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Water Flows in the Economy. An Input-output Framework to Assess Water Productivity in the Castile and León Region (Spain)

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Summary

Traditionally, water policy has focused on coordinating the public effort required to fuel economic growth by supplying water services demanded as a result of the progress in the many areas of the economy. Under this supply-oriented paradigm, population growth and the improvement of living standards brought about by development have driven water demand up and the pressures over water resources have escalated. The failure to acknowledge the limited availability of water and to decouple economic development from water demand has resulted in a water dependent growth model that in many areas is currently threatened by increasing scarcity and more frequent and intense droughts. Consequently, there is an urgent need to use sparse water resources in a sustainable and efficient way. This demands a comprehensive assessment of water productivity dynamics as well as of the linkages among economic sectors in order to calculate the actual costs of eventual water reallocations to the environment and establish priorities in the design of strategic actions such as river basin or drought management plans. However, available studies only offer static analyses that are insufficient to attain the dual objective of reverting current water scarcity trends without impairing economic growth. This paper develops a methodology based on the Hypothetical Extraction Method to estimate inter-temporal indirect (i.e., including intersectoral linkages) water productivity values. The method is applied in the Spanish region of Castile and León for the period 2000-2006. The intensive use and the low water productivity found for agriculture confirms the intuition that this sector has to play a fundamental role in any water saving policy. However, the relevant linkages between agriculture and the rest of the economy, which acts as an indirect consumer of water for irrigation, may complicate the finding of a Pareto improvement in water allocation. Results also show increasing returns to scale in the manufacturing industry and the service sector, which may be regarded as an evidence of the existence of a Verdoorn's Law for water.

Keywords: Environmental Input-output Modeling, Verdoorn's Law, Water Management, Productivity

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Abstract

Traditionally, water policy has focused on coordinating the public effort required to fuel economic growth by supplying water services demanded as a result of the progress in the many areas of the economy. Under this supply-oriented paradigm, population growth and the improvement of living standards brought about by development have driven water demand up and the pressures over water resources have escalated. The failure to acknowledge the limited availability of water and to decouple economic development from water demand has resulted in a water dependent growth model that in many areas is currently threatened by increasing scarcity and more frequent and intense droughts. Consequently, there is an urgent need to use sparse water resources in a sustainable and efficient way. This demands a comprehensive assessment of water productivity dynamics as well as of the linkages among economic sectors in order to calculate the actual costs of eventual water reallocations to the environment and establish priorities in the design of strategic actions such as river basin or drought management plans. However, available studies only offer static analyses that are insufficient to attain the dual objective of reverting current water scarcity trends without impairing economic growth. This paper develops a methodology based on the Hypothetical Extraction Method to estimate inter-temporal indirect (i.e., including intersectoral linkages) water productivity values. The method is applied in the Spanish region of Castile and León for the period 2000-2006. The intensive use and the low water productivity found for agriculture confirms the intuition that this sector has to play a fundamental role in any water saving policy. However, the relevant linkages between agriculture and the rest of the economy, which acts as an indirect consumer of water for irrigation, may complicate the finding of a Pareto improvement in water allocation. Results also show increasing returns to scale in the manufacturing industry and the service sector, which may be regarded as an evidence of the existence of a Verdoorn's Law for water.

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1. Introduction

Water is a scarce input necessary for the production of many valuable goods and services and should be managed accordingly. However, water policy so far has failed to consider water as an economic good and has focused instead in guaranteeing the supply of this resource at subsidized prices. Under this paradigm, population growth and the improvement of living standards brought about by development have driven water demand up and the pressures over water resources have escalated. Consequently, water is now overexploited in many areas across the globe (Massarutto 2003). As water became scarcer, policy making has become reactive and incremental and conventional supply policies, instead of replaced, have been reinforced. As a result, surprise and crisis are now regular occurrences and there is an increasing need worldwide to manage water resources "better"[1] (Molden and Sakthivadivel 1999; Anderies et al. 2006).

