Tourism Management 40 (2014) 90–101

Contents lists available at SciVerse ScienceDirect

Tourism Management

journal homepage: www.elsevier.com/locate/tourman

The water footprint of tourism in Spain

I. Cazcarro[a,c,*], A.Y. Hoekstra[b], J. Sánchez Chóliz[c]

[a] Department of Economics, School of Humanities and Social Sciences, Rensselaer Polytechnic Institute (RPI), 110 8th Street, Troy, NY 12180, USA
[b] Department of Water Engineering and Management, University of Twente, Enschede, The Netherlands
[c] Department of Economic Analysis, University of Zaragoza, Gran Vía 2, 50005 Zaragoza, Spain

HIGHLIGHTS

- We model the embodied water contents needed to satisfy tourism demands in Spain.
- Global embodied water in Spanish exports per year is 22.834 km^3.
- 19.097 km^3 was due to trade in products, and 3.737 km^3 due to foreign tourism.
- The water footprint (WF) of national tourism is 3.248 km^3.
- VAT of 12% reduces the WF more than a 3.5% tax on lodgings and restaurants.

GRAPHICAL ABSTRACT

ARTICLE INFO

Article history:
Received 6 September 2012
Accepted 22 May 2013

Keywords:
Water footprint
Virtual water
Input–output
Spain

ABSTRACT

This study complements the water footprint (WF) estimations for Spain, incorporating insights of the process analysis and input–output (IO) analysis. We evaluate the virtual (both blue and green consumed) water trade of agricultural and industrial products, but also of services, especially through tourism, for a country in which more than 10% of the gross domestic product (GDP) derives from this activity. We use domestic and import disaggregated tables in the agro-alimentary activities, based mainly on national agrarian, industrial, services and trade statistics. In order to obtain import coefficients, water data and IO tables of the main trade partners are used to reproduce the technology of these economies. Results show that 16% of the Spanish exports are due to foreign tourism, thus the water footprint of foreign tourism in Spain is 3.7 km^3. Finally, we compare reductions in total tourism expenditure and the domestic and global water footprint of tourism using four scenarios.

1. Introduction

As a result of the social and structural changes that have taken place in Spain over the last 30 years (Ramos Carvajal & Robles Teigeiro, 2009), the Spanish economy today includes a significant service sector (generating up to 70% of GDP), to which tourism activities are closely related. The Spanish economy also consists of a declining industrial sector (about 25% of GDP) and a still relevant farm sector (close to 5% of GDP). In a country where crop yields and climatic conditions vary widely from region to region, and where differences between irrigated and dry farming have major social and political implications, changes in production methods, demand patterns, trade and technologies have significant effects, not only on direct demand for water but also on indirect demand. Indeed, such changes also alter the water footprint (WF) and the tourism WF in Spain, defined as the volume of water needed to produce the goods and services consumed by foreign and national tourists.

* Corresponding author. Department of Economics, School of Humanities and Social Sciences, Rensselaer Polytechnic Institute (RPI), 110 8th Street, Troy, NY 12180, USA. Tel.: +1 5182763639, +34 646019737; fax: +34 976761996.
E-mail addresses: icazcarr@unizar.es, cazcai@rpi.edu (I. Cazcarro).

0261-5177/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.tourman.2013.05.010

In order to analyse these issues we make use of a Spanish input–output (IO) table for 2004 with a strong disaggregation of the agro-alimentary and tourism sectors, and of the social accounting matrix (SAM) associated with it. One of the key features of our IO analysis is that it accounts precisely for trade in industrial goods and services and, therefore, allows calculation of virtual water[1] (VW, Allan, 1996) embodied in final demand for end products by activity (e.g. hotels and restaurants). IO models usually distinguish between exports and households, but there is rarely any specific focus on tourism, or any table disaggregating its key water-intensive activities. Cross-border studies of the WF including Spain in the analysis (e.g. Chapagain & Hoekstra, 2004; Hoekstra & Chapagain, 2008) focus on traded VW through detailed analyses of exports and imports, but a specific focus on tourism is lacking. Some studies have addressed the issue of the ecological footprint of tourism or activities related to it (Castellani & Sala, 2012; Hunter & Shaw, 2007; Patterson, Niccolucci, & Bastianoni, 2007; Rendeiro Martin-Cejas & Ramírez Sánchez, 2010), however very few attempts are found to study the WF of tourism (not considered simply as 'impact', but accounting for the direct and indirect sectoral water needs), as in Yang, Hens, Wulf, and Ou (2011) for a concrete region of China, making use of a different methodology to the one presented here.

The estimation of the WF of tourism may not have major implications for the estimation of the WF and VW trade in some countries, but it does for Spain, which plays host to more than 50 million tourists every year. Meanwhile, tourism accounts for more than 10% of Spanish GDP. This paper looks at the water impacts of tourism, focusing specifically on agri-food production processes in order to identify policy implications for improving Spain's tourism-related WF. The relevancy of studying the WF of tourism is stressed by showing that consumption of water through the purchase of goods and services by foreign tourists in Spain cannot be attributed to Spanish citizens, and highlighting that it proves to be important in the total WF. Politically, it can also be argued (as often used as a defence in the argument about taxing foreign tourism) that internalization of social costs does not take place entirely through the price mechanism of goods and services, making the costs of tourist activities especially relevant (Green, Hunter, & Moore, 1990).

In Section 2 below we present the data in a SAM of Spain for 2004 (SAMS04), which is constructed on the basis of the national accounts and Supplementary information from other relevant sources. The SAMS04, which shows a strong disaggregation of the agriculture, livestock, food industry and tourism sectors, is used to examine the impact of tourism in Spain on total domestic water resources and the WF of tourism in Spain. We then describe the IO model used, which is based on the SAMS04, in Section 3, focusing especially on the treatment of imports. Section 4 describes the tourism water footprint and its various components. We give our final conclusions in Section 5.

2. SAM for Spain in 2004 (SAMS04) and water data

In the following two sections we introduce the basic structure of our SAM and explain how the direct and virtual water intensities can be obtained in an IO model. After this we address the question of computing VW in trade and finally we describe how estimations of VW intensities from the IO model are improved through process analysis information.

[1] We refer to 'embodied water' in the goods and services sold to end consumers in each activity, as conventionally referred to in IO analysis. Similarly, the term virtual water is normally used with reference to traded quantities, to mean the water it is necessary to consume (directly or indirectly) to produce the goods and services.

2.1. SAM structure

The point of departure in obtaining the SAM are the Supply and Use Spanish Tables for 2004, elaborated by the Spanish Statistical Institute (NSI, 2011, National Accounts), which results in an initial IO table, symmetric and commodity-by-commodity, through the industry technology hypothesis. The inclusion in this table of information from national accounts and the disaggregation of activities, in accordance with our goals, leads us to a SAM of 120 rows and columns which we call SAMS04. We constructed it for the year 2004 (although recently a new one for Spain appeared for 2006, in Cansino, Cardenete, Ordóñez, & Román, 2012), based on several arguments. The strength and main value of our table is the disaggregation of the agro-alimentary sectors (defined from the main downstream agrarian supply chain), for which a vast amount of data was compiled and reorganized. The year 2004 was also an average one in terms of climatic variables (especially precipitations), greatly affecting the levels of water uses in the country, while being before the economic crisis as well. Also it allowed us to construct the model with reference to the input–output matrices from other countries for that year, as we detail below.

For the applications, the SAMS04 is extended to information by sector of the uses of water. The basic scheme of the SAM is as follows:

$$\begin{bmatrix} \mathbf{X}_{d,PP} & \mathbf{0} & \mathbf{X}_{d,PG} & \mathbf{X}_{d,PS} & \mathbf{X}_{d,PH} & \mathbf{x}_{d,P} \\ \mathbf{X}_{d,FP} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{x}_{d,F} \\ \mathbf{X}_{d,GP} & \mathbf{X}_{d,GF} & \mathbf{X}_{d,GG} & \mathbf{X}_{d,GS} & \mathbf{X}_{d,GH} & \mathbf{x}_{d,G} \\ \mathbf{0} & \mathbf{0} & \mathbf{X}_{d,SG} & \mathbf{0} & \mathbf{X}_{d,SH} & \mathbf{x}_{d,S} \\ \mathbf{X}_{d,HP} & \mathbf{X}_{d,HF} & \mathbf{X}_{d,HG} & \mathbf{X}_{d,HS} & \mathbf{X}_{d,HH} & \mathbf{x}_{d,H} \\ \mathbf{x}_{d,P} & \mathbf{x}_{d,F} & \mathbf{x}_{d,G} & \mathbf{x}_{d,S} & \mathbf{x}_{d,H} & \end{bmatrix} \quad (1)$$

where P is productive sectors; F, factors; G, companies-government; S, saving-investment; and H, households and exports are the block of accounts under consideration. In the previous matrix (1), $\mathbf{X}_{d,IJ}$ represents the sales of accounts I to accounts J. Also, $\mathbf{x}_{d,I}$ is the total uses of accounts I, that is the sum of the columns I. These totals are identical to those of the corresponding rows, since uses and supplies must be equal. See Table S1 in the Supplementary material for further details. In the SAMS04 there are 110 productive sectors, three factors (gross wages and salaries, social security taxes paid by employers and capital), three accounts type G (non-profit institutions serving households, companies and government), one saving-investment account, and three households and exports accounts (households, European Union and rest of the world).

