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Sectoral water footprint dynamics: An input-output structural decomposition analysis for Morocco

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Abstract. Over the last decades, Morocco has been facing increasingly severe water scarcity. To quantify water use in Morocco, we refer to the water footprint (WF) concept, including both direct and indirect water use. WF considered covers internal WF and exported virtual water (VW). We used the input-output structural decomposition analysis (SDA) to quantitatively analyze the drivers of changes in Morocco's sectoral WF from 1995 to 2015. The considered mechanisms governing WF changes are the technological, economic system efficiency, and structural effects. The WF growth experienced in Morocco primarily resulted from final demand changes. The technological effect acted as an additional increase factor. Nevertheless, the economic system efficiency effect contributed to the water conservation process. Unfortunately, it was not sufficient to reverse the expansion of Morocco's WF resulted from other driving factors. Agriculture is the dominant economic sector in WF changes, regardless of any driving factor and any period considered. The study provides insight into Morocco's water policy limits and helps develop policies towards sustainable water resources planning and management. That is by suggesting that final demand structure adjustment and technological innovation in the agricultural sector should be at the center of Morocco's strategies in addressing water scarcity.

1 Introduction

Sustainable water use presents a real challenge for sustainable development in Morocco. The maximum annual volume of water resources available in Morocco is among the lowest in the world. Water availability in Morocco has dropped from 3500 m^3/inhabitant/year in 1960 to 730 m^3 in 2005 and 645 m^3 in 2015, while the water stress threshold is defined at 1000 m^3/inhabitant/year [1]. The Moroccan water sector is also characterized by increased financial and environmental costs of increased supply of water, conflicts between different water users, and the emergence of negative externalities [2].

To meet the mentioned challenges in terms of the growing water scarcity, the Moroccan government has put emphasis on integrated water resources management in order to ensure a socially and technically efficient allocation of existing resources between the competing consumer groups in a more sustainable way. For this purpose, several initiatives through political and institutional reforms were launched. In this vein, and to improve water resources management, it is highly relevant to examine the impacts of such measures on the water situation.

Most of previous studies in water resources management economics have focused almost exclusively on water use structure. Among the limitations of these studies is the static analysis which provides limited perspectives using the data for just one year. Furthermore, these studies focus particularly on the analysis of water use status instead of investigating the underlying reasons for the water use changes. One of the most important models in this regard, and which is no exception to the issue of static analysis, is the input-output model. This model is a technique quantitatively depicting the interconnection of economic activities, which has been used recently in the water footprint (WF) analysis. With regard to the WF concept, it is proposed analogously to the ecological footprint concept to indicate the volume of water used by a country, region, business, or an individual person for the production of goods and services [3].

According to [4], the internal WF, external WF, and exported virtual water (VW) are the major components of WF. The internal WF and exported VW constitute the WF within a region or nation, while the internal and external components constitute the WF of a region or nation. Therefore, the WF within a region or nation is an indicator of the local water use situation, which takes the exported VW into consideration. We use the latter in this study as it is an important component linked to domestic water use, while it is often neglected in previous WF studies.

Comprehensive studies in water use changes driving forces are crucial in understanding the current and future water-related problems [5]. Examining the driving forces of WF can be done using structural decomposition analysis (SDA) [6,7]. Generally, SDA is a technique for quantifying the determinants of changes in an aggregate indicator over time. [8–21] are among the studies that

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used SDA to analyze WF drivers. For instance, [21] examined the driving factors of water use trends in the United States. [9] studied the technological, structural, and final demand effects that influence water use in Spain. They identified household final demand and exports growth as key drivers. Several studies have investigated water use issues in China by using SDA at different spatial scales [8,16,18,20,22]. For instance, [16] used SDA to study China's WF determinants, pointing out that technology and economic structure effects have significantly contributed to the reduction of water use. [18] used SDA to decompose the changes in the total WF of China between 1997 and 2007. The results revealed that the consumption level is the dominant driver of China's water use increment. The changes in water-saving technology and final demand make the greatest contribution to offset the water use increase. Accordingly, and in addition to the gaps mentioned regarding previous studies, the majority of papers in this field treat final demand as a whole, without considering the heterogeneity among its different categories.

