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Abstract:

This paper reports the results of an application using an interregional input-output matrix for Morocco together with regional information on water consumption by sectors. We develop a trade-based index that reveals the relative water use intensities associated with specific interregional and international trade flows. We estimate, for each flow associated with each origin-destination pair, measures of trade in value added and trade in water that are further used to calculate our index. We add to the existing literature on virtual water flows by encompassing the subnational perspective in the case study of a country that shows a "climate divide": while a great part of the southern territory is located in the Sahara Desert, with serious water constraints, the northern part is relatively more privileged with access to this natural resource. Furthermore, we compare that Trade-Based Index of Water Intensity to similar metrics related to the use of other natural resources.

Keywords: Water accounting; integrated ecologic-economic modelling; interregional input-output.

JEL Codes: Q25; Q56; C67; D57; R15.

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1. Introduction

Considered as one of the most poorly endowed countries in water resources, Morocco has intimately linked its economic and social development to the control of its natural resources. The country has developed strategies and policies aiming at the best management and valorization of such resources. It has built, in the last decades, a large system of hydropower infrastructure consisting of approximately 139 large dams, with a storage capacity of more than 17 billion m^3, and several transfer systems that allow the physical transposition of water to the driest areas (Ministry of Water, 2016).

These strategies have played a key role in food, water, and energy security for the population, particularly through improved access to drinking water and hydroelectric power, as well as protection against floods and droughts. Nevertheless, good governance of water resources requires continuing attention in Morocco, especially in the face of a significant increase in the demand for water and its multiple uses in the context of a growing population and an expanding economy (Global Nexus, 2017). Moreover, adding to the long-term changes to recent dry conditions in Morocco, global climate change is projected to increase the frequency, length and severity of drought episodes in the country, directly and indirectly compromising the living standards of the population (Esper et al., 2007; Masih et al., 2014; Imani et al., 2014; Roson and Sartori, 2015).

[1] We thank Abdelaaziz Ait Ali for useful comments and suggestions. We are also grateful to Denise Imori for research assistance.

In addition to physical relocation processes, interregional transfers of water resources also take place virtually through trade flows (Allan, 1993). Differences in water availability across the country enhance regional comparative advantage in resource-intensive sectors, such as agriculture, in water-rich areas (Wichelns, 2004; Duchin and López-Morales, 2012). Such differences are revealed in the structure of interregional trade, in which virtual water flows are associated with the resources embedded in the production chain of the traded goods.

Research on water accounting, mainly related to international trade flows, has boosted in the last few years with the development of worldwide input-output systems and the stronger concern with resources availability in the context of global climate change (Hoekstra and Hung, 2002; Dietzenbacher and Velázquez, 2007; Hoekstra and Chapagain, 2009; Feng et al., 2011; Daniels et al., 2011; Lenzen et al., 2013a; Tamea et al., 2016). Accountability of the pressure on the use of the world's natural resources has reached the political debate, as attempts to characterize countries according to their historical, current and expected role played in this process has reopened political fissures (Victor et al., 2014). Similarly to nations, regions within countries can also be characterized by their pressure on the demand for natural resources. As shown by Hoekstra and Chapagain (2009), local water depletion is often closely tied to the structure of the global economy. For regions within a country, the national economy adds another layer to the relevant structural hierarchy to understand resources uses (Zhang et al., 2016; Visentin, 2017).

This paper reports on the results of an application with an interregional input-output matrix for Morocco which allows calculating the total volume of water that is directly and indirectly embodied in specific trade flows. Thus, the concept of virtual water in this paper is defined within the input-output framework, which determines the virtual water content in one monetary unit of a given product (Dietzenbacher and Velázquez, 2007). The input-output system was developed as part of a technical cooperation initiative involving researchers from the Regional and Urban Economics Lab at the University of São Paulo (NEREUS), in Brazil, and the OCP Policy Center and the Department of Economic Studies and Financial Forecast (DESFF), under the Ministry of Economy and Finance, both in Morocco (Haddad et al., 2017). A fully specified interregional input-output database was estimated for 2013, considering 20 sectors in 12 Moroccan regions (IIOM-MOR). Using this database together with information on water consumption by sectors, we develop a trade-based index that reveals the relative water use intensities associated with interregional and international trade flows. We estimate, for each flow originated in one of the Moroccan regions, measures of trade in value added and trade in water that are further used to calculate our index. The parsimonious approach proposed in Los et al. (2016), based on "hypothetical extraction", serves as the methodological anchor. Results point to different ratios of water use to value added, not only when aggregate domestic trade flows are compared to Moroccan international exports, but also to differences within the country.

We add to the existing literature on virtual water flows by encompassing the intra-country perspective in the case study of a country that shows a "climate divide": while a great part of the southern territory is located in the Sahara Desert, with serious water constraints, the northern part is relatively more privileged with access to this natural resource. Few studies have analyzed virtual water flows in Morocco considering different perspectives. Schyns and Hoekstra (2014) carried out a detailed Water Footprint Assesment for Morocco. Using a bottom-up water footprint accounting approach, the authors were able to map the water footprint of different activities at river basin and monthly scale, distinguishing between surface- and groundwater. Boudhar et al. (2017) developed their study relying on a top-down approach based on input-output analysis. The authors used a national input–output model of water use to analyze the relationships between economic sectors and water resources use in Morocco (i.e. direct water use) as well as the intersectoral water relationships (i.e. indirect water use). The results provided insights on a categorization of sectors that exhibits higher direct water use and those with higher indirect water use. From a methodological standpoint, the differences between bottom-up and top-down approaches are due to inter-sectoral effects (Feng et al., 2011). While bottom-up approaches do not fully trace intersectoral linkages, top-down approaches, based on input-output techniques, are able to calculate the water footprint by tracing the whole supply chains. In this paper we have opted to follow a top-down approach, adding to previous work the integrated water-economic analysis of supply chains in an explicit regional (sub-national) setting.

In what follows, Section 2 presents different dimensions of regional disparities in Morocco, considering the geography of water and the spatial economic structure of the country. Section 3 describes the methodology to be used in Section 4 to measure interregional trade in value added and water in Morocco, while Section 5 concludes.

2. Dimensions of Regional Disparities in Morocco

2.1. The Geography of Water Resources

Located in Northern Africa, bordering the Mediterranean in the north and the Atlantic Ocean in the west, Morocco is characterized by diversified reliefs ranging from the mountains in the Rif and the Atlas, passing through plains and central plateaus, and ending in the south in a vast desert area. The heterogeneity observed at the level of the reliefs in Morocco has predestined the country to have a temperate climate marked by contrasts in space and time, and associated with increasing scarcity of water resources.

These natural physical constraints have forced the country to create the capability of storing water during periods of abundant rainfall for use during periods of scarcity, and to transfer water from the surplus basins of the northwest to the deficit basins of the center and the south. This mechanism allows the government to design an integral development plan for all regions of the country taking into consideration different dimensions of regional disparities. Moreover, these natural complexities are exacerbated by excessive evaporation, extensive evapotranspiration and also frequent periods of droughts that result from the impacts of climate variability, which tend to become even more intense in the context of global climate change.

Marked by evident space-temporal variability, rainfall in Morocco is gradually becoming scarce, going eastwards in the Mediterranean zone and towards the south in the Atlantic zone. In fact, the average annual national rainfall varies from 500-1000 mm in the northwest part of the country to less than 100 mm in the arid zones: (i) greater than 800 mm in the most rich area in terms of water resources located in the northwest; (ii) from 600 to 800 mm in the north and the Atlas zone; (iii) from 400 to 600 mm in the Sebou, Bouregreg and Oum Rbia areas; (iv) from 200 to 400 mm in the Tensift, Souss Massa and the Oriental areas; and (v) less than 200 mm in the southern Atlas areas and the Sahara.

According to the inventory of water resources in Morocco, it is estimated that 22 billion cubic meters of water can be mobilized of which 18 billion are surface water and 4 billion are extracting from groundwater (Table 1). In addition, close to 60% of the country's mobilizable surface water resources are located in the Atlantic and central basins, which account for less than one fifth of the territory. In contrast, the Saharan basins, which cover half of the country, account for less than 6% of total surface water availability.

Table 1. Geography of Surface Water Resources in Morocco

River basin	*Surface (km^2)*	*Surface water (Mm^3)*
Loukkos, Tangier, Mediterranean Coastal basins	12,800	3,600
Total for north basins	***12,800***	***3,600***
Moulouya, Figuig, Kert-Isly-Kiss	76,664	1,610
Total for East basins	***76,664***	***1,610***
Sebou	40,000	5,560
Bouregreg and Chaouïa	20,470	850
Oum Er Rbiâa, El Jadida and Safi	48,070	3,315
Tensift and Ksob-Igouzoulen	24,800	800
Total for Atlantic and central basins	***133,340***	***10,525***
Souss-Massa-Draa	126,480	1,444
Total for South Atlantic basins	***126,480***	***1,444***
Guir-Ziz-Rhéris	58,841	626
Sakia El Hamra and Oued Eddahab	302,725	390
Total for Saharan basins	***361,566***	***1,016***
Total	**710,850**	**18,195**

Source: Delegate Ministry in Charge of Water and the Environment, "Stratégie Nationale de l'Eau" (2009, p. 14)

Finally, as far as groundwater is concerned, the exploitable potential of groundwater amounts to about 4 billion m^3 per year. Throughout the Moroccan territory, more than 78 groundwater wells are identified. These water resources constitute an important part of the national water heritage and sometimes represent the only water resources of the desert regions. Although very rare, these resources participate actively to the economic development of the Saharan areas.