2.2. Disaggregation of the SAMS04

The IO approach often does not incorporate precise physical data on crop and livestock requirements, assuming, for example, that agricultural water use is distributed throughout the production process based on the monetary value of products, and not on the primary water requirements of different crops. The same applies to service activities. This deficiency is particularly acute when we consider the impacts on water uses of tourism, which depend crucially on the activities of accommodation, restaurants and other amenities. We should also consider that agricultural products account for almost 86% of the world's entire direct water consumption. For these reasons the SAMS04, which is available on request, has much more sectoral disaggregation that the Spanish IO table for 2004 used as its basis. It identifies 42 specific groups in the farm sector, plus one fishing and aquaculture account, 25 groups for the food, beverages and tobacco industry, and nine activities in commerce. An early relatively balanced disaggregation of the agri-food system is provided by Titos Moreno, de Haro, Gómez Muñoz, & Ramos Real (1995), which we shall use as a guide.

The process followed to obtain the disaggregation introduces physical and monetary data from different sources (mainly from the National Statistics Institute, NSI, 2011), but the aggregate values directly obtained from the IO table are always preserved. The KRAS-type algorithm is utilized to deal accurately with negatives in the government (taxes) and saving-investment rows and columns (see Lenzen, Gallego, & Wood, 2009). Agri-food activities are largely determined and completed on the basis of data from the Spanish Ministry of Agriculture Agrarian Accountancy Net (MAPA, 2004), in order to obtain both total output for each new agrarian account and the costs of energy, machinery, labour and other inputs.

2.3. Crops data

To identify the costs of goods (crops) in detail, it is necessary to achieve further correspondences between the MAPA tables (see Cazcarro, Duarte, & Sánchez Chóliz, 2010). However, given the difficulty of obtaining a complete matrix in physical terms for the purposes of this study, we exploit the theoretical connection between the physical IO table (PIOT) and the monetary IO Table (MIOT) through prices (see discussions on the link between these types of tables in Dietzenbacher, 2005; Giljum, Hubacek, & Sun, 2004; Suh, 2004; Weisz & Duchin, 2006). Thus, to arrive in monetary units at how much of a 'root' product, for example olives, is sold in the country to obtain a certain 'transformed' product, e.g. olive oil, we use the following expression, $z = xv/fp$, where x is the physical output of the transformed product (not including re-use), f the physical fraction of product obtained from one unit of root product, v the share of value of the transformed product when more than one sub-product is obtained, and p the price of the root product. These concepts and processes are more fully explained in Chapagain and Hoekstra (2004), and data available from that work and FAO (2003b) and USDA (1992).

2.4. Trade data

In order to calculate the trade figures in the SAMS04, we considered technological conditions in the source countries of imports rather than assuming harmonized coefficients. We used IO tables from the OECD (2009) for the main source countries of Spanish imports in 2004, in order to achieve specific coefficients and thus a better estimation of embodied water in industrial and service imports. The tables, converted into euros comprise the period 2003–05 for France, Germany, Portugal, Italy, the United Kingdom, the Netherlands, the USA, Belgium, China and Japan. We also obtained tables for Eastern European countries and representative countries such as Argentina, Brazil (which exports numerous water-intensive agricultural products to Spain), Canada, South Africa and Indonesia among others. Finally, trade data was also acquired from the Spanish Revenue Service (Tariff and Combined Nomenclature 2002–2008, adapted to C.N.A.E. 93).

2.5. Tourism data

Tourism is by nature a multi-sector activity, as tourists purchase numerous goods and services (accommodation, food, travel services, souvenirs and so on), each of which uses inputs from other sectors of the economy. As a consequence, spending in each of the relevant sectors must be considered. The data for 'Purchases by residents outside the economic territory', $\mathbf{g}_d$, and 'Purchases by non-residents in the economic territory', $\mathbf{g}_f$ appear in two separate accounts in the IO framework, and we distribute them to obtain new values for the imports, exports and households column vectors. This was done based on additional data from the Institute of Tourism Studies and the Tourism Satellite Accounts for Spain (TSA) (see Cañada Martínez, 2002, for the methodology; and Tarancón, 2005, as an example of integration with IO models/databases).

The 'Expenditure of tourists by country of residence, period, cost/stay and indicator, series 2004–2011' (NSI, 2011) differentiates between the spending of tourists by country of origin. Data are readily available for most European countries. The spending of other countries' tourists is estimated based on the number of visitors. In the case of tourism from the rest of the world, the largest number of tourists and the highest spending come from the United States.

2.6. Water data

Based on Aquastat data (FAO, 2003a), direct industrial water consumption is extracted for each of the countries considered, while (physical) agricultural water consumption is obtained from the evapotranspiration estimates contained in Hoekstra and Chapagain (2008). Spanish data on water uses at industry level were derived from the National Statistics Institute (NSI), whose Satellite Water Accounts (SWA) are used to trace direct consumption of blue water in every sector. On this basis we can establish the abstraction of water and physical consumption in the Spanish economy and in each of the sectors or accounts. Moreover, we can calculate the values per unit of account, which are the vectors $\mathbf{w}$ of direct use intensity, used later, for both the abstraction of water and the physical consumption.

Agricultural activities are those most relevant in terms of direct consumption, and to obtain specific values of $\mathbf{w}$ we use data from Garrido et al. (2010), where both blue and green water consumption are estimated, making crucial distinctions between provinces and between the water needs of dryland/irrigated crops. However, we are not yet able to account for the green water inherent in forestry activities and therefore undervaluation of the VW contents of products/activities such as the paper industry is likely. Data on animal husbandry consumption of drinking water and for other needs were calculated based on average allocations per day and the number of animals according to the census of the Agrarian Accountancy Net for the year examined.

The SWA allow a further differentiation of the direct physical consumption of industries and services by subactivity, in particular for 'Hotels, bed and breakfasts' and 'Other economic activities'. Moreover, following the methodology of manuals such as Nagy, Lenz, Windhofer, Fürst, and Fribourg-Blanc (2008), we also consider direct coefficients of water use in production and buildings per type/plant/unit/employees (e.g. Hosang & Bischof, 1998; Mutschmann & Stimmelmayr, 2007) and Water Consumption benchmarking. Table 1 shows direct blue and green water consumption.

3. The IO model

From the SAM described in the previous section, and considering as exogenous all the accounts corresponding to foreign trade and households, we construct an IO model. With this model and using water accounts for Spain we define the VW and WF concepts following the methodology used by Sánchez-Chóliz, Bielsa, and Arrojo (1992). What is new in our approach is that we use disaggregated information on farming, the agro-alimentary industry and characteristic tourist activities.

By dividing in (1) the $\mathbf{X}_{d,IJ}$ of the endogenous accounts by their totals $\mathbf{x}_{d,I}$ we define the coefficients of each account, which we represent by $\mathbf{A}_{d,IJ}$ and which lets us obtain the linear IO model associated with the SAMS04:

Table 1
Direct domestic and embodied domestic water uses and intensities.