In Morocco, there are few studies focusing on the analysis of the relationship between socio-economic development and water use. Furthermore, dynamic studies investigating WF changes in Morocco at different periods are, to the best of our knowledge, non-existent. Therefore, a decomposition analysis of driving forces to these changes is also absent.

This study seeks to bridge the aforementioned gaps by investigating Morocco's sectoral WF driving forces. That is to identify the key factors and economic sectors leading to the changes, and quantitatively evaluate their contributions to the changes to assist policymakers in taking more effective water-saving measures.

This paper addresses the following specific questions: (1) What are the main drivers of WF changes in Morocco over time? What are the most important economic sectors contributing to these changes (3) Are there differences in WF changes among different final demand categories?

So as to help us visualize the mentioned options, this paper is organized as follows: After describing the methodology and the data used to quantify multiple contributions to changes in sectoral WF, we try to reveal the driving forces that have the most influence on WF changes. Based on our findings, we seek subsequently to explore the potential pressures on water sustainability under policy evolution and provide new insights for relieving water scarcity in Morocco.

2 Methodology and data

2.1 The basic Input-output model

The mathematical structure of an input-output model represents how the production of a given economy depends on intersectoral relations and final demand [23]:

$$x_i = \sum_{j=1}^{n} x_{ij} + y_i \tag{1}$$

Eq. 1 depicts the mathematical structure of an input-output model where n is the number of economic sectors of the economy in question; x_i represents the total economic output of ith sector; y_i is the final demand of sector i and x_{ij} represents the monetary flows from ith sector to jth sector.

Technical coefficient, a_{ij}, is calculated by dividing the intersectoral flows from sector i to sector j (x_{ij}) by the total output of sector j (x_i) :

$$a_{ij} = \frac{x_{ij}}{x_j} \tag{2}$$

Thus, Eq. 1 can be rewritten to include the technical coefficient (a_{ij}):

$$x_i = \sum_{j=1}^{n} a_{ij} x_j + y_i \tag{3}$$

In matrix notation, the Eq. 3 can be written as:

$$\mathbf{x} = \mathbf{ax} + \mathbf{y} \tag{4}$$

Where **x** is a $(\mathrm{n} \times 1)$ vector of gross output, **y** is the $(\mathrm{n} \times 1)$ vector of final demand, and **a** is the coefficient matrix. To solve for **x**, we get:

$$\mathbf{x} = (\mathbf{i} - \mathbf{a})^{-\mathbf{1}}\mathbf{y} = \mathrm{l}\mathbf{y} \tag{5}$$

Where **i** is the identity matrix; $\mathbf{l} = (\mathbf{i} - \mathbf{a})^{-\mathbf{1}}$ is known as the Leontief inverse matrix, which shows the total production of each sector required to satisfy the final demand in the economy[24].

2.2 The water footprint input-output model

The model for sectoral WF can be expressed as:

$$\mathbf{WF} = \mathbf{f}(\mathbf{I} - \mathbf{a})^{-\mathbf{1}}\mathbf{y} = \mathbf{fly} \tag{6}$$

Where, **WF** is the $(\mathrm{n} \times 1)$ vector of blue WF which captures freshwater withdrawal as an internal WF and exported VW used in the economic system directly or indirectly (i.e. cubic meters per dollar); **f** is the diagonal matrix $(\mathrm{n} \times \mathrm{n})$ of water use intensity representing the volume of WF per unit of output, which is calculated as follows :

$$\mathbf{f} = \frac{wf_j}{x_j} \tag{7}$$

Where wf_j represents the water withdrawal in sector j.

2.3 Structural decomposition analysis

SDA is a technique that decomposes the changes in one variable into the changes in its assumed independent determinants [25]. In this study, we performed a SDA to decompose the total change in WF into contributing factors resolved into technological, economic system efficiency, and structural effects.