In the EU, the first reaction of water authorities to the water crisis has been the enactment of command-and-control policies to guarantee water supply for priority uses, namely household and environmental uses. This is the case of the Drought Management Plans, which limit water supply for productive uses during drought events (EC, 2008). As compared to traditional supply policies, command-and-control policies are inexpensive and largely focused on restraining water supply. Nonetheless, they do not change the driving forces behind water consumption and consequently their ability to curb water demand and prevent further (informal) abstractions is very limited. The response to this challenge came through the introduction of economic instruments in the EU agenda. Unlike coercive command-and-control policies, economic instruments such as water pricing use incentives and motivation in order to align individual decisions with collectively agreed goals. Accordingly, economic instruments have the ability to improve water allocation among competing uses without intensifying pressures over water bodies (Veettil et al. 2013; Albiac et al. 2007; Interviews et al. 2006).

[1] Although cited frequently in the water economics literature, the term "better" is rather vague. In this paper we consider that a better water management refers to a strategic allocation of water resources that addresses the collectively agreed goals of water policy without impairing the outcome of the market activities that rely on this input.

These innovative policies aim towards the attainment of an strategic allocation of water that reverts current scarcity trends without impairing economic growth . Therefore, what is crucial in their design is to identify the productive activities in which potential water use restrictions may have a lower impact over the economy, in the short (e.g., Drought Management Plans) and in the longer term (e.g., River Basin Management Plans). This demands a comprehensive understanding of Water Productivity (WP) dynamics that integrates the relevant linkages among economic sectors in order to establish strategic priorities in water use.

WP has been assessed in depth using different techniques and methodologies and as a result there is a vast array of definitions available. However, we can safely define WP as the output of a given activity (in economic terms, if possible) divided by some expression of water input (Playan and Mateos 2006).

As irrigation is by large the main water consumer worldwide, most of the studies available refer to WP in agriculture either from an agronomic, economic or hydrologic perspective, or a combination of them (sectoral models). A very fruitful research field relies on the water balance concept considering different spatial boundaries; this can be found for example in Owen-Joyce and Raymond (1996), Hassan and Bhutta (1966), Perry (1996), Kijne (1996), Helal et al. (1984), Mishra et al. (1995), Rathore et al. (1996), Bhuyian et al. (1995), Tuong et al. (1996) and Molden (1997). More recently the rise of geo-referenced systems and remote sensing has permitted the development of a new series of studies based on spatial models as in Van Dam et al. (2006), Wesseling and Feddes (2006), Zwart and Bastiaanssen (2007), Vazifedoust et al. (2008) and Cai et al. (2011), among others. Although scarcer, there is also research on WP in the secondary and tertiary sectors (see for example Perez et al. 2010 or Maestu et al. 2008). All this research allows a better understanding of the water use within a particular sector, but it only offers an intrasectoral assessment of WP (apparent/direct WP) that excludes the analysis of forward and backward linkages among sectors and therefore is insufficient to assess the potential for intersectoral water reallocations.

The problem of how to better allocate the scant water resources available in an economy requires an integrated assessment of WP. Input-Output (IO) models have the potential to address this issue. There are many examples of IO models for the study of water use and WP. For example, Duarte et al. (2002), Velazquez (2006) and Perez et al. (2011) assessed direct and indirect water flows and WPs in different EU regions using IO methods. Dietzenbacher and Velazquez (2007), Guan and Hubacek (2007) and Zhang et al. (2011) opened the economy for trading and studied trans-boundary water flows. Gonzalez (2011) used IO modeling to estimate monetary losses stemming from hypothetic water supply restriction scenarios. The expected outcome after the implementation of different hypothetic water policy scenarios was analyzed for instance in Tirado et al. (2006) (for water markets) and Llop (2008) (tax rise and efficiency improvements in irrigation). Llop (2013), Feng et al. (2011) and Yu et al. (2010) used IO approach to calculate sustainable indicators for water consumption. Also, Logar and van den Bergh (2013) and Martin-Ortega et al. (2012) used or recommended IO modeling in the economic assessment of drought events.

This body of literature offers an insightful approach to WP assessment for all the sectors in the economy considering different scenarios. In addition, it makes possible the estimation and comparison of both apparent/direct WP (which is measured in the sectoral models above) and indirect WP (missing in the sectoral models). While direct WP only considers water directly consumed by the sector, indirect WP takes into account also the water consumption induced by the sector in other areas of the economy. That is to say, the latter includes the water that the sector consumes as well as the water that would not be used in the remaining sectors if that sector was to be removed from the economy. This information is of great importance to assess the actual impact of policies constraining water use over productive activities.