Classifications – sectors	Blue (& green[a]) water (km^3/yr)	Domestic output (10^6 Mill. €)	Direct domestic water intensity (l/€)[a]	Embodied domestic water intensity (l/€)	Classifications – sectors	Blue Water (km^3/yr)	Domestic output (10^6 Mill. €)	Direct domestic water intensity (l/€)	Embodied domestic water intensity (l/€)
Cereals & leguminous plants	6.17 (6.2)	6.14	1005 (+1015)	2090	Textiles, clothing & fur	0.02	16.88	1.22	23
Vegetables & fruits	4.33 (2.6)	13.39	323 (+196)	537	Manuf. of leather & footwear	0.05	5.89	0.68	39
Industrial crops & woody	3.51 (1.3)	1.70	2061 (+742)	2831	Paper industry	0.07	27.19	2.43	19
Olives	1.18 (2.3)	2.97	399 (+763)	1171	Wood, cork & wood furniture	0.02	9.67	2.18	37
Grape wine	0.45 (0.5)	1.24	363 (+393)	768	Rubber, plastics & oth. manuf.	0.06	31.78	1.89	11
Bovine	0.12	3.67	33.79	563	Construction & engineering	0.02	228.63	0.10	6
Ovine & caprine	0.04	1.73	21.49	283	Recovery & repair	0.00	4.30	0.02	7
Porcine	0.06	4.37	14.68	631	Wholesale of agr. raw materials	0.00	1.64	0.27	43
Poultry	0.02	3.06	5.75	451	Wholesale food	0.01	17.96	0.27	35
Other agrarian & forestry activities	0.81 (0.5)	3.06	266 (+134)	625	Retail trade of fruit & vegetables	0.00	0.55	0.74	6
Fishing & aquaculture	0	2.46	0	229	Retail meat & charcuterie	0.00	1.52	0.22	73
Extraction of energy products	0.05	1.34	39.83	45	Retailing fish	0.00	0.48	0.32	11
Coking, refining & nuclear fuels	0.04	22.18	1.92	3	Other retail food	0.00	2.40	0.36	7
Prod. & distrib. of electricity & gas	0.34	30.88	11.02	18	Retail wine & other beverages	0.00	0.10	0.06	131
Water distribution	0.16	4.38	37.48	42	Trade in hypermarkets	0.00	16.73	0.17	43
Minerals & metals	0.03	0.12	296.00	301	Non-food trade	0.02	109.15	0.16	5
Minerals & non-metallic mineral	0.04	31.49	1.18	6	Restaurants[b]	0.00	16.43	0.09	56
Chemicals	0.01	36.21	0.13	7	Cafés, bars & similar[b]	0.01	63.58	0.10	48
Metallurgy & manufacture of metal	0.07	62.43	1.03	5	Hotels, bed & breakfasts[b]	0.01	12.81	0.89	34
Machinery & equipment	0.01	27.42	0.25	4	Other catering services[b]	0.00	2.89	0.07	22
Manuf. of machinery & equipment	0.00	22.92	0.09	3	Transport & communications[b]	0.02	120.92	0.18	5
Transport equipment	0.02	64.19	0.30	3	Credit & insurance	0.00	55.44	0.01	3
Meat industry	0.02	19.15	0.69	233	Real estate[b]	0.00	103.90	0.03	4
Dairies	0.01	7.76	1.32	200	Private education	0.00	13.89	0.13	9
Industrial oils & greases	0.01	7.27	0.34	640	Private healthcare	0.00	26.03	0.09	9
Ind. vegetables	0.01	3.99	1.53	315	Other services for sale	0.02	151.67	0.15	11
Ind. canned fish	0.01	1.50	1.05	93	Domestic Service	0.00	6.75	0.00	0
Ind. milling	0.00	3.47	0.11	804	Public education	0.00	28.78	0.15	2
Ind. Bread, cakes & biscuits	0.01	7.94	0.93	260	Public health	0.01	36.38	0.16	6
Ind. sugar	0.00	2.30	0.19	741	Public services	0.03	70.13	0.36	6
Cocoa & confectionery industry	0.00	2.18	0.33	219	Gross wages and salaries	0.00	312.84	0.00	0
Ind. feed	0.01	6.55	0.07	803	Social contributions by employers	0.00	89.19	0.00	0
Other food industries	0.01	6.06	0.36	310	Capital factor	0.00	352.12	0.00	2
Ind. alcohols & liquors	0.00	1.60	0.73	63	NPISH	0.00	9.11	0.00	5
Ind. wines & ciders	0.00	4.15	0.54	207	Societies	0.00	284.89	0.00	4
Ind. beer	0.00	2.85	5.88	194	PP. AA.	0.00	505.94	0.00	4
Ind. non-alcoholic beverages	0.01	6.33	3.79	65	Savings/Investment	0.00	188.33	0.00	9
Tobacco industry	0.00	1.32	0.28	85	Households	0.00	769.94	0.10	0.10
					Total Spanish economy	31.46	4128.56	7.62	82.67

(l/€) stands for litres per euro, or which is equivalent, cubic metres (m^3) per 10^3 euros, or km^3 per 10^3 million euros.
Prod.: Production; Distrib.: Distribution; Oth. Manuf.: Other Manufactures; agr.: agrarian.
[a] Quantities of direct green water consumption are in parenthesis. Note that they are smaller than the total quantities if green water from grazing was considered (they are considered only those from the industry of feed).
[b] Typically characteristic tourism activities.
Source: Own elaboration.

$$\begin{bmatrix} \mathbf{x}_{d,P} \\ \mathbf{x}_{d,F} \\ \mathbf{x}_{d,G} \\ \mathbf{x}_{d,S} \end{bmatrix} = \begin{bmatrix} \mathbf{A}_{d,PP} & \mathbf{0} & \mathbf{A}_{d,PG} & \mathbf{A}_{d,PS} \\ \mathbf{A}_{d,FP} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{A}_{d,GP} & \mathbf{A}_{d,GF} & \mathbf{A}_{d,GG} & \mathbf{A}_{d,GS} \\ \mathbf{0} & \mathbf{0} & \mathbf{A}_{d,SG} & \mathbf{0} \end{bmatrix} \begin{bmatrix} \mathbf{x}_{d,P} \\ \mathbf{x}_{d,F} \\ \mathbf{x}_{d,G} \\ \mathbf{x}_{d,S} \end{bmatrix} + \begin{bmatrix} \mathbf{y}_{d,PH} \\ \mathbf{0} \\ \mathbf{y}_{d,GH} \\ \mathbf{y}_{d,SH} \end{bmatrix} \Leftrightarrow \mathbf{x}_d = \mathbf{A}_d\mathbf{x}_d + \mathbf{y}_d \Leftrightarrow \mathbf{x}_d = (\mathbf{I}-\mathbf{A}_d)^{-1}\mathbf{y}_d \qquad (2)$$

$\mathbf{y}_d$ in (2) represents the final demand, i.e. the sum of the columns of the exogenous accounts; $\mathbf{A}_d$ is the domestic matrix of coefficients and $(\mathbf{I}-\mathbf{A}_d)^{-1}$ the matrix of accounting multipliers, a matrix similar to the Leontief inverse.[2]

3.1. Direct and virtual water intensities with an IO model

Building on model (2), to find the embodied water or virtual water contained in a product we first need to determine the vector $\mathbf{w}_d$ of direct uses per unit of endogenous account. This vector can collect the use or the physical consumption (consumptive use), so that embodied water can have different meanings. In the following, we assume that it is physical consumption, i.e. water used less that returned to nature. With (2) and $\mathbf{w}_d$, the virtual water intensities or domestic water values can easily be obtained as:

$$\boldsymbol{\Lambda}'_d = (\lambda_{d,i})' = \mathbf{w}'_d(\mathbf{I}-\mathbf{A}_d)^{-1} \qquad (3)$$

where $\lambda_{d,i}$ is the embodied water in each unit (€) of final demand, capturing all (domestic) water directly and indirectly incorporated per unit (€) of exogenous demand. Hence, if $\mathbf{y}_{d,r}$ is the exogenous column r,

$$\sum_r \boldsymbol{\Lambda}'_d\mathbf{y}_{d,r} = \sum_r \mathbf{w}'_d(\mathbf{I}-\mathbf{A}_d)^{-1}\mathbf{y}_{d,r} \qquad (4)$$

is the total water consumed domestically in the endogenous accounts of the Spanish economy to produce goods to meet exogenous demand (i.e. water directly and indirectly embodied in goods and services).

The domestic productive consumption is only part of the water consumption associated with economic activity in Spain, as households also consume water directly (drinking water and other domestic consumption), and there is also consumption in other countries in the production of Spanish imports. Therefore, if w_{hous} is the direct physical household consumption, $\mathbf{m}_c$ the vector of Spanish imports from country c and $\boldsymbol{\Lambda}_c$ the water value of country c, total consumption attributable to the Spanish final production and to their households will be given by:

$$\sum_r \boldsymbol{\Lambda}'_d\mathbf{y}_{d,r} + \sum_c \boldsymbol{\Lambda}'_c\mathbf{m}_c + w_{hous} = \sum_r \mathbf{w}'_d(\mathbf{I}-\mathbf{A}_d)^{-1}\mathbf{y}_{d,r} + \sum_c \boldsymbol{\Lambda}'_c\mathbf{m}_c + w_{hous} \qquad (5)$$

3.2. Virtual water trade model

As a first approximation of the water embodied in imports, it is common in IO analysis to assume that imported products are made using technologies similar to the local technology, presuming that in (5) every country c verifies $\boldsymbol{\Lambda}_d = \boldsymbol{\Lambda}_c$. This is scenario I (*Autonomous Economies*) described in Lenzen, Pade, and Munksgaard (2004). However, the water embodied in imports is such a key issue that this assumption is probably too simplistic. Consequently, we obtain the imported water for each country using data on their own technologies and on their water consumption, although taking no water rebound into account through exports for each of the countries concerned (Scenario II: *Unidirectional Trade*) and focusing on water contents of goods originating from agriculture and animal husbandry.

Assuming this unidirectional hypothesis, the expressions of the coefficient matrix and of the multipliers matrix for n countries are given by:

$$\mathbf{A} = \begin{bmatrix} \mathbf{A}_{11} & \mathbf{0} & \mathbf{0} & \dots & \mathbf{0} \\ \mathbf{A}_{21} & \mathbf{A}_{22} & \mathbf{0} & \dots & \mathbf{0} \\ \mathbf{A}_{31} & \mathbf{0} & \mathbf{A}_{33} & \dots & \mathbf{0} \\ \dots & \dots & \dots & \dots & \dots \\ \mathbf{A}_{n1} & \mathbf{0} & \mathbf{0} & \dots & \mathbf{A}_{nn} \end{bmatrix} \qquad (6)$$

$$(\mathbf{I}-\mathbf{A})^{-1} = \begin{bmatrix} (\mathbf{I}-\mathbf{A}_{11})^{-1} & \mathbf{0} & \mathbf{0} & \dots & \mathbf{0} \\ (\mathbf{I}-\mathbf{A}_{22})^{-1}\mathbf{A}_{21}(\mathbf{I}-\mathbf{A}_{11})^{-1} & (\mathbf{I}-\mathbf{A}_{22})^{-1} & \mathbf{0} & \dots & \mathbf{0} \\ (\mathbf{I}-\mathbf{A}_{33})^{-1}\mathbf{A}_{31}(\mathbf{I}-\mathbf{A}_{11})^{-1} & \mathbf{0} & (\mathbf{I}-\mathbf{A}_{33})^{-1} & \dots & \mathbf{0} \\ \dots & \dots & \dots & \dots & \dots \\ (\mathbf{I}-\mathbf{A}_{nn})^{-1}\mathbf{A}_{n1}(\mathbf{I}-\mathbf{A}_{11})^{-1} & \mathbf{0} & \mathbf{0} & \dots & (\mathbf{I}-\mathbf{A}_{nn})^{-1} \end{bmatrix} \qquad (7)$$

where $\mathbf{A}_{cc}$ is the matrix of technical coefficients for country (or group of countries) c, $c = 1$ Spain and $\mathbf{A}_{c1}$ the Spanish import coefficients matrix from c.

