions. In 2000 the contribution of the agricultural sector in Central/Eastern European countries to total output was, on average, 6%; this decreased to 5% in 2005 and to 4% in 2009. The maximum was in Romania where agriculture accounted for 9% of total output in 2000 and 2005, and 7% in 2009. In the Mediterranean countries, agriculture output accounts for, on average, 3.5% of output in 2000 and less than 3% of total output in both 2005 and 2009. The output intensity of agriculture is lowest in Northern Europe, where it is less than 2% in all years.

Our subsystem decomposition shows that the water embedded in agricultural products is mainly driven by demand for inputs into other sectors in Northern Europe, while in Central/Eastern and Mediterranean European countries it is driven by the demand for final goods produced by the agricultural sector. Furthermore, we have shown that there has been an increase in proportion of output produced by the agriculture sector in Central/Eastern Europe driven by demand from abroad, indicating that this sector is becoming more exported orientated. This does however raise the question of who should bear the ultimate responsibility of the water used in the production of agricultural output.

The heterogeneous patterns of water consumption that we have highlighted in our analysis suggest that different policies should be adopted in the various European regions in order to ensure sustainable consumption of water and, more generally, to achieve water savings. In Central/Eastern European countries attention should be given to the domestic consumption of agricultural produce, in order to promote the more responsible use of water in agriculture. In the Mediterranean countries, water tariffs should be adopted to take into account the water scarcity in these regions and to ensure that water is appropriately priced into the export of water-intensive products, which is high in certain Mediterranean countries.

Finally, the inter-temporal aspect of our analysis shows that, with the exception of the agricultural sector, there are no obvious indications that the patterns of water intensity, or the drivers of water use, have changed over time. In the agricultural sector however, there have been some indications of improved efficiency of water use particularly amongst Central/Eastern EU countries; nonetheless, in all years the overall levels of water and output intensity in the agricultural sector in this region remain high.

The results in this paper are extremely useful to the successful definition and implementation of water conservation measures in the European Union. To ensure the efficient consumption of water resources across Europe, the general steps established in the Water Framework Directive should be implemented via specific policies that take into account not only the specific characteristics of the sector of production but also of the country.

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