The main drawback of available IO models is that they are static and do not assess WP dynamics. This is mostly owed to the lack of continuous data series (Lenzen 2011). Nonetheless, this has changed recently as environmental satellite accounts (including water accounting) and IO tables have become regularly available in some regions. New statistical data now makes possible not only an intersectoral but also an inter-temporal assessment of WP.

This paper aims to shed light over the inter-temporal problem of how to efficiently assign scarce water resources among productive sectors. The study uses the Hypothetical Extraction Method (HEM) (Strasser 1968; Cella 1984) and applies it to the particular case of water resources to obtain annual indirect and direct WP in the Spanish region of Castile and León (CL) for a 7 years period (2000-2006[2]). Results confirm the existence of a relevant gap between the low (and decreasing) WP in agriculture (the largest water consumer) and that of the other sectors, which are nonetheless largely dependent on the agricultural output and water demand to supply their goods and services. As expected, there is also a significant gap between the results obtained with the direct WP method and those obtained with the preferred indirect WP method, with important implications over water policy design (which usually relies on the former). Results also suggest the existence of a positive relationship between GDP growth and WP growth in the manufacturing industry as well as in the service sector. This relationship can be regarded as a Verdoorn's Law for water and illustrates the significant potential for water savings stemming from industrial and tertiary development. This constitutes an opportunity to limit or even reduce urban water use in the economy without impairing GDP growth.

2. The case study area: The Castile and León Region (Spain)

CL is at the same time the largest region of Spain (94,223 km^2, 18.7% of the Spanish territory) and one of the most depopulated regions of Europe (26.6 population per km^2) (Eurostat 2011). The structure of the CL's economy is similar to that of the Spanish economy as a whole. Industry, construction and the tertiary sector have a similar composition in CL and in Spain and their weights over regional and national GDP, although slightly smaller in the case of CL, have also showed a similar evolution during the last decades. However, CL has been traditionally and is still today an agrarian region with classic agrarian periphery socio-economic problems, namely, depopulation and low income.

In 2006, agriculture represented 6.6% of the GDP and 10.2% of total employment in CL, more than doubling the Spanish shares (2.7% of the GDP and 4.4% of the employment) and well above the EU-27 shares (1.7% and 5.4%). More than a half (52%) of CL surface is devoted to agricultural uses (Spain: 52%; EU-27: 43%). Prevailing agro-ecosystems in CL are cereal landscapes and irrigated areas that produce

[2] IO tables in are usually made available with a with a 4-5 years delay (the last year for the CL Region is 2008). Environmental accounting such as the Water Satellite Accounts may experience even larger delays (the last year available is 2006).

relatively low agrarian incomes[3]. Irrigation is the main water user and represents 92% of total consumption in the region (DRBA 2012; INE 2011).

82% of the CL Region is located inside the Duero River Basin (DRB) boundaries. Since the 1990s the DRB has experienced its more intense, spread and lasting droughts in a century (DRBA, 2007). Moreover, average water availability has fallen and this trend is expected to continue (DRBA, 2007; EEA 2005; IPCC 2007), thus threatening all water uses including priority environmental and household supply (DRBA, 2007). Authorities have reacted to these challenges in two ways. Regarding *droughts*, authorities have regulated drought response through a Drought Management Plan that decreases water availability for productive uses under these events (DRBA 2007). Unlike other Drought Management Plans that clearly specify the water restrictions to be applied for every sector under each drought threshold, the DRB Drought Management Plan offers a considerable degree of flexibility (DRBA, 2007). Therefore, this new regulation may have a different impact over regional GDP depending on the sectors affected by water restrictions (Gonzalez 2011). Regarding *scarcity*, the recently approved Duero River Basin Management Plan established a set of guidelines to restore environmental services that will likely demand a permanent restriction in water use in some productive activities (DRBA, 2012).

Although with a different time scope (short run in the case of the Drought Management Plan and medium-long run in the case of the River Basin Management Plan), both regulations determine a reallocation of water resources from productive activities to the environment. This demands a profound understanding of the financial (i.e., market) impacts of permanent and temporary reallocation policies and thus of WP dynamics and the linkages among economic sectors.