Then, if $\mathbf{w}'_1$ are the Spanish direct water coefficients, $\mathbf{w}'_{\substack{c \\ c\neq 1}}$ those of the other countries, $\mathbf{y}_{d,1}$ the Spanish domestic demand and $\mathbf{y}_{\substack{m,c \\ c\neq 1}}$ their imported final demands, proceeding as in (4) we have the following expression of total embodied water in Spanish final demand:

[2] We know that from an economic point of view the basic relation of Equation (2), i.e. $\mathbf{x} = (\mathbf{I}-\mathbf{A}_d)^{-1}\mathbf{y}$, needs to have a unique and positive solution. This will be so if $(\mathbf{I}-\mathbf{A}_d)^{-1}$ exists and is semi-positive, i.e. $(\mathbf{I}-\mathbf{A}_d)^{-1} \geq 0$. It is well known, see for example Duchin and Steenge (2009), that if $\mathbf{A}_d$ is a non-negative $n \times n$ matrix, $(\mathbf{I}-\mathbf{A}_d)^{-1}$ exists and is semi-positive if and only if its dominant eigenvalue λ (the so-called Frobenius root) is positive and less than unit, i.e. $0 < \lambda < 1$. In general, $\mathbf{A}_d$ is generally estimated empirically from an input–output table for a particular year, being a non-negative matrix. Thus, what we need to check is whether the Frobenius root of matrix $\mathbf{A}_d$ is positive and less than unit. We can use, for example, the Brauer-Solow conditions that assert that if all column sums or all row sums of the elements of the matrix $\mathbf{A}_d$ are less than unit, then $0 < \lambda < 1$. In the case of our database, in spite of the existence of a few negative values in the row of public administrations (and in most input–output ones obtained empirically) it does indeed comply with the condition $|\mathbf{I}-\mathbf{A}_d| \neq 0$ to have such inverse. Moreover, it verifies $(\mathbf{I}-\mathbf{A}_d)^{-1} \geq 0$.

$$\mathbf{w}_1'(\mathbf{I}-\mathbf{A}_{11})^{-1}\mathbf{y}_{d,1}+\sum_c \mathbf{w}_c'(\mathbf{I}-\mathbf{A}_{cc})^{-1}\mathbf{A}_{c1}(\mathbf{I}-\mathbf{A}_{11})^{-1}\mathbf{y}_{d,1} + \sum_c \mathbf{w}_c'(\mathbf{I}-\mathbf{A}_{cc})^{-1}\mathbf{y}_{m,c}+w_{hous} \quad (8)$$

In this the first and fourth addend coincide with the first and third of (5), and the sum of the second and third capture more precisely the same as the second of (5).

However, (8) is not sufficient if we wish to work with differently sized tables. The OECD tables used to obtain the $\mathbf{A}_{cc}$ of other countries have 48 productive sectors, while the $\mathbf{A}_{11}$ and $\mathbf{A}_{c1}$ obtained from SAMS04 have 110 productive sectors and 117 endogenous accounts. Therefore it is clear that we have to modify (8) by introducing for each country c an $\mathbf{R}_c$, or correspondence matrix between the classifications of activities or accounts in country c and the Spanish ones, as follows:

$$\mathbf{w}_1'(\mathbf{I}-\mathbf{A}_{11})^{-1}\mathbf{y}_{d,1}+\sum_c \mathbf{w}_c'(\mathbf{I}-\mathbf{A}_{cc})^{-1}\mathbf{R}_c\mathbf{A}_{c1}(\mathbf{I}-\mathbf{A}_{11})^{-1}\mathbf{y}_{d,1} + \sum_c \mathbf{w}_c'(\mathbf{I}-\mathbf{A}_{cc})^{-1}\mathbf{R}_c\mathbf{y}_{m,c}+w_{hous} \quad (9)$$

3.3. Detailed water intensities of imports

$\mathbf{R}_c$ in (9) is an activity bridge matrix, but its meaning can be better explained by observing that $\mathbf{R}_c$ transforms the foreign water multipliers $\mathbf{\Lambda}_c' = (\lambda_{c,i^*})' = \mathbf{w}_c'(\mathbf{I}-\mathbf{A}_{cc})^{-1}$ into Spanish water import multipliers $\overline{\mathbf{\Lambda}}_c' = (\overline{\lambda}_{c,i})' = \mathbf{w}_c'(\mathbf{I}-\mathbf{A}_{cc})^{-1}\mathbf{R}_c = \left(\sum_{i^*}\lambda_{c,i^*}r_{c,i^*,i}\right)$ associated with the column vectors of imports $\mathbf{A}_{c1}(\mathbf{I}-\mathbf{A}_{11})^{-1}\mathbf{y}_{d,1}$ and $\mathbf{y}_{m,c}$. Moreover, the introduction of $\mathbf{R}_c$ in (9) should not alter the valuations in water of imports. Let us see how this works.

The most challenging case is when an i^* needs to be broken down into various $i(i^*)$,[3] which basically occurs in the disaggregated agri-food activities. Several alternatives could be applied. One option would be to use the same intensity for the various i (i.e. $r_{c,i^*,i(i^*)} = 1$ and $\overline{\lambda}_{c,i(i^*)} = \lambda_{c,i^*}$), thereby preserving the water balance, as in $\lambda_{c,i^*}m_{c,i^*} = \lambda_{c,i^*}\left[\sum_{i(i^*)} m_{c,i^*,i}\right] = \sum_{i(i^*)}\overline{\lambda}_{c,i}m_{c,i^*,i}$. However, this option would not distinguish between the water intensities of different crops. To solve this problem, we normalise the intensity of the country of origin by using the VW export content of food products i^{**} (there are 414) from country c estimated in Chapagain and Hoekstra (2004), to $VWE_{c,i^{**}}$ (in m^3/ton). If $i^{**}(i)$ is the i^{**} associated with an i, and $m_{c,i^{**},i}$ is the import of i^{**} which is part of import i, then

$$r_{c,i^*,i} = \frac{\sum_{i^{**}(i)} VWE_{c,i^{**},i}\times m_{c,i^{**},i}}{m_{c,i^*,i}} \Bigg/ \frac{\sum_{i^{**}} VWE_{c,i^{**},i}m_{c,i^{**},i}}{m_{c,i^*}} \quad (10)$$

for every i. Once again the water balance is preserved, as $\sum_i \lambda_{c,i^*}r_{c,i^*,i}m_{c,i^*,i} = \lambda_{c,i^*}m_{c,i^*}$ is satisfied for every i^*.

[3] There are two other cases. When i^* and i accounts match, there is one row vector $\mathbf{r}_{c,i^*}'$ for each i^*, with $r_{c,i^*,i=i^*} = 1$ and $r_{c,i^*,i\neq i^*} = 0$. In the case of l accounts i^* leading to i, there would be l non-zero elements in the corresponding column vector $\mathbf{r}_{c,i}$ of $\mathbf{R}_c$ with $r_{c,i^*,i} = m_{c,i^*,i}\Big/\sum_{i^*} m_{c,i^*,i}$, where $m_{c,i^*,i}$ is the value of import i included in import i^* from c. Since the value of imports of type i verifies $m_{c,i} = \sum_{i^*} m_{c,i^*,i}$ the water balance is maintained with the new coefficients: $\sum_{i^*}\lambda_{c,i^*}m_{c,i^*,i} = \left[\sum_{i^*}\lambda_{c,i^*}r_{c,i^*,i}\right]\left[\sum_{i^*}m_{c,i^*,i}\right] = \overline{\lambda}_{c,i}m_{c,i}$.