2.2. The Geography of Economic Activity

The use of a regionalization based on river basins is fundamental for studies dealing with impact assessment of the use of water resources on their availability to extract measures of sustainability (Visentin, 2017). Nonetheless, regionalization issues arise when one attempts to integrate other quantifiable dimensions for which data are collected under different geographical definitions. This is the case for regional economic statistics in Morocco, which are available for administrative divisions whose limits differ from those of the river basins. Given the twelve-region setting of the IIOM-MOR, and the nine-basin setting of the Moroccan watershed system, a one-to-one mapping is not available. Thus, a different regional perspective, based on administrative regions, will permeate the forthcoming analysis, to be also used throughout the rest of the paper.

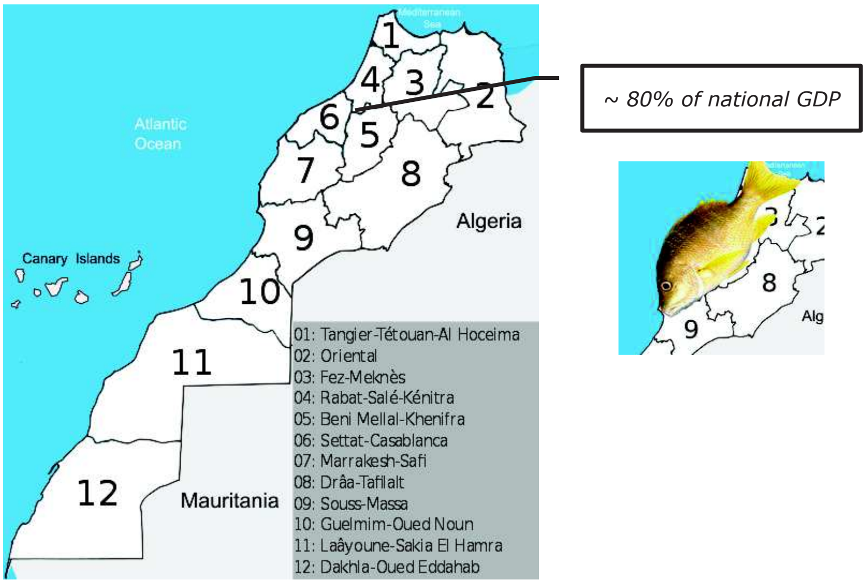
Information on the regional distribution of population and GDP (Table 2) shows Grand Casablanca-Settat as the prime region of the country. It concentrates 20% of the population and 30% of national GDP. Asymmetries in the distribution of the productive activity, with the primacy of Casablanca, serve to strengthen existing competitive advantages. Higher productivity levels are perceived mainly in the two largest urban agglomerations of the country, which present higher GDP shares than population shares. In a broader territorial context, the presence of other relevant industrial areas outside Casablanca reveals the economic core of the Moroccan economy comprising six of the twelve regions, namely, Tanger-Tetouan-Al Hoceima (R1), Fès-Meknès (R3), Rabat-Salé-Kénitra (R4), Béni Mellal-Khénifra (R5), Grand Casablanca-Settat (R6) and Marrakech-Safi (R7), which, together, are responsible for over 80% of the GDP. Given the fish-shaped-like cartographical representation of the territorial limits of this cluster, this set of regions is referred to as "the fish" (Figure 1).

Table 2. Basic Socioeconomic Indicators for Morocco, 2013

		Population (1,000)		GRP/GDP (in million DHS)		Per Capita GRP/GDP (in DHS)	
		2013	%	2013	%	2013	Share of national
R1	Tanger-Tetouan-Al Hoceima	3.344	10,15	65.373	7,95	19.551	0,78
R2	Oriental	2.219	6,73	52.031	6,33	23.449	0,94
R3	Fès-Meknès	4.257	12,92	81.145	9,87	19.061	0,76
R4	Rabat-Salé-Kénitra	4.674	14,19	123.331	15,01	26.385	1,06
R5	Béni Mellal-Khénifra	2.505	7,60	57.814	7,03	23.082	0,93
R6	Grand Casablanca-Settat	6.425	19,50	241.976	29,44	37.662	1,51
R7	Marrakech-Safi	4.289	13,02	91.593	11,14	21.355	0,86
R8	Drâa-Tafilalet	1.489	4,52	24.017	2,92	16.127	0,65
R9	Souss-Massa	2.684	8,15	55.228	6,72	20.576	0,82
R10	Guelmim-Oued Noun	455	1,38	10.643	1,30	23.398	0,94
R11	Laayoune-Sakia El Hamra	406	1,23	14.267	1,74	35.141	1,41
R12	Dakhla-Oued Eddahab	203	0,62	4.438	0,54	21.863	0,88
MOROCCO		32.950	100,00	821.856	100,00	24.943	1,00

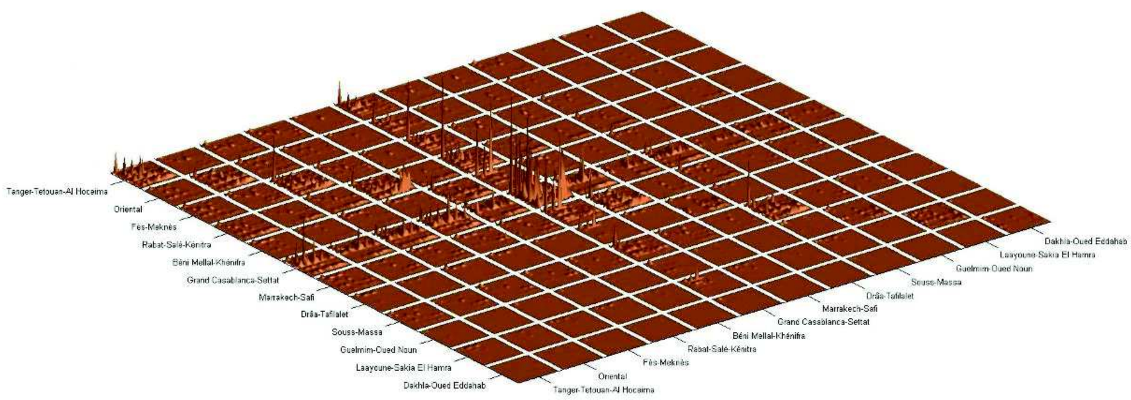
Source: High Commission for Planning and IIOM-MOR

Figure 1. Regional Setting in Morocco: Administrative Regions and the "Fish"



The IIOM-MOR is calibrated for 2013 and considers 12 regions and 20 sectors. Figure 2 shows, in monetary terms, how the flows of goods and services for production take place among the Moroccan regions: columns refer to the buying sectors and regions, and rows refer to the selling sectors and regions. The figure shows that, in productive terms, five relatively more integrated regions, all of them part of the "fish", concentrated most of the flows: Casablanca, Rabat, Marrakech, Fès-Meknès, and Tanger. As Table 3 indicates, these regions were responsible for more than 75% of the total output value of the Moroccan economy in 2013. For the remaining regions, there is practically little integration among them, with the production linkages taking place mainly inside each one of them, with some trade with Casablanca.

Figure 2. Interregional Flows of Goods and Services for Production in Morocco, 2013



Source: Prepared by the authors

Table 3 presents the regional output shares for the regions in Morocco. Casablanca dominates the national production, with a share of 35.7% in total output, followed by Rabat (13.0%), Marrakech (9.9%), Fès-Meknès (9.2%) and Tanger (8.8%). The regional output shares by sectors in Morocco reveal some evidence of spatial concentration of specific activities: agriculture in Fès-Meknès, Marrakech, Rabat, Casablanca, and Béni (69.7% of total output); fishing in Souss-Massa, Dakhla-Oued Eddahab, Guelmin-Oued Noun and Laayoune-Sakia Le Hamra (79.0%); mining in Béni and Marrakech (78.0%), manufacturing in Casablanca, where at least 50% of the output is generated for each of the sectors. Some regions play important roles in the production of specific manufacturing sectors, such as food industry in Souss-Massa (12.6%) and Fès-Meknès (9.9%); textile and leather in Tanger (21.3%) and Fès-Meknès (11.3%); and mechanical, metal and electrical products in Tanger (26.4%). Services, in general, are concentrated in Rabat and Casablanca. However, Marrakech and Souss-Massa concentrate the major part of tourism services (36.8% and 26.4%, respectively).

Table 4 shows the sectoral shares in regional output, revealing the important role of some activities in relatively specialized regions: the dominant role of agriculture in Drâa-Tafilalet (27.5% of total regional output), Béni (25.6%) and Fès-Meknès (21.7%); fishing in Dahla-Oued Eddahab (38.6%); mining in Béni (21.%); food industry in Souss-Massa (21.1%); and the relevance of the public administration in the more remote regions of the south: Guelmin-Oued Noun (28.0%), Laayoune-Sakia Le Hamra (27.7%) and Dakhla-Oued Eddahab (20.7%).

Relative regional specialization can also be assessed by the calculation of the sectoral location quotients, as presented in Table 5. The highlighted cells identify sectors relatively concentrated in specific regions, i.e. sectors for which their share in total regional output is greater than the respective shares in national output (location quotient greater than unit).