3. Data and methods

For the assessment of WP this research uses the Water Satellite Accounts (WSA) and the IO symmetric tables (product-by-product, constant prices) for CL. WSA are a statistical source yearly available in Spain since 1997 that provide information on the amount of water used by every economic sector (INE 2012b). On other hand, symmetric tables are offered intermittently by national and regional institutes

[3]Which are nonetheless heavily subsidized. For example, during the period considered (2000-2006) the agricultural income increased by 6.5% in spite of the sharp fall in the agricultural Gross Value Added (-8.6%). This is explained by the 136.9% increase of agrarian subsidies in this period (real values) (INE 2012a).

of statistics; however, CL Institute of Statistics has been yearly supplying symmetric IO tables since 2000 (JCYL 2012). As a result, both symmetric tables and WSA have been available simultaneously for every year during the period 2000-2006. This study uses the Hypothetical Extraction Method (HEM) to combine WSA with IO symmetric tables in order to estimate intersectoral water flows and from here their corresponding direct and indirect WPs. We repeat the process for each one of the seven years of the period considered.

This paper starts from an IO model where the production of an economy comprising *n* sectors is described as follows:

$$x = Ax + y = \begin{pmatrix} A_{s,s} & A_{s,-s} \\ A_{-s,s} & A_{-s,-s} \end{pmatrix} \begin{pmatrix} x_s \\ x_{-s} \end{pmatrix} + \begin{pmatrix} y_s \\ y_{-s} \end{pmatrix} \qquad [1]$$

Being $x = x_i$ the production vector or total output, $y = y_i$ the vector of final demands (i.e., the final output of the economy[4]) and $A = A_{ij}$ the matrix of technical coefficients. The economy can be split into blocks comprising one or more sectors. The subscript *s* refers to a specific block, and the subscript –*s* to the remaining blocks of the economy. Alternatively, [1] can be formulated as follows:

$$x = (I - A)^{-1} y = \begin{pmatrix} \Delta_{s,s} & \Delta_{s,-s} \\ \Delta_{-s,s} & \Delta_{-s,-s} \end{pmatrix} \begin{pmatrix} y_s \\ y_{-s} \end{pmatrix}$$

Where: $\begin{pmatrix} \Delta_{s,s} & \Delta_{s,-s} \\ \Delta_{-s,s} & \Delta_{-s,-s} \end{pmatrix} = \begin{pmatrix} (I - A_{s,s})^{-1} & (I - A_{s,-s})^{-1} \\ (I - A_{-s,s})^{-1} & (I - A_{-s,-s})^{-1} \end{pmatrix}$ [2]

Being $(I - A)^{-1}$ the Leontief inverse. The HEM measures the impact of every block (namely, *s*) by comparing the production vector of that economy with (x) and without (x^*) that block. The production of the economy in which a given block (*s*) is extracted is described as follows:

$$x^* = (I - A^*)^{-1} y^* = \begin{pmatrix} (I - A_{s,s})^{-1} & 0 \\ 0 & (I - A_{-s,-s})^{-1} \end{pmatrix} \begin{pmatrix} y_s \\ y_{-s} \end{pmatrix} \qquad [3]$$

[4] The total output of each sector in the vector x equals the intermediate output (Ax) plus final demand (alternatively, the final output, y). Macroeconomic variables such as GDP or GVA refer to this final demand, y.

The change in production is obtained as the difference between x and x^* and shows the effect of the block *s* over the remaining blocks of the economy:

$$\mathrm{x}-\mathrm{x}^* = \begin{pmatrix} \mathrm{C}_{s,s} & \mathrm{C}_{s,-s} \\ \mathrm{C}_{-s,s} & \mathrm{C}_{-s,-s} \end{pmatrix} \begin{pmatrix} \mathrm{y}_s \\ \mathrm{y}_{-s} \end{pmatrix} \quad [4]$$