3.4. Water footprint of foreign tourism

Based on (9), the WF of foreign tourism is estimated by identifying the purchases by non-residents in the host economy (which are in fact exports, and therefore a part of final demand). If $\mathbf{y}_{d,ftour,1}$ is the domestic final demand of foreign tourism and $\mathbf{y}_{m,ftour,1}$ the subset of final foreign tourism-related demand for imported products, the complete foreign tourism WF equation is:

$$WF_{ftour} = \mathbf{w}_1'(\mathbf{I}-\mathbf{A}_{11})^{-1}\mathbf{y}_{d,ftour,1} + \sum_c \mathbf{w}_c'(\mathbf{I}-\mathbf{A}_{cc})^{-1}\mathbf{R}_c\mathbf{A}_{c1}(\mathbf{I}-\mathbf{A}_{11})^{-1}\mathbf{y}_{d,ftour,1} + \sum_c \mathbf{w}_c'(\mathbf{I}-\mathbf{A}_{cc})^{-1}\mathbf{R}_c\mathbf{y}_{m,ftour,c}+w_{hous,ftour} \quad (11)$$

Since w_{hous} is the direct consumption of water in households, here $w_{hous,ftour}$ refers to the small part of consumption by tourists staying in private houses, which we have roughly estimated at 0.001 km^3 based on the survey of tourist occupancy of apartments and household water consumption. By substituting *ftour* (foreign tourism) by *ntour* (domestic tourism) in every possible place in Equation (11), we obtain the equation for the WF of Spanish tourists within the country, which is as follows:

$$WF_{ntour} = \mathbf{w}_1'(\mathbf{I}-\mathbf{A}_{11})^{-1}\mathbf{y}_{d,ntour,1} + \sum_c \mathbf{w}_c'(\mathbf{I}-\mathbf{A}_{cc})^{-1}\mathbf{R}_c\mathbf{A}_{c1}(\mathbf{I}-\mathbf{A}_{11})^{-1}\mathbf{y}_{d,ntour,1} + \sum_c \mathbf{w}_c'(\mathbf{I}-\mathbf{A}_{cc})^{-1}\mathbf{R}_c\mathbf{y}_{m,ntour,c}+w_{hous,ntour} \quad (12)$$

4. Results

4.1. Spanish water footprint

In Fig. 1 an overview of the water footprint (WF) accounting scheme of the country is presented. The domestic water consumption of 31.5 km^3/year is shown as WC. Vi is the water import, estimated as 46.5 km^3/year, of which more than 60% originated in a country outside the European Union, mainly due to primary and transformed agrarian products. Ve, the virtual water export (i.e. the embodied water in exported products and services) is estimated as 22.8 km^3, which comes from water of domestic origin (Ve,d) and re-exported water of foreign origin. Thus Spain is a net virtual water importer. This condition is not necessarily determined by its climatic water situation, since several water-rich countries such as Japan and Indonesia, and also Portugal, which is a close trading partner, are also high net virtual water importers, as shown by Kumar and Singh (2005). In Fig. 1 we can see that the Spanish WF results in 55.1 km^3/year, which is composed by 32.9 km^3/year of what has been called external WF (WFe), and 22.2 km^3/year of internal WF (WFi).

For reasons of space, we classify the 37 agricultural activities in five groups in Table 1, and the 25 food sector activities in 16 groups. More detailed information is available upon request. The third column shows the direct intensities ($\mathbf{w}_1'$, in m^3/thousand euros or in litres/euro) obtained by dividing the first column by the second one. The fourth column shows the domestic water multipliers $\mathbf{w}_1'(\mathbf{I}-\mathbf{A}_{11})^{-1}$, again in litres/euro. The highest multipliers are those for Industrial crops and timber, representing 2831 litres per euro of final demand, and Cereals and leguminous plants, 2090 litres/euro of final demand. However, the largest differences between direct and embodied intensities are found in the block of Food, beverages and tobacco. Finally, endogenous accounts such as Gross wages and salaries or Capital factor, which are highly relevant in monetary terms, have a very low multipliers because they play a clear role as bridging accounts in the model and are not presented as final but as intermediate users (i.e. they end up as payments for goods and services, or as investments).

We may also draw an analogy between the Saving and investment account and the Credit and insurance account; and between NPISH, Societies, and Construction and engineering, which also have low direct and embodied water intensities. Interestingly, the intermediate role of these accounts is also apparent if we apply structural path analysis (SPA, see Crama, Defourny, & Gazon, 1984; Defourny & Thorbecke, 1984) to examine the paths through which the largest amounts flow through the economy, as accounts such as Gross wages and salaries, Capital and Government frequently connect water-relevant chains.

4.2. Water footprint of tourism

Tourism affects the Spanish water footprint through the characteristic tourist activities and their purchases. This generates both direct and indirect uses. The analysis also allows us to take into account the importance of water embodied in imports destined for tourism, which in the end are re-exported.

If we look at the six characteristic tourism sectors of Table 1, all have very low direct uses, with intensities of less than a litre per euro. Except for Hotels, bed and breakfasts which have an intensity of about 0.9 litres per euro, all the others are below 0.2 litres per euro. In contrast, the ratio between embodied domestic water and water uses is very high in all six, being always above 20 (Transport and communications and Hotels, bed and breakfasts have the lowest ratios) and exceeding 600 in Restaurants and 450 in Cafés, bars and similar. The virtual or embodied water per euro of expenditure in these characteristic tourism activities reaches the maximum values for Restaurants, Cafés, bars and similar, Hotels, bed and breakfast (which includes other holiday accommodation), but these are in turn lower than the majority of total water intensities in agricultural agrarian and food sector activities. We can also see that the embodied water per euro is lower in the hotel activities than in Restaurants and Café, bars and similar, even if the direct water consumption per euro of production of the hotels activities is much higher, due to the accounting of all supply chains (see Supplementary material for a partial approximation to examining the supply chains behind that result). In general then, what occurs is that the final demand on goods provided by the Restaurants and bars, notably (high virtual water intense) food and drinks embodies more water than the goods and services provided by the hotel activities. In truth the hotel activities have, as stressed above, high direct water consumption intensities (due to washing machines, cleaning, water use by the guests, sometimes swimming pools, even golf courses, etc.), and also need inputs of food and drinks, as well as a moderately high virtual water intense product such as the distribution of electricity and gas,[4] but they buy much less food and drink per euro of output and more from less virtual water intense sectors such as Real estate, Other services for sale, Construction and engineering or Transport and communications.

In Table 2 we see that the estimated water embodied in Spanish exports is 22.834 km^3 per year. This can be further broken down into 19.097 km^3 attributable to trade in goods and 3.737 km^3 to non-residents. Thus, the WF of foreign tourism in Spain given by Equation (11) is 3.737 km^3. Tourism-related exports represent 16% of the trade in goods, although this percentage is higher for some countries, in particular the United Kingdom.

These figures also include the VW contents of imports acquired for further transformation and re-export, since domestic and import water coefficients are used. Thus the above estimate does not mean that foreign tourists in Spain consume 3.737 km^3 of Spanish water resources. To calculate the consumption, we need to focus only on the first term of Equation (11), which is 1.570 km^3 of blue and green water consumption, the water used in Spain in productive activities to obtain the domestic demand of tourists. The second term, i.e. foreign water entering Spanish domestic processes that goes to meet domestic tourist demand, totals 1.598 km^3, while 0.569 km^3 of imported water is exported through tourism buying and finally 0.001 km^3 of water is directly consumed by tourists (drinking water, cleanliness, etc.).

4.3. Foreign versus domestic tourism

While tourism in Spain is thought of primarily as foreigners who visit the country, the scale of national tourism is so large that we cannot forget it when quantifying the Tourism WF. Based on Equations (11) and (12), we can distinguish between and compare the effects of Spanish tourists and foreign tourists. Table 3 compares the water footprints of foreign and domestic tourism in wide groups of activities, reflecting the different water impacts arising from dissimilarities in spending patterns. In this table we can see that water consumption necessary to satisfy demand from both resident and non-resident tourists is 6.985 km^3, 3.248 km^3 being the water footprint of Spanish tourists and 3.737 km^3 that of the foreigners. We found this same figure in Table 2.

We can see in Table 3 that the direct goods and services typical of tourism (CH sectors), Restaurants, coffee shops and bars, Hotels, bed and breakfasts, Real estate, Transport and communications, and leisure services, which account for about 76.8% of total spending, only consume 3.322 km^3/yr, less than 50% of the total tourism WF, with the rest attributable to activities that are not typical of tourism (NCH sectors), especially to food, with 2.567 km^3/yr. Indeed, two sectors in Table 2, food and Restaurants, coffee shops and bars, together make up 4.662 km^3/yr, which is 66.74% of the total tourism WF.

If we look at the total WF for national and for foreign tourism, although the two figures are not very different, its composition is. Regarding the goods and services characteristic of tourism, foreign holidaymakers spend a higher percentage on hotel activities than Spanish tourists (20.3% against 12.8%, which implies that its contribution to the tourist WF is 0.425 km^3 and 0.269 km^3 respectively) and on Transport and communications, with 17.6% against 15.2% and a contribution to the WF of 0.182 km^3 and 0.156 km^3. Foreign tourists spend a similar percentage to national tourists on Restaurants, coffee shops and bars, but a smaller one on leisure services and especially on Real estate, where the percentage is 4.7%–19.3%. Of the nine non-characteristic groups of goods and services shown in Table 3, in five the weight of foreign tourism is greater and in three it is similar. Other commerce and especially food stand out. Table 3 shows that the final goods for food, although they account for only 6% of spending by foreign tourists and 4.8% by nationals, represent a greater volume of virtual water, with their contribution to the WF of 1.411 km^3 and 1.156 km^3 respectively, due to the high water value of these assets. Although expenditure does not reach 10% in either case, the share of the tourism WF is approximately one third for both.

4.4. Policy implications of the tourism water footprint

Nowadays, when most of us defend the need for a sustainable economy, there is a strong consensus that water issues, in particular the water consumed by services and tourism activities, also are the

[4] Relevant volumes of water in the final production of the hotels activity also come directly or indirectly from the sector of Construction and engineering, Other services for sale, or Metallurgy and manufacture of metal products; see Table S2 in the Supplementary material for further details.