Table 3. Regional Structure of Sectoral Output: Morocco, 2013

		R1	*R2*	*R3*	*R4*	*R5*	*R6*	*R7*	*R8*	*R9*	*R10*	*R11*	*R12*	*TOTAL*
A00	Agriculture, forestry, hunting, related services	0.078	0.083	0.178	0.123	0.134	0.130	0.131	0.061	0.070	0.011	0.000	0.000	1.000
B05	Fishing, aquaculture	0.098	0.021	0.000	0.012	0.000	0.042	0.038	0.000	0.328	0.122	0.119	0.221	1.000
C00	Mining industry	0.000	0.030	0.005	0.019	0.508	0.002	0.271	0.089	0.001	0.000	0.075	0.000	1.000
D01	Food industry and tobacco	0.053	0.018	0.099	0.056	0.036	0.523	0.058	0.004	0.126	0.007	0.015	0.006	1.000
D02	Textile and leather industry	0.213	0.008	0.113	0.101	0.000	0.540	0.022	0.000	0.001	0.000	0.000	0.000	1.000
D03	Chemical and para-chemical industry	0.027	0.010	0.031	0.051	0.003	0.753	0.093	0.001	0.015	0.000	0.016	0.000	1.000
D04	Mechanical, metallurgical and electrical industry	0.264	0.043	0.044	0.084	0.005	0.541	0.006	0.000	0.011	0.000	0.000	0.000	1.000
D05	Other manufacturing, excluding petroleum refining	0.103	0.019	0.059	0.064	0.012	0.625	0.058	0.001	0.044	0.002	0.011	0.002	1.000
D06	Oil refining and other energy products	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
E00	Electricity and water	0.114	0.069	0.110	0.208	0.053	0.219	0.110	0.023	0.070	0.010	0.013	0.003	1.000
F45	Construction	0.121	0.096	0.089	0.128	0.067	0.201	0.147	0.059	0.059	0.009	0.023	0.002	1.000
G00	Trade	0.096	0.107	0.117	0.133	0.062	0.250	0.116	0.022	0.070	0.013	0.011	0.003	1.000
H55	Hotels and restaurants	0.071	0.028	0.064	0.041	0.009	0.120	0.368	0.028	0.264	0.002	0.002	0.002	1.000
I01	Transport	0.084	0.086	0.109	0.151	0.048	0.291	0.101	0.027	0.070	0.016	0.013	0.004	1.000
I02	Post and telecommunications	0.084	0.086	0.109	0.151	0.048	0.291	0.101	0.027	0.070	0.016	0.013	0.004	1.000
J00	Financial activities and insurance	0.050	0.050	0.063	0.214	0.027	0.436	0.086	0.013	0.049	0.006	0.005	0.001	1.000
K00	Real estate, renting and services to enterprises	0.050	0.050	0.063	0.214	0.027	0.436	0.086	0.013	0.049	0.006	0.005	0.001	1.000
L75	General public administration and social security	0.050	0.064	0.098	0.305	0.052	0.151	0.093	0.034	0.045	0.040	0.056	0.013	1.000
MNO	Education, health and social action	0.067	0.077	0.129	0.158	0.058	0.243	0.120	0.028	0.083	0.016	0.017	0.005	1.000
OP0	Other non-financial services	0.086	0.062	0.088	0.211	0.047	0.269	0.143	0.018	0.060	0.007	0.007	0.002	1.000
	TOTAL	0.088	0.056	0.092	0.130	0.058	0.357	0.099	0.025	0.064	0.011	0.015	0.005	1.000

Source: Haddad et al. (2017)

Table 4. Sectoral Structure of Regional Output: Morocco, 2013

		R1	*R2*	*R3*	*R4*	*R5*	*R6*	*R7*	*R8*	*R9*	*R10*	*R11*	*R12*	*TOTAL*
A00	Agriculture, forestry, hunting, related services	0.099	0.166	0.217	0.106	0.256	0.041	0.149	0.275	0.122	0.115	0.000	0.000	0.112
B05	Fishing, aquaculture	0.009	0.003	0.000	0.001	0.000	0.001	0.003	0.000	0.042	0.093	0.064	0.386	0.008
C00	Mining industry	0.000	0.013	0.001	0.004	0.219	0.000	0.069	0.090	0.000	0.000	0.122	0.000	0.025
D01	Food industry and tobacco	0.063	0.033	0.115	0.046	0.065	0.156	0.062	0.017	0.211	0.067	0.106	0.130	0.107
D02	Textile and leather industry	0.086	0.005	0.044	0.028	0.000	0.054	0.008	0.000	0.000	0.000	0.000	0.000	0.036
D03	Chemical and para-chemical industry	0.012	0.006	0.013	0.015	0.002	0.079	0.035	0.001	0.009	0.000	0.038	0.000	0.037
D04	Mechanical, metallurgical and electrical industry	0.210	0.054	0.034	0.046	0.007	0.106	0.004	0.001	0.012	0.000	0.002	0.000	0.070
D05	Other manufacturing, excluding petroleum refining	0.055	0.016	0.030	0.023	0.010	0.083	0.028	0.003	0.032	0.009	0.034	0.016	0.047
D06	Oil refining and other energy products	0.000	0.000	0.000	0.000	0.000	0.088	0.000	0.000	0.000	0.000	0.000	0.000	0.031
E00	Electricity and water	0.027	0.026	0.025	0.034	0.019	0.013	0.024	0.020	0.023	0.019	0.018	0.012	0.021
F45	Construction	0.112	0.139	0.079	0.080	0.094	0.046	0.122	0.193	0.076	0.070	0.121	0.039	0.082
G00	Trade	0.084	0.148	0.098	0.079	0.083	0.054	0.091	0.068	0.085	0.092	0.054	0.049	0.078
H55	Hotels and restaurants	0.017	0.010	0.015	0.007	0.003	0.007	0.079	0.023	0.088	0.004	0.003	0.010	0.021
I01	Transport	0.040	0.064	0.049	0.048	0.035	0.034	0.043	0.045	0.046	0.062	0.034	0.033	0.042
I02	Post and telecommunications	0.021	0.035	0.027	0.026	0.019	0.018	0.023	0.024	0.025	0.033	0.019	0.018	0.022
J00	Financial activities and insurance	0.023	0.037	0.028	0.067	0.019	0.050	0.035	0.022	0.031	0.021	0.014	0.013	0.041
K00	Real estate, renting and services to enterprises	0.041	0.065	0.050	0.120	0.034	0.089	0.063	0.039	0.055	0.038	0.024	0.023	0.073
L75	General public administration and social security	0.043	0.086	0.081	0.179	0.068	0.032	0.072	0.103	0.054	0.280	0.277	0.207	0.076
MNO	Education, health and social action	0.045	0.081	0.083	0.072	0.059	0.041	0.072	0.067	0.077	0.088	0.064	0.060	0.059
OP0	Other non-financial services	0.011	0.012	0.011	0.018	0.009	0.009	0.016	0.008	0.011	0.008	0.005	0.005	0.011
	TOTAL	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Source: Haddad et al. (2017)

Table 5. Location Quotients: Morocco, 2013

		R1	*R2*	*R3*	*R4*	*R5*	*R6*	*R7*	*R8*	*R9*	*R10*	*R11*	*R12*
A00	Agriculture, forestry, hunting, related services	0.882	1.482	1.939	0.951	2.290	0.363	1.332	2.457	1.093	1.031	0.000	0.000
B05	Fishing, aquaculture	1.111	0.365	0.000	0.089	0.000	0.116	0.390	0.000	5.139	11.275	7.737	46.896
C00	Mining industry	0.000	0.529	0.056	0.148	8.713	0.005	2.753	3.573	0.012	0.000	4.854	0.000
D01	Food industry and tobacco	0.596	0.312	1.081	0.432	0.613	1.464	0.584	0.158	1.978	0.631	0.999	1.217
D02	Textile and leather industry	2.414	0.149	1.230	0.782	0.008	1.513	0.227	0.000	0.011	0.000	0.000	0.000
D03	Chemical and para-chemical industry	0.310	0.171	0.337	0.395	0.050	2.110	0.938	0.026	0.242	0.000	1.026	0.002
D04	Mechanical, metallurgical and electrical industry	2.995	0.762	0.479	0.649	0.094	1.514	0.063	0.019	0.176	0.000	0.027	0.003
D05	Other manufacturing, excluding petroleum refining	1.171	0.342	0.637	0.492	0.212	1.751	0.584	0.059	0.683	0.192	0.711	0.334
D06	Oil refining and other energy products	0.000	0.000	0.000	0.000	0.000	2.800	0.000	0.000	0.000	0.000	0.000	0.000
E00	Electricity and water	1.286	1.218	1.193	1.601	0.902	0.612	1.120	0.943	1.093	0.880	0.866	0.586
F45	Construction	1.368	1.704	0.968	0.983	1.149	0.562	1.491	2.357	0.928	0.857	1.485	0.473
G00	Trade	1.089	1.905	1.267	1.022	1.069	0.701	1.177	0.879	1.100	1.188	0.697	0.630
H55	Hotels and restaurants	0.810	0.495	0.694	0.316	0.152	0.337	3.735	1.108	4.138	0.174	0.148	0.473
I01	Transport	0.956	1.536	1.183	1.164	0.828	0.814	1.024	1.077	1.097	1.488	0.827	0.794
I02	Post and telecommunications	0.956	1.536	1.183	1.164	0.828	0.814	1.024	1.077	1.097	1.488	0.827	0.794
J00	Financial activities and insurance	0.567	0.897	0.682	1.648	0.466	1.220	0.870	0.541	0.760	0.527	0.334	0.314
K00	Real estate, renting and services to enterprises	0.567	0.897	0.682	1.648	0.466	1.220	0.870	0.541	0.760	0.527	0.334	0.314
L75	General public administration and social security	0.565	1.129	1.069	2.347	0.888	0.423	0.947	1.356	0.706	3.681	3.634	2.715
MNO	Education, health and social action	0.759	1.365	1.402	1.218	0.989	0.682	1.214	1.128	1.299	1.475	1.085	1.018
OP0	Other non-financial services	0.973	1.104	0.956	1.628	0.798	0.754	1.447	0.739	0.932	0.685	0.444	0.417

Source: Haddad et al. (2017)

3. Methodology

The analysis in the previous section has revealed distinct spatial regimes associated with both the geography of water resources and the geography of economic activity in Morocco. On one hand, the climate divide, heavily influenced by the physical barrier established by the Atlas mountain range, affects regional water availability, creating regionally differentiated comparative advantage on water-resource-intensive sectors. On the other hand, the regional distribution of economic activity and population creates a complex structure of supply and demand in space that helps shaping the geography of trade flows and domestic value chains (Meng et al., 2017).