Every block has four separate effects over the economy: an internal effect, a mixed effect, an external or net backward linkage and an external or net forward linkage. The internal effect of the block *s*(IE_s) represents the effect of the goods produced, sold and purchased inside the sector *s* to obtain y_s. The mixed effect (ME_s) measures the impact of the products sold by the block *s* to other blocks and later re-purchased to produce y_s. The net backward linkage (NBL_s) represents the direct and indirect requirements of the sector *s* from the rest of the economy to obtain y_s, namely the 'imports' of the sectors. Finally, the net forward linkage (NFL_s) represents the direct and indirect requirements of the rest of the economy from the sector *s* to obtain y_{-s}, namely the 'exports' of the sectors:

$$\mathrm{IE}_s = \mathrm{c}'\left(\mathrm{I}-\mathrm{A}_{s,s}\right)^{-1}\mathrm{y}_s \quad [5]$$

$$\mathrm{ME}_s = \mathrm{c}'[\Delta_{s,s} - \left(\mathrm{I}-\mathrm{A}_{s,s}\right)^{-1}]\mathrm{y}_s \quad [6]$$

$$\mathrm{NBL}_s = \mathrm{c}\,\Delta_{-s,s}\,\mathrm{y}_s \quad [7]$$

$$NFL_s = c'\Delta_{s,-s}y_{-s} \quad [8]$$

Where c' denotes the vector (1, …, 1).

Vector c' is now replaced by a vector of unitary inputs of water (w') calculated as the quotient of water use in every sector *s* (available in the WSA) to its final demand y_s (or final output, available in the IO symmetric tables). With this information it is possible to obtain the four effects over the economy of the block *s*, but this time referred to the amount of water embodied in the part of the production process that the different effects represent. Now the internal effect (IEw_s) is the water consumed exclusively inside the block *s*; the mixed effect (MEw_s) is the water consumed in the block *s*, then used as an input in other block/s and again used as an input in the block *s*; the net backward linkage ($NBLw_s$) is the water originally used in other blocks than *s* and then 'imported' and used in *s* to generate the final demand; and the net forward linkage ($NFLw_s$) is the water originally used in the block s and then 'exported' and used in other block/s to generate their final demand:

$$\mathrm{IEw_s} = \mathrm{w}'\left(\mathrm{I} - \mathrm{A_{s,s}}\right)^{-1}\mathrm{y_s} \quad [9]$$

$$\mathrm{MEw_s} = \mathrm{w}'[\Delta_{\mathrm{s,s}} - \left(\mathrm{I} - \mathrm{A_{s,s}}\right)^{-1}]\mathrm{y_s} \quad [10]$$

$$\mathrm{NBLw_s} = \mathrm{w}\,\Delta_{-\mathrm{s,s}}\,\mathrm{y_s} \quad [11]$$

$$\mathrm{NFLw_s} = \mathrm{w}'\Delta_{\mathrm{s,-s}}\mathrm{y_{-s}} \quad [12]$$

These effects are subsequently added into two groups in order to obtain the vertically integrated effect and the direct effect. The direct effect (DE_s) stems from direct consumption and is the result of the aggregation of the mixed effect, internal effect and net forward linkages of the block s. The ratio between the final demand (y_s) and the direct effect (DE_s) of that block is its direct water productivity (DWP) (namely, the quotient of total production to observed water uses or apparent productivity):

$$\mathrm{DE_s} = \mathrm{IEw_s} + \mathrm{MEw_s} + \mathrm{NFLw_s} \quad [13]$$

$$\mathrm{DWP} = \frac{\mathrm{y_s}}{\mathrm{DE_s}} \quad [14]$$

The Vertically integrated effect (VIE_s) stems from indirect consumption and is the result of the aggregation of the internal effect, mixed effect and the net backward linkages. It is used to obtain indirect WP. The ratio between the final demand (y_s) and the vertically integrated effect (VIE_s) of a given block is its indirect water productivity (IWP).

$$\mathrm{VIE_s} = \mathrm{IEw_s} + \mathrm{MEw_s} + \mathrm{NBLw_s} \quad [15]$$

$$\mathrm{IWP} = \frac{\mathrm{y_s}}{\mathrm{VIE_s}} \quad [16]$$

WSA offer information on water use disaggregated in 24 productive sectors for different types of water. For the purposes of this research, this paper will distinguish between *irrigation* (92% of total water demand) and the sum of drinkable and non-drinkable water (to which this paper will refer as *urban* *water*, representing the remaining 8% of the total water demand). On the other hand, the IO symmetric tables for CL offer economic information disaggregated in 58 sectors. In this paper all the different sectors in the WSA and IO tables are put into the seven homogeneous blocks described below following the grouping suggested by Duarte et al. (2002) and Sanchez-Choliz and Duarte (2003):

Block 1 (B1): Agriculture, livestock, hunting, forestry and fishing.