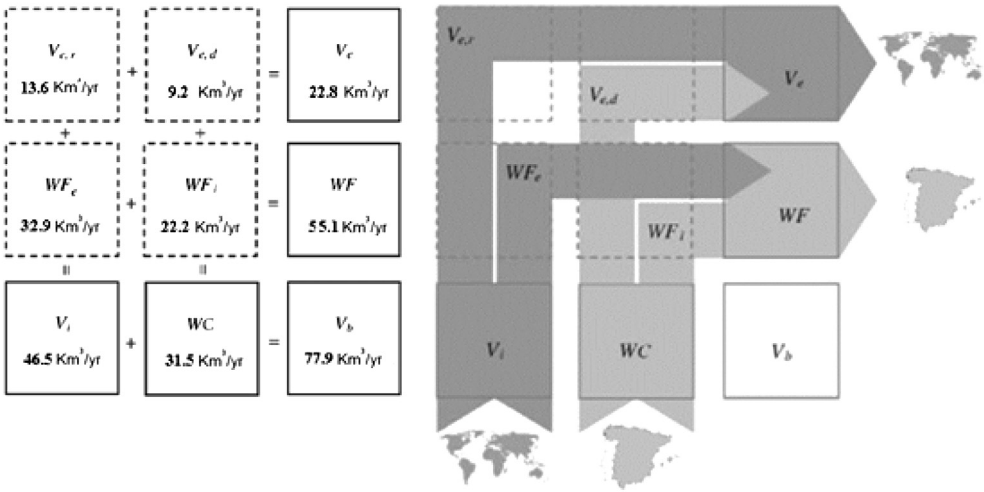

Fig. 1. Spanish water footprint accounting scheme, showing the balances related to national consumption (WF cons, nat), the total virtual water export (Ve), virtual water import (Vi), etc. Source: Own figures for Spain, after the figure of the water footprint accounting scheme by Van Oel et al. (2009).

responsibility of political authorities and society in general. The 3.737 km^3/yr of the foreign tourist WF is the equivalent of annual urban/household direct use (total embodied use is much greater, especially through agriculture) for a population of over 63 million people, assuming the standard of 160 litres per day per person usual in Spain. If we add that the foreign tourist WF represents, valued in water, 16% of water embodied in exports, there is probably little doubt that the Spanish tourism WF has serious economic and political implications. In the difficult task of contextualizing these results, due to the scarcity of studies on WF of tourism, with respect to results in countries or regions with similar climatic characteristics to Spain, we would only expect similar absolute numbers in the Mediterranean regions of France and Italy, based on the volume of visitors and expenditure.[5]

The policy relevance is even greater if we highlight the different impact of tourists (higher) and citizens, and if we add the characteristics of spatial (except in Northern Spain, the climate is arid) and temporal concentration of these demands. See Cazcarro, Duarte, and Sánchez Chóliz (2013), where it is shown that in Spain interregional flows are very intense, moving large volumes of water (virtual water) from the arid to the most industrialized areas.

Since the beginning of the development of Spanish tourism in the 1960s, concern over the needs for water has been real, given that strong industry and quality services could hardly be developed without the guarantee of water. The supply of water through new infrastructure mainly tried to cover the growing needs of the population, industry and agriculture. However, works such as the Ebro to Tarragona Field, which opened in 1989, were basically determined by the needs of the tourist Catalonian 'Costa Dorada' ('Golden Coast'). Moreover, this transfer has allowed the expansion of recent developments in the area and the development of theme parks such as 'Port Aventura'. Some of the desalination plants in the Balearic and Canary islands and on the Mediterranean Coast had a similar objective, although in most cases agricultural demand was also decisive in their construction. Perhaps the high point of this phase of supply policy was the projected but unrealized transfer (by diversion or shipping) of more than 1000 hm^3/yr from the River Ebro to Almeria in southern Spain, which would have meant a guaranteed supply of water to hundreds of developments and resorts on the Mediterranean coast. The high cost and environmental impact (for both water and energy) made it unfeasible.

The decline of the supply policy, to a large extent due to water scarcity, caused a step change in water policies, with demand management and a reduction in the supply policies being placed at the heart of water planning in the last two decades. The dissemination of good practices and technological change have been its main pillars.

In recent years an attempt is being made in hotels to reduce direct water consumption. Dual-flush toilets, towel reuse, non-renewal of pool water and many other measures have actually been implemented and have been relatively effective. No doubt these best practices have been helped by the increase in the price of water by municipalities, which needed to cover the real costs of supply.

However, we must not forget that these kind of savings affect only part of the tourism WF, specifically the direct consumption, which as seen in Table 1 was well below that of embodied water (in Hotels, bed and breakfasts the direct use was 0.89 l/€, while the embodied water was 34 l/€). Consequently, the real water savings must come from the tourism industry reducing inputs (or their water intensities) used directly or indirectly for the production of tourist goods and services. We have seen, in Table 3, how the sectors food and Restaurants, Coffee shops and bars represent 66.74% of the total tourism WF, largely due to the importance of Food, beverages and related products. Therefore, the great water-saving policy of tourism must be to increase the efficiency of agricultural uses, the main direct consumer of water in Spain. And to achieve that, the two main routes are the modernization of Spanish agriculture and the modernization of irrigation. Neither is considered a tourism policy, but its effects on the WF of tourism are very important.

Certainly technological improvement in the rest of the processes, which supply goods to tourists, will also improve the WF by saving inputs and thus water, but the effects will be much smaller than those due to savings in agriculture. Information on the production chains, which can be found in the Supplementary material, can help to assess the true effect of each change. Whatever the route used to reduce the tourism WF, (over) dimensioning of the

[5] We do not attempt to make a guess at the different behaviour in other countries of consumption by tourists in contrast to Spain or the local citizens, which depends on issues such as the whole supply structure, local traditions and diets, as well as the composition of the countries of origin of the tourists. Some hints can be found since the WF per capita of Spanish citizens has already been estimated as one of the highest across the globe (in part because of a rich meat diet, similar to Greece and Italy), and clearly higher than that of Egypt, Algeria, Germany or France.

Table 2
Virtual water export (or embodied water in exported goods and services) through trade and foreign tourism (km^3/yr).

Classifications – sectors	Embodied water in exports because of traded goods and services (km^3/yr)	Embodied water in exports because of foreign tourism (km^3/yr)	Total embodied water in exports (km^3/yr)
Belgium	0.634	0.119	0.753
Germany	2.129	0.713	2.842
France	3.859	0.308	4.167
United Kingdom	1.377	1.133	2.510
Italy	2.551	0.189	2.740
the Netherlands	0.830	0.145	0.975
Portugal	2.364	0.065	2.429
Other European Union countries	1.005	0.579	1.584
Total European Union	**14.751**	**3.252**	**18.003**
United States	0.663	0.135	0.798
Other rest of the world countries	3.682	0.350	4.032
Total rest of the world	**4.346**	**0.485**	**4.831**
Total B & G W.[a] (Equation (11))	**19.097**	**3.737**	**22.834**
B & G W.[a] Equation (11). 1st term	**9.692**	**1.570**	**11.262**
B & G W. Equation (11). 2nd term	**9.405**	**1.598**	**11.003**
B & G W. Equation (11). 3rd term (EU)	**0**	**0.449**	**0.449**
B & G W. Equation (11). 3rd term (RW)	**0**	**0.120**	**0.120**
B & G W. Equation (11). 4th term	**0**	**0.001**	**0.001**

[a] B & G W.: Blue and green water.
Source: Own Elaboration.

water infrastructures and services to satisfy tourists' seasonal needs, good business practices or measures to improve the efficiency of irrigation or water uses, each has associated costs and requires the collaboration of those affected, in this case the tourists as well. This deeply concerns economists, who often envisage using the following ways to move forward in the right direction: use of economic incentives and pricing to encourage water conservation (Gössling et al., 2012), taxing foreign tourism (Pazienza, 2011) or relying on the altruism of people.

Incentive policies (sometimes in the form of a good public image) and higher water prices have been used in Spain to promote good practice, to cover supply costs following the recommendations of the Water Framework Directive of the EU and to promote agricultural modernization. The results have generally been positive, but their efficiency levels have been mixed, perhaps because of poor implementation.

Indirect tourism taxes can be justified on the grounds of covering the conventional costs of public services, internalizing external costs or avoiding overcrowding and environmental degradation. The latter has been the main justification for the recent tourism taxes in the Balearic Islands and Catalonia.[6] We should not forget that these policy measures have to be considered while understanding their limitations, since the link between changes such taxes and water damage would be somewhat vague. Any environmental tax needs to have a clear relationship with a specific environmental problem if it is to show that it is intended to penalize the negative effects. For example, the hotel accommodation tax implemented by the Balearic government in 2002 would fail in this respect, because the hotel itself is not the only source of the water footprint. Moreover, when considering these taxes the possible negative impact, for instance on income, should not be forgotten.

Finally, altruism can also be critical in implementing measures that will lead to reducing the WF, which can be used as an educational tool to help tourists understand the real dimensions of their impact and encourage them to become 'water-neutral'. Consider for instance that it could be argued that the above examples of taxation are justified because they cover at least part of the impact on domestic resources.[7] In the literature on footprinting, the voluntary purchase of water-neutral certificates has been proposed. An example of such an initiative was taken by the Water Neutral Foundation in South Africa, which included the water-neutral concept as a central element in an awareness and conservation campaign targeted at individuals, corporations and other organizations keen to contribute towards more sustainable and equitable water use in South Africa, portrayed as quenching the thirst of Africans who currently do not have access to clean drinking water.