The technological effect depicts the influence of changes in direct water use efficiency. It represents the effect of technological changes on water withdrawal for one monetary unit of output. The economic system efficiency effect represents the changes in the supply and demand relationship between different sectors in the economic system. The latter is mathematically reflected by changes in the Leontief inverse matrix. Final demand is also an important determinant in this study since water withdrawal is ultimately driven by the final demand for products and services in most countries[13]. The structural effect represents the changes in the final demand [8,12].

The structural effect can be considered from the final demand composition or the final demand destination perspective. This study considers both.

The changes of WF over time are decomposed into changes in three variables, which can be given in matrix format as:

$$\mathbf{\Delta WF = \Delta flY + f\Delta ly + fl\Delta y} \tag{8}$$

Where each term in the right-hand side of eq. 8 indicates how much the change of WF ($\mathbf{\Delta WF}$) is caused by the change of the technological effect ($\mathbf{\Delta f}$), the economic system efficiency effect ($\mathbf{\Delta l}$), and the structural effect ($\mathbf{\Delta y}$), ceteris paribus.

When it comes to the choice of the additive decomposition form, it is worth mentioning that in SDA studies, most authors choose additive over multiplicative decomposition form because the former is generally simpler and easier to interpret (See [26–28] for a comparative review).

In SDA analysis, the non-uniqueness problem should be considered. That is because there are several ways to decompose eq. 8 (see [26] for an overview of methods). The application of SDA in this study leads to 3! = 6 possible decompositions [6]. As the results from different decomposition forms may vary greatly, [6] proposed to take the average of the two polar decompositions. This method is simple to apply, intuitive in mathematical format, and is widely accepted in the relevant studies [29]. Specifically, it has been shown to be zero-residual and non-parametrical [30].

The SDA method is conducted based on a start period and an end period data. If we suppose that the start period and end period can be denoted by the subscripts "O" and "1", respectively, then the contributions of the three factors are determined by the following equations:

The contribution of the technological effect ($\mathbf{\Delta F}$) to the WF changes is represented by:

$$\mathbf{\Delta F} = \frac{\mathbf{1}}{\mathbf{2}}(\mathbf{\Delta fl_0}\boldsymbol{y_0} + \mathbf{\Delta fl_1}\boldsymbol{y_1}) \tag{9}$$

The contribution of the economic system efficiency effect, ($\mathbf{\Delta L}$) , is represented by:

$$\mathbf{\Delta L} = \frac{\mathbf{1}}{\mathbf{2}}(\mathbf{f_0\Delta l}\boldsymbol{y_0} + \mathbf{f_1\Delta l}\boldsymbol{y_1}) \tag{10}$$

The contribution of the structural effect, ($\mathbf{\Delta Y}$), is represented by:

$$\mathbf{\Delta Y} = \frac{\mathbf{1}}{\mathbf{2}}(\mathbf{f_0l_0\Delta y + f_1l_1\Delta y}) \tag{11}$$

As mentioned above, we distinguish in the structural effect between the final demand composition and final demand destination. We show in the results section the WF changes using the final demand composition ($\mathrm{n} \times 1$) first. Then, we present the results calculated based on final demand destination ($\mathrm{n} \times \mathrm{m}$), where m is the number of final demand categories. That is to gain an insight into the changes in the distribution of the final demand among different categories.

2.4 Data

To assess changes in Morocco's water footprint, this study conducts a national input-output SDA to reveal the motivations behind WF dynamics, during 1995−2015. Focusing on this period is partly because of the availability of data. It is also because this period is the time when Morocco experienced many measures directly influencing its water sector. Especially, the promulgation of Law NO. 10-95 which was a major breakthrough in the Moroccan water policy, the introduction of the generalized rural water supply program (PAGER) also in 1995, the national program for water saving in irrigation (PNEEI) adopted in 2007 and the green Morocco plan launched in 2008. We divided the study's time span, which is 1995-2015, into two different periods, 1995-2005 and 2005-2015, to compare the two periods so as to put forward specific policy implications.