In a context in which interregional physical transfers of water do not suffice to respond to specific regional needs, what role do virtual water trade flows play? Coming up with appropriate methods to measure interregional trade in water may be deem important for water management in a country like Morocco, characterized by a very heterogeneous availability across its regions. Thus, in this Section, we describe the methodology to be applied in the calculation of our trade-based index of water intensity. It takes into consideration important elements of an integrated interregional system and the demand of natural resources, namely information on the adopted technology by different sectors in the form of input-output linkages, the specific regional economic structures, the structure of interregional and international trade flows, and information on water consumption by sectors.

3.1. Background

Los et al. (2016) have proposed a decomposition of gross exports based on the "hypothetical extraction" (HE) methodology, which allows verifying how much domestic value added is included in a country's exports. They have provided a measurement of domestic value added in exports based on global and national input-output tables.

In the case of national interregional input-output tables, with *n* regions, the ideal framework to evaluate the domestic value added in exports would be to have a global input-output table where the national system is inserted in a global multi-regional model. However, such a system would demand a large amount of information, such as trade flows from each sector in each region to each sector in the Rest of the World (RoW) and vice versa. Thus, given the scarcity of these data, we will follow an alternative approach in which we will consider the RoW as an exogenous region, i.e. as a column vector in the final demand of a national interregional system.

Following the methodology presented by Los et al. (2016), we will then make the calculation of domestic value added in exports (DVA) based on a national interregional input-output system with exports to the RoW exogenously specified. Furthermore, by the same logic, we will be able to measure domestic traded water in exports (DTW). Finally, using both measures, we will calculate a *Trade-Based Index of Water Intensity*.

3.2. Measurement of Domestic Value Added in Exports

The input-output model can be expressed by

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{f} \qquad (1)$$

and

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} = \mathbf{L}\mathbf{f} \qquad (2)$$

where $\mathbf{x}$ and $\mathbf{f}$ are the vectors of gross output and final demand; $\mathbf{A}$ is a matrix with the input coefficients (a_{ij}); $\mathbf{I}$ is the identity matrix; and $\mathbf{L}$ is the Leontief inverse.[2]

Considering a national interregional input-output model with *n* different regions and the RoW as a column vector in the final demand, (1) and (2) can be represented as

$$\begin{bmatrix} \mathbf{x}^1 \\ \vdots \\ \mathbf{x}^n \end{bmatrix} = \begin{bmatrix} \mathbf{A}^{11} & \cdots & \mathbf{A}^{1n} \\ \vdots & \ddots & \vdots \\ \mathbf{A}^{n1} & \cdots & \mathbf{A}^{nn} \end{bmatrix} \begin{bmatrix} \mathbf{x}^1 \\ \vdots \\ \mathbf{x}^n \end{bmatrix} + \begin{bmatrix} \mathbf{f}^{11} & \cdots & \mathbf{f}^{1n} & \mathbf{f}^{1row} \\ \vdots & \ddots & \vdots & \vdots \\ \mathbf{f}^{n1} & \cdots & \mathbf{f}^{nn} & \mathbf{f}^{nrow} \end{bmatrix} \mathbf{i} \qquad (3)$$

and

[2] See Miller and Blair (2009) for more details.

$$\begin{bmatrix}\mathbf{x}^1\\ \vdots\\ \mathbf{x}^n\end{bmatrix} = \left\{\begin{bmatrix}\mathbf{I} & \cdots & \mathbf{0}\\ \vdots & \ddots & \vdots\\ \mathbf{0} & \cdots & \mathbf{I}\end{bmatrix} - \begin{bmatrix}\mathbf{A}^{11} & \cdots & \mathbf{A}^{1n}\\ \vdots & \ddots & \vdots\\ \mathbf{A}^{n1} & \cdots & \mathbf{A}^{nn}\end{bmatrix}\right\}^{-1} \begin{bmatrix}\mathbf{f}^{11} & \cdots & \mathbf{f}^{1n} & \mathbf{f}^{1row}\\ \vdots & \ddots & \vdots & \vdots\\ \mathbf{f}^{n1} & \cdots & \mathbf{f}^{nn} & \mathbf{f}^{nrow}\end{bmatrix}\mathbf{i}$$

$$= \begin{bmatrix}\mathbf{L}^{11} & \cdots & \mathbf{L}^{1n}\\ \vdots & \ddots & \vdots\\ \mathbf{L}^{n1} & \cdots & \mathbf{L}^{nn}\end{bmatrix} \begin{bmatrix}\mathbf{f}^{11} & \cdots & \mathbf{f}^{1n} & \mathbf{f}^{1row}\\ \vdots & \ddots & \vdots & \vdots\\ \mathbf{f}^{n1} & \cdots & \mathbf{f}^{nn} & \mathbf{f}^{nrow}\end{bmatrix}\mathbf{i} \quad (4)$$

where $\mathbf{i}$ is a column vector with all elements equal unity which sums all elements in each of the n+1 rows of the matrix $\mathbf{f}$.

Following Los et al. (2016), the value added in region 1 (GDP_1) can be expressed as

$$GDP_1 = \mathbf{v}_1(\mathbf{I} - \mathbf{A})^{-1}\mathbf{f}\mathbf{i} \quad (5)$$

where $\mathbf{v}_1$ is a row vector with ratios of value added to gross output in industries in region 1 as first elements ($\tilde{\mathbf{v}}_1$) and zeros elsewhere ($\mathbf{v}_1 = [\tilde{\mathbf{v}}_1 \quad \mathbf{0}]$); and $\mathbf{i}$ is a column vector which all elements are unity.

In order to attribute the amount of domestic value added in exports from region 1 to region n, as proposed by Los et al. (2016), we consider a hypothetical world where region 1 does not export anything to region n. In this case, the new GDP or hypothetical GDP can be represented by

$$GDP_{1,n}^{*} = \mathbf{v}_1(\mathbf{I} - \mathbf{A}_{1,n}^{*})^{-1}\mathbf{f}_{1,n}^{*}\mathbf{i} \quad (6)$$

where $\mathbf{A}_{1,n}^{*}$ and $\mathbf{f}_{1,n}^{*}$ are the hypothetical matrix of input coefficients and final demand, respectively, expressed as

$$\mathbf{A}_{1,n}^{*} = \begin{bmatrix}\mathbf{A}^{11} & \cdots & \mathbf{0}\\ \vdots & \ddots & \vdots\\ \mathbf{A}^{n1} & \cdots & \mathbf{A}^{nn}\end{bmatrix} \quad (7)$$

$$\mathbf{f}_{1,n}^{*} = \begin{bmatrix}\mathbf{f}^{11} & \cdots & \mathbf{0} & \mathbf{f}^{1row}\\ \vdots & \ddots & \vdots & \vdots\\ \mathbf{f}^{n1} & \cdots & \mathbf{f}^{nn} & \mathbf{f}^{nrow}\end{bmatrix} \quad (8)$$

In addition, in order to attribute the amount of domestic value added in exports from region 1 to the RoW, we consider a hypothetical world where region 1 does not export to the RoW. In this case, the hypothetical GDP can be represented as

$$GDP_{1,row}^{*} = \mathbf{v}_1(\mathbf{I} - \mathbf{A})^{-1}\mathbf{f}_{1,row}^{*}\mathbf{i} \tag{9}$$

where $\mathbf{A}$ is the original matrix with the input coefficients as in (5); and $\mathbf{f}_{1,row}^{*}$ is the hypothetical matrix of final demand, expressed as

$$\mathbf{f}_{1,row}^{*} = \begin{bmatrix} \mathbf{f}^{11} & \cdots & \mathbf{f}^{1n} & \mathbf{0} \\ \vdots & \ddots & \vdots & \vdots \\ \mathbf{f}^{n1} & \cdots & \mathbf{f}^{nn} & \mathbf{f}^{nrow} \end{bmatrix} \tag{10}$$

From (5) and (6), we can define the domestic value added in exports (DVA) from region 1 to region *n* as follows:

$$DVA_{1,n} = GDP_1 - GDP_{1,n}^{*} \tag{11}$$

and, from (5) and (9), we can define DVA in exports from region 1 to the RoW as

$$DVA_{1,row} = GDP_1 - GDP_{1,row}^{*} \tag{12}$$

Similarly, we can attribute the amount of domestic value added in exports from region 1 to all regions (2, 3, …, *n*), and from each region to the *n*-regions (1, 2, …, *n*), excluding itself. We can also attribute the DVA from each region to the RoW. In this sense, in an interregional system with *n* regions and the RoW exogenous, we have *n* DVA in exports for each region, as illustrated in Table 5.