Block 2 (B2): Extraction of energy products, extraction of other mineral products, oil refining and nuclear fuels, water collection, purification and distribution and energy, gas and water production and distribution.

Block 3 (B3): Food, drinks and tobacco.

Block 4 (B4): Textile and clothing, leather and footwear, timber and cork, paper and publishing and other non-metallic mineral products industries.

Block 5 (B5): Chemicals, rubber and plastic materials transformation, metallurgy and manufacture of metal products, machinery and mechanical equipment, electric and electronic material, transport material and diverse manufacturing industries.

Block 6 (B6): Construction.

Block 7 (B7): Public sanitation, public Administration and other service sector activities.

4. Results

We obtain IWP and DWP for every single block and year during the period 2000-2006, for both urban and irrigation water. All WP values are shown in constant prices (real WP).

IWP values in the year 2006 are distorted as a result of the extreme drought that suffered Spain and particularly the DRB since mid-2005, the most intense ever recorded in the basin (DRBA 2012). Water supply restrictions significantly increased water efficiency and IWP. The opposite can be said for the relatively water abundant period 2002-2003. In any case and in spite of these anomalies, a clear trend for IWP in every block and water type (irrigation, urban) can be inferred for the period analyzed.

Irrigation water (Table 1) represents 92% of total water demand in the region and is directly consumed by agriculture. The remaining blocks demand irrigation water only indirectly through the significant backward linkages that they have with agriculture. The observed IWP in the CL Region is low and lower than the values available for other Spanish regions (Duarte et al. 2002; Velazquez 2006; Perez et al.,2011). Moreover, IWP in the agricultural sector shows a negative trend, thus dragging IWP in the other sectors of the economy. This means that most of the water being used in the economy (92%) is employed with a low and decreasing efficiency.

Table 1. Indirect water productivity (IWP) in the Castile and León Region, 2000-2006 (€/m^3, constant prices). Irrigation water.

Block/year	2000	2001	2002	2003	2004	2005	2006
B1	1.81	1.81	1.72	1.58	1.67	1.46	1.92
B2	186.46	193.91	172.6	172.62	179.45	141.38	145.42
B3	4.06	4.27	3.98	3.74	3.99	3.35	3.73
B4	26.84	29.1	26.09	24.97	29.04	22.98	24.32
B5	103.19	104.41	95.38	93.53	99.6	81.11	91.55
B6	77.24	82.07	72.92	67.79	72.21	55.29	57.73
B7	63.72	66.82	60.42	56.34	59.81	50.07	55.79

Source: Own elaboration

In the case of *urban water* (Table 2) there are two clearly differentiated trends. In the primary sector (B1) and in the food industry (B3) IWP is low and shows a negative trend. IWP low value in B3 is a consequence of its dependency on B1, which results in a high indirect demand (high net backward linkage) from low productive B1. The construction sector (B6) shows a constant trend for IWP[5] (until the

[5] This model uses constant prices and therefore avoids the effect of inflated prices in this sector.

2005-2006 drought) . On other hand, the tertiary sector (B7), manufacturing industry (B4 and B5) and the energy and water block (B2) show a significant and continued increase of IWP along the period: IWP increases by 15.5% in B2, 6.8% in B4, 7.1% in B5 and 11.7% in B7 in the period 2000-2005. At the same time GDP also shows significant growth rates for these sectors. This empirical result may be regarded as a Verdoorn's Law for water: faster growth in output increases productivity due to increasing returns in certain blocks of the economy prone to technological improvements and efficiency gains (such as manufacturing industry). Original research by Verdoorn (1949) and Kaldor (1966) estimated that changes in the volume of production, say about 1%, tend to be associated with an average increase in input productivity (in those cases, labor) between 0.45% and 0.484%, with extreme values of 0.41 in UK and 0.57 in the US. Subsequent estimations of the law found figures close to this value. In our case, a 1% increase in the volume of production results in an increase of IWP in the selected blocks of 0.49% (B2), 0.38% (B4), 0.39% (B5) and 0.41% (B7) in the period 2000-2005. Longer series are needed to obtain concluding evidence; nonetheless, these results suggest the existence of a Verdoorn's law for water in these economic sectors.

Table 2. Indirect water productivity (IWP) in the Castile and León Region, 2000-2006 (€/m^3, constant prices). Urban water.