To conclude these reflections we may recall a fundamental property of the global water footprint: since both the direct and the indirect supply chains and impacts are considered, the WF reveals that a local approach might not be sufficient and that a more ambitious and global dimension is necessary for correct water governance. Moreover, in our understanding, together with information gathered on positive effects in terms of employment or income for a host community, indicators such as the EF or the WF (both for domestic and global resources) could be used as a tool to benchmark and measure tourism progress, weighting decisions on tourist attraction and types of services offered in a more comprehensive manner.

5. Final comments

The water footprint (WF) and virtual water (VW) concepts have become popular during the last decade, although in some studies (e.g. Wichelns, 2011) they have been accused of being of little policy relevance (especially for humid countries). Indeed, water is one of many inputs in production, but other strategic and economic

[6] As an example of tourist eco-taxes, that on accommodation brought in by the Balearic government in 2002, ranging from 0.25 to 2 euros per person per day depending on the quality of the establishment, aimed to raise funds to ensure the environmental sustainability of the islands. Also, in late 2012 the Catalan government planned to charge 2.5 euros per passenger on any cruise ship entering a Catalan port.

[7] For example, a foreign tourist in Spain spends on average €681 and consumes 69.7 m^3 of VW, which means to a consumption of 102 litres per euro spent. If a tax of 3.5% on accommodation is viewed as payment for global VW, the tourist would be paying 7.5 cents per m^3 of total VW or a cent per euro spent. However, if understood as payment for domestic VW, the tourist would be paying 16.3 cents per m^3 of domestic green and blue water.

Table 3
Water footprint of foreign tourism (exports) and national tourism expenditures, by activity, through which consumers obtain the embodied water in products and services.

[a]	Classifications – sectors	Foreign tourism in Spain		National tourism in Spain		Total tourism in Spain	
		% of expenditure	Water footprint (km^3/yr)	% of expenditure	Water footprint (km^3/yr)	% of expenditure	Water footprint (km^3/yr)
NCH	Food	6.0%	1.411	4.8%	1.156	5.3%	2.567
NCH	Energy, water, silviculture and extractives	2.1%	0.059	1.5%	0.042	1.9%	0.101
NCH	Consumption goods	3.5%	0.384	1.8%	0.195	2.5%	0.579
NCH	Rest of industry	0.5%	0.017	0.5%	0.018	0.5%	0.035
NCH	Construction	0.1%	0.001	0.1%	0.000	0.1%	0.001
NCH	Wholesale of agricultural raw materials and food	0.4%	0.051	3.5%	0.158	3.0%	0.209
NCH	Other commerce	7.4%	0.083	3.3%	0.033	3.6%	0.116
CH	Restaurants, coffee shops, bars	28.0%	1.043	28.2%	1.052	28.1%	2.095
CH	Hotels, bed and breakfasts	20.3%	0.425	12.8%	0.269	16.9%	0.694
CH	Real estate	4.7%	0.026	19.3%	0.110	12.5%	0.136
CH	Transport and communications[b]	17.6%	0.182	15.2%	0.156	16.5%	0.338
CH	Leisure services (cultural, recreational, sport, etc.)	2.5%	0.027	2.9%	0.032	2.8%	0.059
NCH	Financial services	6.0%	0.023	5.5%	0.022	5.6%	0.045
NCH	Public services	0.7%	0.003	0.7%	0.004	0.7%	0.007
	Total	**100%**	**3.737**	**100%**	**3.248**	**100.0%**	**6.985**

[a] CH: Characteristic (tourism) goods and services; NCH: Non-characteristic.
[b] Includes services of travel agencies, other services related to transport and hiring of vehicles.
Source: Own elaboration.

considerations are usually the drivers of trade (not only comparative advantage, as is often emphasized). Thus, being aware of the limitations, we do not attempt to make political recommendations on production, trade or taxing only based on water concerns, although we have reflected about it in the previous section. However, we consider that the water footprint and virtual water concepts are extremely relevant, especially for arid/semi-arid countries, since the knowledge of flows, demands and pressures on water associated with them help to identify critical impacts and solutions for better water governance, which should be assessed together with other economic and social variables.

We think this article connects very well, showing a specific application, with the insights of Gössling et al. (2012), who explain that in general direct tourism-related water use is not very relevant, but that the situation is different when looking at more specific hotpots, because tourism is concentrated 'in time and space, and often in dry regions where renewable water reserves are limited. Furthermore, the understanding of tourism's indirect water requirements, including the production of food, building materials and energy, remains inadequately understood, but is likely to be more substantial than direct water use'.

This study combines the disaggregated IO techniques with process analysis data, in order to achieve precise computations of water flows within a consistent framework and reveal the water needed to satisfy the final demand for products by the exogenous accounts, particularly demand induced by tourism in Spain.

So as to estimate the VW in agrarian imports, we used both water content estimates per ton of output in each country selected, and the VW contents in primary and transformed agrarian products (to complete specific import coefficients). The major improvement in relation to most existing IO analyses of embodied water was the disaggregation of the agri-food system, to obtain relevant water intensities based on agrarian, industrial and trade data etc., by using the product and value fractions, as defined by Chapagain and Hoekstra (2004).

The WF of tourism in Spain, at 6.9 km^3/year, was put in perspective by the total WF figures, 55.1 km^3/year, measured as the consumption of national water resources, plus water imports and minus water exports. Out of the 6.9 km^3/year of global water resources for tourism, 3.2 km^3/year is due to national tourists and 3.7 km^3/year to foreign tourists, who thereby also contribute to the net virtual water importer character of Spain (i.e. some of the net VW imports are due to foreign tourists). The numbers thus revealed are significant, despite the fact that characteristic tourism activities do not have high direct water consumption intensities (they are mainly services), since virtual water contents are considerable because Spaniards frequently act as tourists and Spain has more than 50 million tourists a year, leading to a high tourist WF. High and concentrated tourism may exceed the levels of assimilation of (water) resources, as is happening in Spain in areas with rural tourism and as already has happened in areas with the winter sport activities. Furthermore, the largest kind of tourism in Spain is that of 'sun and beach', concentrated in arid and water-stressed regions, some of which have already needed water transfers to prevent salinization. This makes it necessary to develop appropriate policies for the reduction of direct and indirect water use.

As far as we are aware, this is the first integration of all processes of transformation of goods, with a disaggregated IO in agri-food activities, that specifically has been used for the study of the tourism WF, which is very significant in the case of Spain.

To estimate the tourism WF, we first considered sales and cost relationships in the national economy, and then the related tourist spending on specific activities in the IO table, using the Tourism Satellite Accounts. Tourism accounts for more than 10% of Spain's GDP and the water consumption needed to meet demand from both resident and non-resident tourists totals 6.985 km^3. The necessary blue and green water consumption to satisfy the demand of non-residents in Spain (WF of foreign tourism in Spain) is 3.737 km^3 and the requirements from Spanish resources only are 1.570 km^3, while consumption of Spanish blue water resources (the part that is politically controlled and the subject of public debate) is 0.885 km^3.

Finally, and more as an approximation of the policy implications than of specific proposals on water tourism policy, we have looked at the kind of action on tourism demand water supply policy through infrastructure development that was used in the last century and compared it to the policy of control of and reduction in demand that is currently dominant, finding that improvement of irrigation technologies in Spain is one of the key instruments to reduce the WF. In any case, economic incentives, price increases, environmental levies or altruism are key topics in implementing any type of tourism policy with regard to water.

Acknowledgements

The authors acknowledge the helpful comments made by the three anonymous reviewers. Ignacio Cazcarro acknowledges the great help from Professor E. Dietzenbacher and from the Water Engineering and Management group at the University of Twente with previous versions of this article, which also improved the work considerably. The usual disclaimer applies.

Appendix A. Supplementary material

Supplementary material related to this article can be found at http://dx.doi.org/10.1016/j.tourman.2013.05.010.

References

Allan, J. A. (1996). Policy responses to the closure of water resources: regional and global issues. In P. Howsam, & R. C. Carter (Eds.), *Proceedings of international conference on water policy*: *Water policy: Allocation and management in practice*. London, UK: Cranfield University.

Cañada Martínez, A. (2002). La cuenta satélite del turismo de España: objetivos, aspectos metodológicos y primeras estimaciones (1996–1999). *Información Comercial Española, ICE: Revista de economía, 798*, 45–62.

Cansino, J. M., Cardenete, M. A., Ordóñez, M., & Román, R. (2012). Economic analysis of greenhouse gas emissions in the Spanish economy. *Renewable and Sustainable Energy Reviews, 16*(8), 6032–6039.

Castellani, V., & Sala, S. (2012). Ecological Footprint and Life Cycle Assessment in the sustainability assessment of tourism activities. *Ecological Indicators, 16*, 135–147.

Cazcarro, I., Duarte, R., & Sánchez Chóliz, J. (2010). Water consumption based on a disaggregated Social Accounting Matrix of Huesca (Spain). *Journal of Industrial Eco1ogy, 4*(3), 496–511.