Table 5. Domestic Value Added in Exports (DVA)

Hypothetical no export	to					
from	R_1	R_2	…	R_{n-1}	R_n	RoW
R_1		$DVA_{1,2}$	…	$DVA_{1,n-1}$	$DVA_{1,n}$	$DVA_{1,row}$
R_2	$DVA_{2,1}$		…	$DVA_{2,n-1}$	$DVA_{2,n}$	$DVA_{2,row}$
⋮	⋮	⋮		⋮	⋮	⋮
R_{n-1}	$DVA_{n-1,1}$	$DVA_{n-1,2}$	…		$DVA_{n-1,n}$	$DVA_{n-1,row}$
R_n	$DVA_{n,1}$	$DVA_{n,2}$	…	$DVA_{n,n-1}$		$DVA_{n,row}$

3.3. Measurement of Domestic Traded Water in Exports

Following the logic of the GDP, we can determine the total traded water (TTW) in region 1 as

$$TTW_1 = \mathbf{w}_1(\mathbf{I} - \mathbf{A})^{-1}\mathbf{fi} \tag{13}$$

where $\mathbf{w}_1$ is a row vector with water use in industries in region 1 as first elements ($\widetilde{\mathbf{w}}_1$) and zeros elsewhere ($\mathbf{w}_1 = [\widetilde{\mathbf{w}}_1 \quad \mathbf{0}]$); and $\mathbf{i}$ is a column vector which all elements are unity.

In order to attribute the amount of water in exports from region 1 to region *n*, we consider, similarly to (6), a hypothetical world where region 1 does not export anything to region *n*, which allows us to represent the hypothetical total traded water by

$$TTW_{1,n}^* = \mathbf{w}_1(\mathbf{I} - \mathbf{A}_{1,n}^*)^{-1}\mathbf{f}_{1,n}^*\mathbf{i} \tag{14}$$

where $\mathbf{A}_{1,n}^*$ and $\mathbf{f}_{1,n}^*$ are expressed as (7) and (8), respectively.

And to attribute the amount of water in exports from region 1 to the RoW, we consider, similarly to (9), a hypothetical world where region 1 does not export anything to the RoW, represented by

$$TTW_{1,row}^* = \mathbf{w}_1(\mathbf{I} - \mathbf{A})^{-1}\mathbf{f}_{1,row}^*\mathbf{i} \tag{15}$$

where **A** is a matrix with the input coefficients as in (5); and $\mathbf{f}^*_{1,row}$ is expressed as (10).

From (13) and (14), we can define the domestic total traded water in exports (DTW) from region 1 to region *n* as

$$DTW_{1,n} = TTW_1 - TTW^*_{1,n} \tag{16}$$

And, from (13) and (15), we can define the DTW in exports from region 1 to the RoW as

$$DTW_{1,row} = TTW_1 - TTW^*_{1,row} \tag{17}$$

In a similar fashion, we can attribute the amount of domestic total traded water in exports from region 1 to all regions (2, 3, …, *n*) and from each region to the *n*-regions (1, 2, …, *n*), excluding itself, and from each region to the RoW. In the same sense than DVA, we have *n* DTW for each region, as illustrated in Table 6.

Table 6. Domestic Total Traded Water in Exports (DTW)

Hypothetical no export	to					
from	R_1	R_2	…	R_{n-1}	R_n	RoW
R_1		$DTW_{1,2}$	…	$DTW_{1,n-1}$	$DTW_{1,n}$	$DTW_{1,row}$
R_2	$DTW_{2,1}$		…	$DTW_{2,n-1}$	$DTW_{2,n}$	$DTW_{2,row}$
□	□	□		□	□	□
R_{n-1}	$DTW_{n-1,1}$	$DTW_{n-1,2}$	…		$DTW_{n-1,n}$	$DTW_{n-1,row}$
R_n	$DTW_{n,1}$	$DTW_{n,2}$	…	$DTW_{n,n-1}$		$DTW_{n,row}$

3.4. Trade-Based Index of Water Intensity

The Trade-Based Index of Water Intensity (TWI) is based on the information on domestic value added in exports (DVA) and domestic total traded water in exports (DTW). The index calculation considers three steps. First, we calculate the relative importance of each domestic value added in export (I^{DVA}) inside the whole economy by computing the ratio of each DVA to the sum of all of them, expressed as

$$I_{n,k}^{DVA} = \frac{DVA_{n,k}}{\left[\sum_{i=1}^{n}\sum_{j=1}^{k} DVA_{n,k} + \sum_{i=1}^{n} DVA_{n,row}\right]}, \; i = 1, 2, \dots, n;\; j = 1, 2, \dots, k;\; \forall k \neq n \quad (18)$$

and

$$I_{n,row}^{DVA} = \frac{DVA_{n,row}}{\left[\sum_{i=1}^{n}\sum_{j=1}^{k} DVA_{n,k} + \sum_{i=1}^{n} DVA_{n,row}\right]}, \; i = 1, 2, \dots, n;\; j = 1, 2, \dots, k;\; \forall k \neq n \quad (19)$$

where *n* and *k* are the number of regions.

In this case, we have *n* I^{DVA} for each region, as illustrated in Table 7.

Table 7. Relative Importance of each DVA in the Whole Economy (step 1)

Hypothetical no export	to					
from	R_1	R_2	…	R_{n-1}	R_n	RoW
R_1		$I_{1,2}^{DVA}$	…	$I_{1,n-1}^{DVA}$	$I_{1,n}^{DVA}$	$I_{1,row}^{DVA}$
R_2	$I_{2,1}^{DVA}$		…	$I_{2,n-1}^{DVA}$	$I_{2,n}^{DVA}$	$I_{2,row}^{DVA}$
⋮	⋮	⋮		⋮	⋮	⋮
R_{n-1}	$I_{n-1,1}^{DVA}$	$I_{n-1,2}^{DVA}$	…		$I_{n-1,n}^{DVA}$	$I_{n-1,row}^{DVA}$
R_n	$I_{n,1}^{DVA}$	$I_{n,2}^{DVA}$	…	$I_{n,n-1}^{DVA}$		$I_{n,row}^{DVA}$

Second, by the same logic, we can calculate the relative importance of domestic total traded water in exports (I^{DTW}) inside the whole economy by computing the ratio of each DTW to the sum of all of them, expressed as

$$I_{n,k}^{DTW} = \frac{DTW_{n,k}}{\left[\sum_{i=1}^{n}\sum_{j=1}^{k} DTW_{n,k} + \sum_{i=1}^{n} DTW_{n,row}\right]}, \; i = 1, 2, \dots, n;\; j = 1, 2, \dots, k;\; \forall k \neq n \quad (20)$$

and

$$I_{n,row}^{DTW} = \frac{DTW_{n,row}}{\left[\sum_{i=1}^{n}\sum_{j=1}^{k} DTW_{n,k} + \sum_{i=1}^{n} DTW_{n,row}\right]}, \; i = 1, 2, \dots, n; \; j = 1, 2, \dots, k; \; \forall k \neq n \quad (21)$$

where *n* and *k* are the number of regions.

In this case, we have *n* I^{DVA} for each region, as illustrated in Table 8.

Table 8. Relative Importance of each DTW in the Whole Economy (step 2)

Hypothetical no export	to					
from	R_1	R_2	…	R_{n-1}	R_n	RoW
R_1		$I_{1,2}^{DTW}$	…	$I_{1,n-1}^{DTW}$	$I_{1,n}^{DTW}$	$I_{1,row}^{DTW}$
R_2	$I_{2,1}^{DTW}$		…	$I_{2,n-1}^{DTW}$	$I_{2,n}^{DTW}$	$I_{2,row}^{DTW}$
□	□	□		□	□	□
R_{n-1}	$I_{n-1,1}^{DTW}$	$I_{n-1,2}^{DTW}$	…		$I_{n-1,n}^{DTW}$	$I_{n-1,row}^{DTW}$
R_n	$I_{n,1}^{DTW}$	$I_{n,2}^{DTW}$	…	$I_{n,n-1}^{DTW}$		$I_{n,row}^{DTW}$

Finally, in the third step, we calculate the Trade-Based Index of Water Intensity (TWI) as follows

$$TWI_{n,k} = {I_{n,k}^{DTW}} \Big/ {I_{n,k}^{DVA}}, \; i = 1, 2, \dots, n; \; j = 1, 2, \dots, k; \; \forall k \neq n \quad (22)$$

and

$$TWI_{n,row} = {I_{n,row}^{DTW}} \Big/ {I_{n,row}^{DVA}}, \; i = 1, 2, \dots, n; \; j = 1, 2, \dots, k; \; \forall k \neq n \quad (23)$$

As before, we have *n* TWI for each region, as illustrated in Table 9.