	2000	2001	2002	2003	2004	2005	2006
B1	169.06	148.15	129.08	112.51	137.32	124.15	168.72
B2	250.75	269.39	272.46	237.76	295.46	292.79	458.47
B3	265.84	252.38	220.72	199.14	243.78	213.27	247.31
B4	557.77	585.93	557.41	471.81	615.26	598.05	802.64
B5	531.68	526.79	501.64	459.93	562.00	570.78	822.52
B6	869.88	869.99	826.12	732.37	878.23	807.52	1088.99
B7	701.30	685.85	671.72	623.25	810.61	788.63	1065.41

Source: Own elaboration

DWP values largely differ from IWP. In the case of *irrigation water* (Table 3), DWP method does not consider the water indirectly demanded by other blocks and consumed in agriculture. As a result, DWP underestimates WP in agriculture as compared to the preferred IWP method by 26%-31%. DWP in the rest of the blocks of the economy equals 0, since backward linkages are not considered with this method.

Table 3. Direct/apparent water productivity (DWP) in the Castile and León Region, 2000-2006 (€/m^3, constant prices). Irrigation water.

Block/year	2000	2001	2002	2003	2004	2005	2006
B1	0.56	0.55	0.52	0.47	0.51	0.40	0.51

Source: Own elaboration

In the case of urban water demand (Table 4), DWP method largely overestimates WP in the water-importing blocks (B3, B4, B5, B6 and B7) and underestimates it in the water-exporting blocks (B1 and B2) as compared to IWP. DWP method supports the existence of increasing returns in water for blocks B2, B4, B5 and B7, but also for B6. In this case, the construction sector (B6) shows this positive relationship as the negative effect of its net backward linkages with low WP blocks is replaced by the positive effect of its net forward linkages with high WP blocks.

Table 4. Direct/apparent water productivity (DWP) in the Castile and León Region, 2000-2006 (€/m^3, constant prices). Urban water.

Block/year	2000	2001	2002	2003	2004	2005	2006
B1	57.86	55.48	46.20	42.25	54.81	43.21	49.07
B2	144.80	145.56	156.37	142.80	174.41	185.96	338.47
B3	1030.70	921.67	860.56	952.85	982.45	832.67	952.22
B4	1044.29	1506.13	1539.60	843.55	1374.38	1701.20	2727.97
B5	677.72	734.66	695.81	604.52	808.37	855.78	1295.45
B6	3421.15	2635.68	2733.49	3679.54	3846.88	4012.62	6525.80
B7	639.89	650.63	704.48	693.59	955.72	978.06	1418.25

Source: Own elaboration

5. Discussion and conclusion

This paper uses the HEM applied for water to estimate WP in the production of goods and services in the CL Region during the period 2000-2006. Using the internal effect, the mixed effect, the net forward linkage and the net backward linkage values and the concepts of vertically integrated and direct consumption this paper assesses direct and indirect WP in the different sectors of the economy for *irrigation water* and drinkable and non-drinkable water (*urban water*). It is argued that apparent/direct WP is not the proper measure to obtain WP, as it misses the relevant links that exist among sectors and that explain observed water demand. The results obtained with this methodology may be used to draw relevant conclusions for policy making in increasingly water stressed and drought exposed regions.

Water saving policies need to have a strong focus on *irrigation*. Agriculture is the main water consumer worldwide, and in the CL Region it shows a low and decreasing WP that results in an overall low and decreasing WP in the economy. Moreover, with only a few exceptions in small agricultural areas where water availability is very low and agricultural income is very high (Gomez and Perez 2012), it would be unrealistic to expect that agricultural water use may reach a WP level comparable to those of other economic sectors. Therefore, a large potential for water saving may be found here and several proposals to limit water demand in agriculture have been advanced. This is the case of command-and-control policies such as Drought Management Plans, which establish temporary irrigation restrictions during drought events and are a key element of the EU strategy against droughts (EC 2008). Nonetheless, it is necessary to consider that most of the water that is directly demanded by agriculture is used to produce goods that supply other sectors of the economy. This paper contributes to shed light upon this relevant issue and estimates not only the direct, but also the indirect productivity of irrigation water. In the case of CL, where irrigation represents 92% of total water demand, the net forward linkages ('exports') of this sector meant between 69% and 73.5% of irrigation water demand along the period 2000-2006. Therefore, any attempt to reduce the volume of water used by agriculture, even in the less water productive areas, may significantly affect other sectors of the economy -such as the food industry or the service sector, both essential in the CL and Spanish economies. For example, during the 2005-2006 drought event in CL, water restrictions reduced agricultural GDP by 6.2% and as a result production in the food industry fell by more than 3% (INE 2010a). If the new Drought Management Plan had been applied, restrictions over irrigation water supply may have been larger and thus may have had a more negative impact over both sectors, which together represent 14% of the employment and 20.1% of the GVA in the region.