Cazcarro, I., Duarte, R., & Sánchez Chóliz, J. (2013). Water footprints for Spanish regions based on a Multi-Regional Input–Output (MRIO) model (Chapter 13). In J. Murray, & M. Lenzen (Eds.), *The sustainability practitioners guide to multi-regional input–output analysis* (in press).

Chapagain, A. K., & Hoekstra, A. Y. (2004). *Water footprints of nations*. In *Value of water research report series n° 16*: Delft, The Netherlands: UNESCO-IHE.

Crama, Y., Defourny, J., & Gazon, J. (1984). Structural decomposition of multipliers in input–output or social accounting matrix analysis. *Economie Apliquée, 37*(1), 215–222.

Defourny, J., & Thorbecke, E. (1984). Structural path analysis and multiplier decomposition within a social accounting matrix framework. *The Economic Journal, 94*(373), 111–136.

Dietzenbacher, E. (2005). Waste treatment in physical input–output analysis. *Ecological Economics, 55*(1), 11–23.

Duchin, F., & Steenge, A. E. (2009). Mathematical models in input–output economics. In W. Zhang (Ed.), *Mathematical science, UNESCO encyclopedia of life support systems (EOLSS)*.

FAO. (2003a). *Aquastat*. Rome, Italy: Food and Agriculture Organization of the United Nations.

FAO. (2003b). *Technical conversion factors for agricultural commodities*. Rome, Italy: Food and Agriculture Organization of the United Nations.

Garrido, A., Llamas, M. R., Varela-Ortega, C., Novo, P., Rodríguez-Casado, R., & Aldaya, M. M. (2010). Water footprint and virtual water trade in Spain: Policy implications. In Natural resource management and policy series: Springer-Fundación Marcelino Botín.

Giljum, S., Hubacek, K., & Sun, L. (2004). Beyond the simple material balance: a reply to Sangwong Suh's note on physical input–output analysis. *Ecological Economics, 48*(1), 19–22.

Gössling, S., Peeters, P., Hall, C. M., Ceron, J.-P., Dubois, G., Lehmann, L. V., et al. (2012). Tourism and water use: supply, demand, and security. An international review. *Tourism Management, 33*(1), 1–15.

Green, H., Hunter, C., & Moore, B. (1990). Assessing the environmental impact of tourism development: use of the Delphi technique. *Tourism Management, 11*(2), 111–120.

Hoekstra, A. Y., & Chapagain, A. K. (2008). *Globalization of water: Sharing the planet's freshwater resources*. Oxford, UK: Blackwell Publishing.

Hosang, W., & Bischof, W. (1998). *Abwassertechnik*. B. G. Teubner Stuttgart-Leipzig.

Hunter, C., & Shaw, J. (2007). The ecological footprint as a key indicator of sustainable tourism. *Tourism Management, 28*, 46–57.

Kumar, M. D., & Singh, O. P. (2005). Virtual water in global food and water policy making: is there a need for rethinking? *Water Resources Management, 19*, 759–789.

Lenzen, M., Gallego, B., & Wood, R. (2009). Matrix balancing under conflicting information. *Economic System Research, 21*(1), 23–44.

Lenzen, M., Pade, L.-L., & Munksgaard, J. (2004). CO_2 multipliers in multi-region input–output models. *Economic System Research, 16*(4), 391–412.

MAPA. (2004, 2007). *Agrarian accountancy net (RECAN = AAN, 2004)*. In *Agro-alimentary statistical yearbook (2007)*: Madrid, Spain: Ministry of Agriculture. Ministry of Agriculture, Fisheries and Food in Spanish.

Mutschmann, F., & Stimmelmayr, F. (2007). *Taschenbuch der Wasserversorgung* (14th ed.). Wiesbaden.

Nagy, M., Lenz, K., Windhofer, G., Fürst, J., & Fribourg-Blanc, B. (2008). *Data collection for the OECD/Eurostat manual on inland waters. Concepts, definitions, current practices, evaluations and recommendations*. OECD/Eurostat.

National Statistics Institute (NSI=INE, 2011). Madrid. National Accounts of Spain. Accounting Series (Spanish National Accounts, Industrial Products, Services and Trade Surveys, Continuous Household Budget Survey, Wage Structure Survey, Labour Force Survey, Health, Tourism Satellite Account, Satellite Accounts of water, Surveys of water supply and treatment, on water use in agriculture and in industry).

OECD. (2009). *Input–output tables* (edition 2006).. Organisation for Economic Cooperation and Development.

van Oel, P. R., Mekonnen, M. M., & Hoekstra, A. Y. (2009). The external water footprint of the Netherlands: geographically-explicit quantification and impact assessment. *Ecological Economics, 69*(1), 82–92.

Patterson, T. M., Niccolucci, V., & Bastianoni, S. (2007). Beyond "more is better": ecological footprint accounting for tourism and consumption in Val di Merse, Italy. *Ecological Economics, 62*, 747–756.

Pazienza, P. (2011). Should we tax tourism? Theoretical justifications from the economics of non-renewable resource use. *Environmental Economics, 2*(1), 8–16.

Ramos Carvajal, C., & Robles Teigeiro, L. (2009). Cambio estructural en España (1980–2000). *Estadística española, 51*(172), 505–541.

Rendeiro Martín-Cejas, R., & Ramírez Sánchez, P. P. (2010). Ecological footprint analysis of road transport related to tourism activity: the case for Lanzarote Island. *Tourism Management, 31*(1), 98–103.

Sánchez-Chóliz, J., Bielsa, J., & Arrojo, P. (1992). Water values for Aragon. In L. M. Albisu, & C. Romero (Eds.), *EAAE/CIHEAM proceedings*: *Environmental and land use issues: An economic perspective*. Kiel, Germany: Wissenschaftsverlag Vauk Kiel KG.

Suh, S. (2004). A note on the calculus for physical input–output analysis and its application to land appropriation of international trade activities. *Ecological Economics, 48*, 9–17.

Tarancón, M. A. (2005). Diferencias estructurales en las actividades del turismo entre Andalucía y Comunidad Valenciana: aplicación del análisis input–output cualitativo con análisis de sensibilidad. *Revista de estudios regionales, 72*, 165–190.

Titos Moreno, A., de Haro, T., Gómez Muñoz, A. C., & Ramos Real, F. (1995). *El sistema agroalimentario español: tabla input–output y análisis de las relaciones intersectoriales*. Madrid, Spain: Ministry of Agriculture, Fisheries and Food in Spanish, General Technical Secretary.

USDA. (1992). *Weights, measures, and conversion factors for agricultural commodities and their products, agriculture handbook*. United States Department of Agriculture.

Weisz, H., & Duchin, F. (2006). Physical and monetary input–output analysis: what makes the difference? *Ecological Economics, 57*(3), 534–541.

Wichelns, D. (2011). Virtual water and water footprints. Compelling notions, but notably flawed. *GAIA, 20*(3), 171–175.

Yang, M., Hens, L., Wulf, R., & Ou, X. (2011). Measuring tourist's water footprint in a mountain destination of Northwest Yunnan, China. *Journal of Mountain Science, 8*(5), 682–693.

Doctor Ignacio Cazcarro Castellano is BA, MA and PhD, cum laude, in Economics from the University of Zaragoza (Spain), where he has been a member of the research group "Growth, Demand and Natural Resources". He is currently a Post-doctoral researcher at the Department of Economics at Rensselaer Polytechnic Institute in Troy, USA (with NSF grant project: 10-612). His research focuses mainly in the agri-food economy, national and environmental accounts and resources (especially on water), and makes extensive use of input-output models and water models. He has published several book chapters and articles in journals such as Environmental Science and Technology, Journal of Industrial Ecology, Economic Systems Research or the Spanish Journal of Agricultural Research.

Prof.dr.ir Arjen Y. Hoekstra is Professor in Water Management at the University of Twente, the Netherlands. He received his education at Delft University of Technology, the Netherlands, where he obtained an MSc degree, cum laude, in Civil Engineering and a PhD degree in Policy Analysis. Hoekstra is creator of the water footprint concept (2002) and established the interdisciplinary field of water footprint assessment, addressing the relations between water management, consumption and trade. He was initiator and co-founder of the Water Footprint Network. He published a large number of peer-reviewed articles in water management. His books include *Perspectives on Water* (International Books), *Globalization of Water* (Blackwell), *The Water Footprint Assessment Manual* (Earthscan) and *The Water Footprint of Modern Consumer Society* (Routledge).

Doctor Julio Sánchez-Chóliz is Professor of Mathematics and Economic Analysis at the University of Zaragoza, teaching Game theory and Mathematics in undergraduate and graduate courses. The core of his research areas are growth and technological change, water economy, natural resources and economic dynamics, being currently the Principal Investigator of the Consolidated Group S 10 of the Government of Aragon. Along more than 30 years, his research has been marked by using multisectoral models (input-output and CGE), evolutionary economics and dynamic problems, publishing a large number of peer-reviewed articles: Environmental Science and Technology, Energy Policy, Economic Systems Research, Industrial and Corporate Change, Journal of Evolutionary Economics, Energy Economics, Journal of Industrial Ecology, Journal of Economic Behavior and Organization, Ecological Economics (http://www.credenat.com/category/personal/).