Table 9. Trade-Based Index of Water Intensity (step 3)

Hypothetical no export	to					
from	R_1	R_2	…	R_{n-1}	R_n	RoW
R_1		$TWI_{1,2}$	…	$TWI_{1,n-1}$	$TWI_{1,n}$	$TWI_{1,row}$
R_2	$TWI_{2,1}$		…	$TWI_{2,n-1}$	$TWI_{2,n}$	$TWI_{2,row}$
⋮	⋮	⋮		⋮	⋮	⋮
R_{n-1}	$TWI_{n-1,1}$	$TWI_{n-1,2}$	…		$TWI_{n-1,n}$	$TWI_{n-1,row}$
R_n	$TWI_{n,1}$	$TWI_{n,2}$	…	$TWI_{n,n-1}$		$TWI_{n,row}$

The TWI can be interpreted as follows:

(i) if **greater** than 1, in that particular trade flow the region is more intensive in domestic total traded water in exports than in domestic value added in exports; and
(ii) if **lower** than 1, the opposite.

4. Analysis

4.1. Data

The methodology described in Section 3 relies on the use of an interregional input-output system linked to a water accounting system. We illustrate the calculation of the TWI using data for Morocco. We use the IIOM-MOR, a fully specified interregional input-output database estimated for 2013, together with total water sectoral use coefficients from Eora (Lenzen et al., 2012, 2013b).[3] Despite the fact that water consumption within a given activity differs across regions in Morocco (Schyns and Hoekstra, 2014), data availability precludes the use of regionally differentiated sectoral use coefficients in this study.

[3] Eora is a multi-region input-output table (MRIO) database that provides a time series of high resolution IO tables with matching environmental and social satellite accounts for 187 countries.

In Eora, total water use (in m^3), or total water footprint[4], is available for 26 Moroccan sectors[5], and the information includes different components, namely, (i) water footprint by crop demand; (ii) water footprint of grazing (green water); (iii) water footprint of animal supply (blue); and (iv) water footprint of industrial production and water footprint of domestic water supply (grey). The consolidated information is presented in Table 10, in which the adjusted coefficients are presented in m^3 per million DHS. The top sector in terms of direct water use is Agriculture, forestry, hunting, related activities (A00), whose total water use is mainly concentrated in the crop water use component. Food industry and tobacco (D01) is also a heavy user, with important shares of crop water and blue water use. Other manufacturing, excluding petroleum refining (D05) is also an important user, dominated by the blue water use component.

Table 10. Coefficients of Water Use by Sector: Morocco, 2013

Sectors		*Water use (m^3 /GO in 1,000,000 DHS)*				
		Crop Water	*Blue Water*	*Green Water*	*Grey Water*	*Total*
A00	Agriculture, forestry, hunting, related services	189,116.14	12,113.38	281.99	27.90	201,539.39
B05	Fishing, aquaculture	0.00	5,612.29	127.25	0.00	5,739.54
C00	Mining industry	0.00	0.00	8.18	31.09	39.27
D01	Food industry and tobacco	31,942.30	22,984.21	535.05	52.94	55,514.49
D02	Textile and leather industry	163.43	0.00	21.65	82.28	267.37
D03	Chemical and para-chemical industry	0.00	0.00	28.05	106.58	134.63
D04	Mechanical, metallurgical and electrical industry	0.00	0.00	45.32	172.20	217.51
D05	Other manufacturing, excluding petroleum refining	0.00	11,165.40	292.73	150.39	11,608.52
D06	Oil refining and other energy products	0.00	0.00	28.05	106.58	134.63
E00	Electricity and water	0.00	0.00	17.55	66.69	84.24
F45	Construction	0.00	0.00	0.00	0.00	0.00
G00	Trade	0.00	0.00	0.00	0.00	0.00
H55	Hotels and restaurants	0.00	0.00	0.00	0.00	0.00
I01	Transport	0.00	0.00	0.00	0.00	0.00
I02	Post and telecommunications	0.00	0.00	0.00	0.00	0.00
J00	Financial activities and insurance	0.00	0.00	10.53	40.00	50.53
K00	Real estate, renting and services to enterprises	0.00	0.00	10.53	40.00	50.53
L75	General public administration and social security	0.00	0.00	0.00	0.00	0.00
MNO	Education, health and social action	0.00	0.00	0.00	0.00	0.00
OP0	Other non-financial services	0.00	0.00	0.00	0.00	0.00

Source: Eora and IIOM-MOR

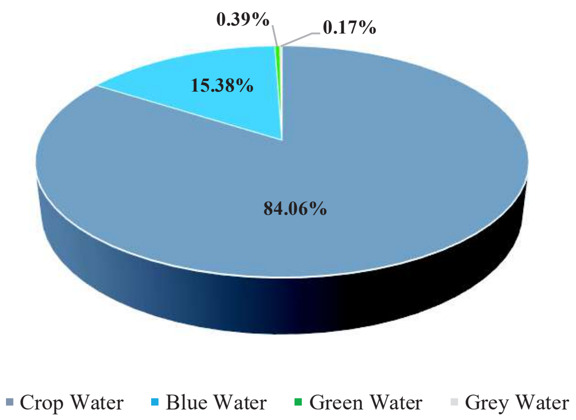
[4] "The term 'virtual water' refers exclusively to indirect consumption, while the term 'water footprint' includes both direct use (e.g. turning on the faucet at home or drinking imported Perrier) and indirect use." (Lenzen et al., 2013a).

[5] The version of the model used in this paper is Eora26 MRIO, which aggregates all countries to a common 26-sector classification and converts the supply-use tables from the full Eora MRIO to symmetric product-by-product IO tables using the Industry Technology Assumption. This version is compatible with the procedures used to build the IIOM-MOR and a simple mapping was used to consolidate Moroccan data from the 26 sectors in Eora26 MRIO to the 20 sectors in IIOM-MOR.

4.2. Results

We have first computed the values of Table 6 (DTW), with the domestic total traded water in interregional and international exports originating in each of the twelve Moroccan regions. To grasp the relevance of each type of water use, we have decomposed total water use into its four different components according to information in Table 10. We have generated the results based on equations (16) and (17) by using such information to construct the row vectors of type *t* sectoral water use in region *r*, $\mathbf{w}_r^t$. Aggregate results are presented in Figure 3 showing that the overall use of domestic resources embodied in trade flows is mainly associated with crop water requirements (84.06% of total traded water), followed by the use of ground or surface water, i.e. blue water, that accounts for 15.38% of the total.

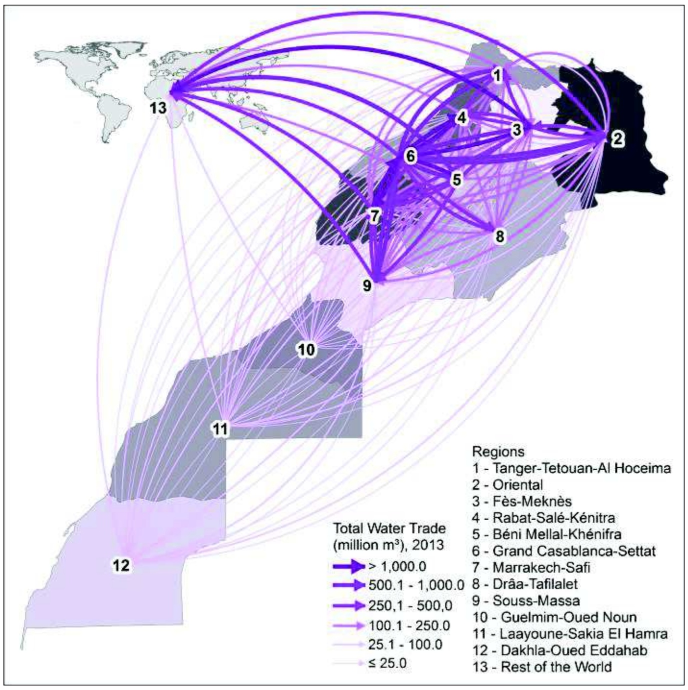
Figure 3. Composition of Domestic Total Traded Water in Exports (DTW)



We can map the results obtained from Table 6[6] to visualize the geography of domestic traded water in Morocco. Figure 4 depicts the "shipments" of virtual water from each origin to all destinations, both domestic and foreign. It also shows the magnitude of the flows with lines of proportional thickness.

[6] The forthcoming analysis is concentrated in total water use.

Figure 4. Total Traded Water in Exports (DTW)



We have also computed the values of the elements presented in Table 5 (DVA), which provide the estimates of the value added content in each export flow originating in Moroccan regions. Table 11 presents the aggregate results for both regional traded value added and regional total traded water embodied in regional exports, by main destinations. Overall, the amount of total water embodied in interregional exports surpasses that of foreign exports in the Moroccan case in a ratio of 6.4 to 1, i.e. for each m^3 of virtual water in foreign exports, 6.4 m^3 were traded within the country. Nonetheless, this ratio varies across exporting regions, ranging from 0.3 in Dakhla-Oued Eddahab, and 0.9 in Laayoune-Sakia El Hamra, both regions in the Sahara, to 16.5 in Grand Casablanca-Settat, and 28.2 in Rabat-Salé-Kénitra, the two largest urban agglomerations in Morocco.

Comparing the regional share of value added in total exports to the regional share of total traded water, we see that the contributions to value added by Laayoune-Sakia El Hamra, Dakhla-Oued Eddahab, Grand Casablanca-Settat, Tanger-Tetouan-Al Hoceima, and Rabat-Salé-Kénitra exceed their respective contributions to water. As described in Section 2, these regions are associated with relative scarcity of water resources due to their structural characteristics. Relative abundance (or scarcity) of factors of production may arise from both supply and demand considerations. In our case, the scarcity of water in the Sahara explains the results for Laayoune and Dakhla. In the case of the second subset of regions, associated with the cities of Casablanca, Tanger, and Rabat, on one hand, the relative scarcity of water is associated with high levels of demand due to urbanization and the important presence of manufacturing activities. On the other hand, these regions face strong agglomeration economies that potentially generate high productivity levels of capital and labor, partially explaining, from the supply side, the relative higher value added shares in trade flows originating in these areas.