Consequently, although a reduction in water use in the agricultural sector would result in an overall WP increase, it would have also adverse effects over production and employment in the rest of the economy in the short run (e.g., through restrictions during drought events as considered in Drought Management Plans). In the case of medium to long run irrigation restrictions (e.g., permanent water reallocations through the public buyback of agricultural water use rights as considered in some River Basin Management Plans), the dependence of some sectors on the agricultural output would likely result in the substitution of local products by imports (noteworthy, this may increase the costs and in some sectors such as the agro industry this may not be possible due to a series of variables, including transportation costs). The water scarcity problem would be then transferred outside, though it may end up worsening the balance of payments.

In addition, agriculture still has a fundamental and strategic role in terms of food supply independence, habitat and landscape protection, soil conservation, carbon dioxide sequestration, biodiversity conservation and food security (OECD 2013). Moreover, the transaction costs of these policies may be prohibitive (McCann 2013; Pannell et al. 2013). These spin-offs are outside our financial analysis but are undoubtedly a relevant factor to understand agricultural policies in the EU and worldwide and may result in a reluctance to implement significant water restrictions in this sector.

Because of the negative impact over other productive activities (estimated in this paper) and especially due to the high transaction costs and the strategic role of agriculture, policy makers have been traditionally unwilling to reduce and even to limit agricultural water use. However, unless current water demand trends are reverted, this situation will eventually become unsustainable as the river basin closes (i.e., when additional water commitments for domestic, industrial, agricultural or environmental uses cannot be met during all or part of a year). In the meanwhile, though, an alternative solution has been the implementation of water restrictions in the urban sector (DRBA 2007 and 2012), even if the potential for water saving here is marginal and the impact over markets is larger as compared to irrigation. In any case, this paper also shows that relevant WP gains in *urban water* (drinkable and non-drinkable water) can be obtained along with GDP growth, thus creating an opportunity to reduce urban water use without impairing market performance. Evidence of the existence of a Verdoorn's Law for water has been found in CL for the energy and water block (B2), manufacturing (B4 and B5) and the service sector (B7), which together represent 76%-78% of CL's GDP in the period considered and a decreasing share of indirect urban water consumption (from 66.7% in 2000 to 56.1% in 2006). Although urban water means a minor fraction of total water demand (8% in CL), it may still represent an important source for water saving in urban areas[6]. However, it should be noted that the higher WP stemming from GDP growth is only an opportunity to save water that may be lost if water authorities fail to acknowledge the limits of water supply. If this is the case, higher economic output might indeed result in higher WP but also in higher water use, in line with the findings of Calzadilla et al. (2010), who showed that if water authorities do not address the river basin closure this may result in a trade-off between economic welfare and water use.

In conclusion, the necessary WP gains in the economy in order to preserve water resources without impairing GDP growth can be obtained in two different ways. In the case of closing or closed basins, it is necessary to implement the necessary reforms to limit and even reduce water use in agriculture, the main water consumer worldwide and the sector with a lowest WP, avoiding a negative cascade effect over production. This goal may be attained, for example, through the progressive implementation of demand side policies that allow an internalization of the costs of the resource and encourage a higher technical efficiency and WP. This paper contributes to this objective through the estimation of the market impact that could be expected from irrigation water restrictions as opposed to urban water restrictions. Second, relevant WP increases can be obtained as an economy develops towards a more secondary and tertiary structure, and this constitutes an opportunity to save water without impairing economic performance. This paper contributes to this objective through a first estimation of the

[6] In addition, there are recent studies that link higher WP values to quality improvements in water and reductions in sanitation costs (Perez et al. 2010).

relationship between WP and GDP growth, which nonetheless needs to be refined when further data is made available.

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