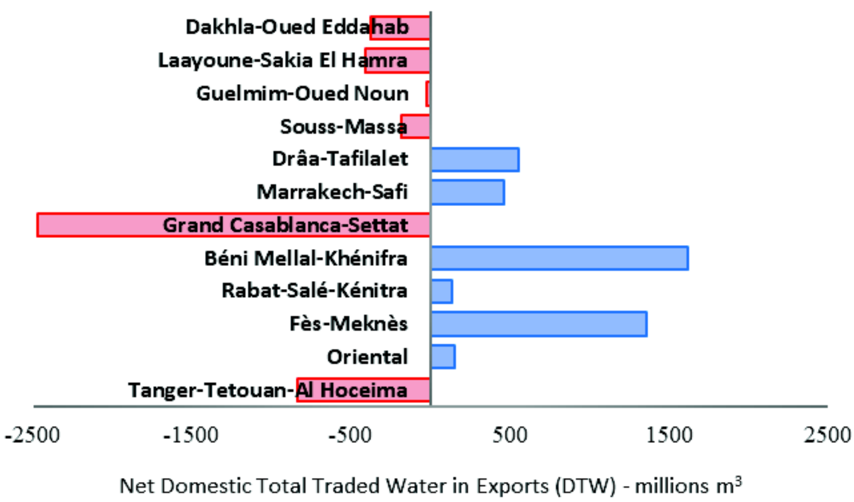
This result is in agreement with the Heckscher-Ohlin model, which predicts patterns of trade and production based on the factor endowments of a trading region: each region exports the good that makes relatively intensive use of its relatively abundant factor. Differences in factor endowments lead to differences in autarky prices, generating comparative advantage to regions where factors are relatively abundant. Since goods can be traded more cheaply than factors – factors are usually more costly to move – trade can at least partly alleviate factor scarcity. Thus, regions can import their scarce factor services embodied in goods. This seems to be the case in domestic trade within Morocco, when comparing the content of water in regional exports to that of aggregate payments to capital and labor (value added).

Table 11. Regional Traded Value Added and Water in Exports, by Destination

Region	*Value Added (million DHS)*				*Water (million m^3)*			
	Domestic	*Foreign*	*Total*	*%*	*Domestic*	*Foreign*	*Total*	*%*
Tanger-Tetouan-Al Hoceima	16.708	12.863	29.571	6,95	1.710	209	1.919	5,88
Oriental	14.857	5.426	20.283	4,77	1.707	278	1.985	6,08
Fès-Meknès	29.992	6.000	35.992	8,46	4.014	1.259	5.272	16,15
Rabat-Salé-Kénitra	45.848	9.029	54.876	12,89	3.538	126	3.664	11,22
Béni Mellal-Khénifra	24.622	11.228	35.850	8,42	3.144	871	4.015	12,30
Grand Casablanca-Settat	107.971	49.529	157.501	37,00	7.174	435	7.609	23,31
Marrakech-Safi	37.912	4.871	42.783	10,05	3.284	357	3.641	11,15
Drâa-Tafilalet	8.992	1.162	10.154	2,39	1.333	244	1.577	4,83
Souss-Massa	23.683	2.927	26.611	6,25	2.047	462	2.509	7,69
Guelmim-Oued Noun	3.041	906	3.947	0,93	239	66	305	0,93
Laayoune-Sakia El Hamra	4.200	1.659	5.859	1,38	49	55	104	0,32
Dakhla-Oued Eddahab	585	1.642	2.227	0,52	12	34	46	0,14
TOTAL	318.412	107.241	425.653	100,00	28.250	4.395	32.645	100,00

The pattern of water content of trade within Morocco can also be associated with the physical concepts of "water loss" and "water savings", discussed in Hoekstra and Chapagain (2008, p. 39). Accordingly, whereas import of goods intensive in the use of water (see Table 10) implies regional water resources are saved, export of such goods entails the loss of regional water resources. That is, water used for producing commodities that are consumed in other regions is no longer available for in-region purposes. Figure 5 presents the physical balance of traded water by Moroccan region. The regions with the largest net water savings (deficit with other regions) are Grand Casablanca-Settat and Tanger-Tetouan-Al Hoceima, followed by the two regions in the direct area of influence of the Saharan basins, namely Laayoune-Sakia El Hamra and Dakhla-Oued Eddahab. On the other hand, the regions with the largest net water loss (surplus with other regions) are in the direct area of influence of the water-rich basins of the Atlantic with a relevant presence of agricultural activities, namely Béni Mellal-Khénifra and Fès-Meknès.

Figure 5. Net Regional Total Traded Water in Interregional Trade (million m^3)



Finally, based on the specification presented in Table 9, we have computed the Trade-Based Index of Water Intensity (TWI), which reveals the relative water use intensities associated with specific interregional and international export flows. We estimate, for trade flows associated with each origin-destination pair, measures of trade in value added and trade in water that were further used to calculate our index. The results are presented in Table 12 and point to different ratios across flows of share in total traded water to the respective share in total traded value added. Different patterns appear not only when international export flows are compared to domestic export flows, but when looking at trade flows within the country.

The regional patterns of relative factor content in trade revealed by the TWI can be grasped by reading Table 12 in two different perspectives. First, going through the rows, one can verify that values for the TWI smaller than one relative to interregional trade prevail in regions that present relative scarcity of water resources – urban agglomerations of Rabat (R4) and Casablanca (R6), as well as the desert areas in the southern part of the country. In those cases, trade flows are relatively more concentrated in terms of value added than in water content. Second, as we look at the column results, we can conclude that (i) more water-intensive trade flows directed to the areas under the influence of the Sahara basins are spatially concentrated in Fès-Meknès, Béni Mellal-Khénifra and Drâa-Tafilalet, that benefit from their relative abundance of water resources and their strategic location to access the southern areas of the country; (ii) except for sales from Casablanca and Rabat, domestic trade within the "fish" area is dominated by more water intensive flows; and (iii) despite the documented fact that Morocco imports water in virtual form, more than it exports, so that in effect it partially depends on water resources from other countries (Hoekstra and Chapagain, 2009, p. 73), the above-unity TWI results in the RoW column suggest that international exports from Fès-Meknès, Béni Mellal-Khénifra, Drâa-Tafilalet, and Souss-Massa are responsible, in relative terms, to put more pressure on the use of domestic water resources

Table 12. Trade-Based Index of Water Intensity (TWI)

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	RoW
R1		1.039	1.404	1.112	1.256	1.490	1.368	0.795	1.799	0.803	0.963	1.161	0.211
R2	1.242		1.794	1.158	1.583	1.631	1.637	0.777	2.189	0.786	0.993	1.230	0.668
R3	1.627	1.548		1.329	1.825	2.079	1.945	1.164	2.427	0.949	1.099	1.453	2.735
R4	0.588	0.521	0.801		0.640	1.352	0.774	0.338	1.108	0.308	0.418	0.558	0.181
R5	1.768	1.901	2.259	1.592		1.387	2.120	1.466	2.684	1.350	1.668	1.989	1.011
R6	0.774	0.887	0.962	0.852	0.841		0.951	0.713	1.066	0.620	0.476	0.819	0.115
R7	1.015	0.870	1.225	0.805	1.186	1.127		0.760	2.034	0.650	0.846	1.052	0.955
R8	1.971	1.984	2.428	1.737	2.390	1.489	2.306		2.927	1.549	2.001	2.349	2.742
R9	1.072	0.946	1.090	0.684	1.101	1.418	1.479	0.957		0.650	0.638	0.955	2.059
R10	0.845	0.745	0.945	0.601	0.942	1.212	1.037	0.582	1.337		0.731	0.910	0.950
R11	0.193	0.292	0.202	0.097	0.222	0.088	0.226	0.308	0.217	0.172		0.267	0.432
R12	0.300	0.348	0.246	0.156	0.274	0.300	0.343	0.372	0.267	0.246	0.121		0.271

R1 - Tanger-Tetouan-Al Hoceima; **R2** - Oriental; **R3** - Fès-Meknès; **R4** - Rabat-Salé-Kénitra; **R5** - Béni Mellal-Khénifra; **R6** - Grand Casablanca-Settat; **R7** - Marrakech-Safi; **R8** - Drâa-Tafilalet; **R9** - Souss-Massa; **R10** - Guelmim-Oued Noun; **R11** - Laayoune-Sakia El Hamra; R12 - Dakhla-Oued Eddahab; **RoW** - Rest of the World.

5. Epilogue: Natural Resources Intensity

We have focused the preceding analysis on the relative intensity in the use of water resources in regional supply chains, focusing on the water content in bilateral export flows from Moroccan regions. In what follows, we take structural elements of the Moroccan economy a step further in our analysis. The proposed index, TWI, can be compared to similar metrics related to other natural resources. Economic activity demand different scarce resources whose availability varies across regions within a country. By using information on sectoral use of other natural resources, the integrated water-economic analysis of regional supply chains that we have discussed can be expanded. In so doing, we add another layer of complexity to a system of resources management, as other trade-offs may appear involving different regional actors. Thus, the forthcoming final analysis justifies the need for coordinated resources management systems.

To illustrate this point, we will focus on CO_2 emissions associated with energy use in the production process. Similarly to the calculation of the TWI, we calculate the TEI, the trade-based index of CO_2 emission intensity, using information for the sectoral CO_2 emission coefficients from Eora. Results are presented in Table 13.

Table 13. Trade-Based Index of CO_2 Emission Intensity (TEI)

O | D	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	RoW
R1		1.450	1.288	1.310	1.433	1.280	1.496	1.201	1.250	1.131	0.838	1.225	0.777
R2	0.783		0.890	0.751	0.974	0.736	1.002	0.820	0.809	0.682	0.470	0.714	2.068
R3	0.867	1.185		0.792	1.026	0.983	1.027	0.875	0.822	0.675	0.582	0.835	0.375
R4	0.908	1.110	1.050		1.067	1.462	1.225	0.818	1.065	0.699	0.537	0.873	0.792
R5	0.595	0.847	0.635	0.591		0.417	0.715	0.739	0.576	0.603	0.449	0.650	0.182
R6	0.839	0.908	0.911	0.904	0.923		0.952	0.805	0.923	0.792	0.617	0.746	1.959
R7	0.729	0.921	0.758	0.670	0.883	0.671		0.801	0.823	0.629	0.526	0.762	1.779
R8	0.559	0.856	0.575	0.547	0.690	0.395	0.656		0.512	0.582	0.458	0.650	0.218
R9	0.707	0.834	0.672	0.612	0.807	0.871	0.908	0.707		0.553	0.540	0.746	0.346
R10	0.611	0.875	0.563	0.541	0.724	0.718	0.749	0.645	0.581		0.540	0.747	1.336
R11	0.835	1.046	0.814	0.609	1.067	0.538	1.014	1.138	0.942	0.941		1.182	1.082
R12	0.432	0.488	0.347	0.394	0.482	0.430	0.545	0.473	0.413	0.474	0.477		0.198

R1 - Tanger-Tetouan-Al Hoceima; **R2** - Oriental; **R3** - Fès-Meknès; **R4** - Rabat-Salé-Kénitra; **R5** - Béni Mellal-Khénifra; **R6** - Grand Casablanca-Settat; **R7** - Marrakech-Safi; **R8** - Drâa-Tafilalet; **R9** - Souss-Massa; **R10** - Guelmim-Oued Noun; **R11** - Laayoune-Sakia El Hamra; R**12** - Dakhla-Oued Eddahab; **RoW** - Rest of the World.

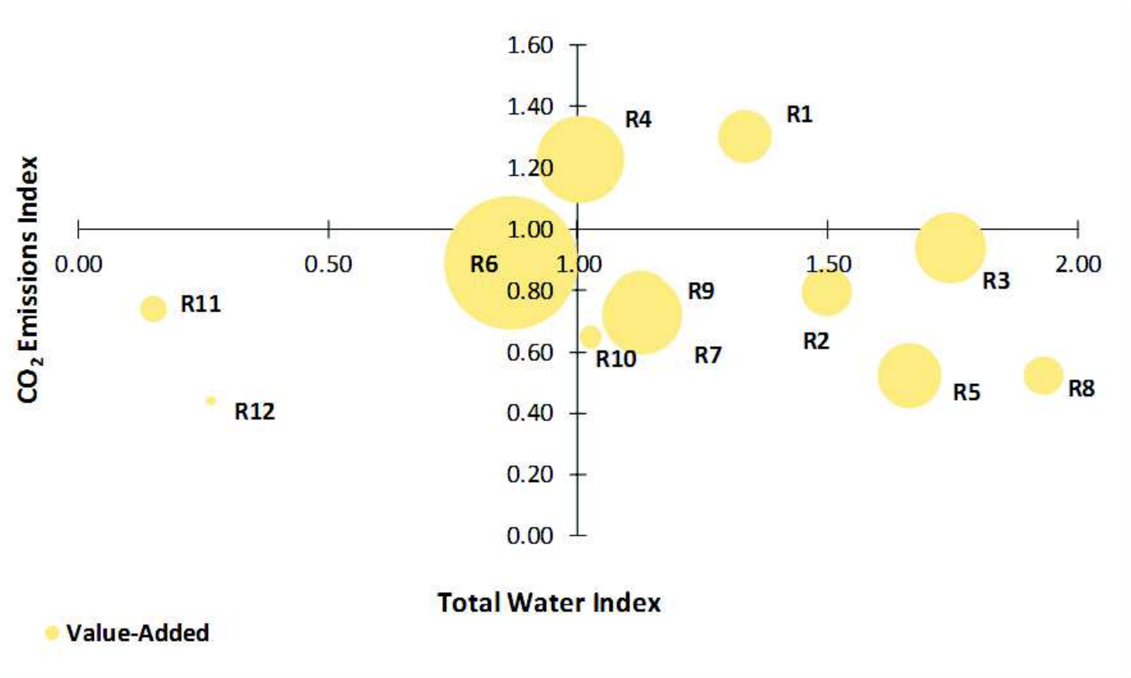
The next step is to compare the TWI with the TEI. In this analysis, instead of examining differences in each single O-D pair, we compute the two indices for exports aggregated by the two main destinations, i.e. other Moroccan regions and other countries. We then present the results in Figure 6. In each of the scatter plots, the size of the "bubble" is proportional to the value added content in each export flow. The two axes cross at unity, the threshold value for both indices that indicate whether a particular trade flow from the region is more intensive in domestic total traded water (CO_2 emissions) than in domestic value added. Thus, the interpretation of the location of the "bubbles" follows: (i) NE quadrant – relatively more intensive in the use of both natural resources; (ii) SE quadrant – relatively more intensive in the use of water resources; (iii) SW quadrant – relatively less intensive in the use of both natural resources; and (iv) NW quadrant – relatively more intensive in the use of energy resources.

We can divide the analysis in two parts. First, regional exports to other regions of the country reveal the following: (i) domestic sales from Tanger (R1) are relatively more intensive in the use of both water and energy resources; (iii) exports from the Sahara regions (R11 and R12) present relative low levels of water use and emissions; moreover, trade flows from the main selling region (Casablanca – R6) are dominated by relative stronger value added generation when compared to their relative use of natural resources; (iii) the relative "clean" export flows, mainly from regions in the "fish" territory are relatively more intensive in the use of water resources; and (iv) sales originated in Rabat (R4) are more intensive in the use of energy inputs that generate higher CO_2 emissions.

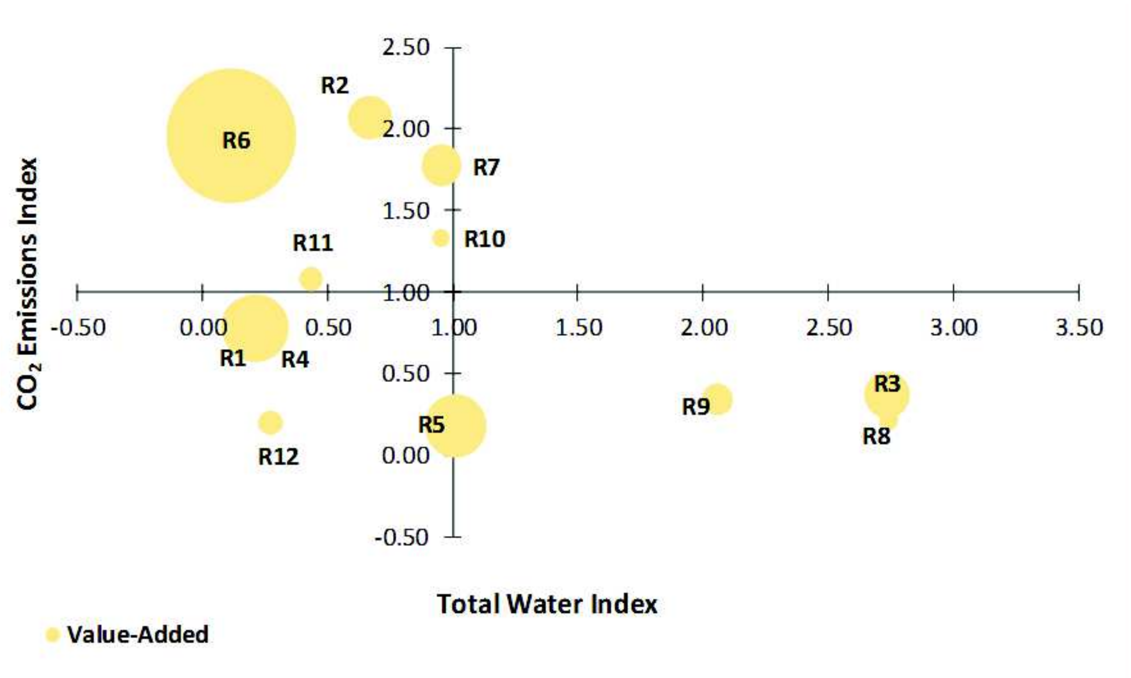
Finally, in the case of international exports, there appears a negative relationship between the TWI and the TEI, evidencing another trade-off. The main export flows in value added terms are concentrated in the NW quadrant, revealing a relative higher intensity in the use of CO_2 emissions generating energy inputs. On the other hand, export flows with low contribution to value added generation, mainly located in the SE quadrant, use water resources relatively more intensively.

Figure 6. Trade-Based Indices of Natural Resources Intensity: Water *versus* CO_2 Emissions

Regional Exports to the Rest of the Country



Regional Exports to the Rest of the World



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