The input-output data for morocco were obtained from the Eora global MRIO database [31,32], which contains time series data aggregated to 26 sectors. However, due to the lack of data in constant prices, and because of the relevance of the issue of the prices to SDA, we decided to convert the data from current prices to constant prices based on the data available. The issue of the prices is relevant because if the output prices increase (e.g. due to inflation) the WF per dollar of output will decrease even if nothing else has changed. Using current prices rather than constant prices can seriously bias the results. To make the data comparable, we adjusted it to prices for the year 2010. For that, and because of the lack of appropriate price indices, we applied an implicit GDP price deflator, which we derived by dividing nominal GDP by real GDP in 2010 constant dollars obtained from the world bank's world development indicators database.

3 Results

3.1 Changes in total water use coefficients

The total water use coefficient (TWUC) for one monetary unit of production shown in Table. 1, calculated by multiplying **f** by the **l**, reflects the water use throughout the whole production chain. Because **f** measures only the sectoral water use intensity in the downstream production chain, it neglects a large amount of water use which occurs in the upstream production chain.

Table 1 illustrates that most sectors experienced a decrease in TWUC during both periods (Viz. 1995-2005 and 2005-2015). TWUC of "Agriculture", "Mining and Quarrying", "Textiles and Wearing Apparel", "Petroleum, Chemical and Non-Metallic Mineral Products", "Metal Products", "Electrical and Machinery" and "Transport Equipment" all decreased by more than 10% in both periods considered jointly. While the TWUC decrease of all sectors excluding "Fishing", "Food & Beverages" and "Recycling" exceeded 10% during 2005-2015. "Mining and Quarrying" and "Electrical and Machinery" have the highest decrease of TWUC during 1995-2005, with a relatively substantial decrease of more than 30%. During 2005-2015, the sectors with a decrease exceeding 30% are: "Construction", "Retail Trade", "Public Administration", "Education, Health and Other Services" and "Re-export & Re-import". On the contrary, the sectors with an increase in TWUC are: "Fishing" during 2005-2015 and "Re-export & Re-import" during 1995-2005.

Table 1. Changes in sectoral total water use coefficients (TWUC) during 1995-2005 and 2005-2015

Sectors	ΔTWUC (%)	
	1995-2005	**2005-2015**
Agriculture	-11.06	-12.94
Fishing	-29.31	4.39
Mining and Quarrying	-32.79	-25.47
Food & Beverages	-4.99	-3.35
Textiles and Wearing Apparel	-29.61	-11.06
Wood and Paper	-4.40	-18.46
Petroleum, Chemical and Non-Metallic Mineral Products	-12.17	-24.75
Metal Products	-17.44	-21.66
Electrical and Machinery	-41.57	-21.82
Transport Equipment	-11.75	-26.55
Other Manufacturing	-5.86	-15.37
Recycling	-0.58	-7.81
Electricity, Gas and Water	-1.95	-23.34
Construction	-6.79	-38.71
Maintenance and Repair	3.40	-28.64
Wholesale Trade	-5.06	-25.33
Retail Trade	8.93	-30.95
Hotels and Restraurants	0.54	-27.38
Transport	-7.74	-24.93
Post and Telecommunications	-4.28	-28.81
Finacial Intermediation and Business Activities	-3.04	-26.40
Public Administration	-8.33	-37.03
Education, Health and Other Services	-1.56	-31.54
Private Households	0.52	-16.40
Others	-2.74	-23.82
Re-export & Re-import	18.88	-94.27

3.2 Drivers of WF changes

3.2.1 The technological effect

Figure 1 below represents an overview of the drivers of WF during 1995-200 and 2005-2015. Totally, the technological effect (Δ**F**) increments WF by over 293 million m^3 during 1995–2005 and 717 million m^3 during 2005-2015. This accounts for over 3.96% during 1995-2005 and 6.96% during 2005-2015 of the total absolute effects of all the contributing factors. According to table 2 and table 3 below, the technological effect induces WF increases within all economic sectors. Table 2 and table 3 clearly show that the agricultural sector exhibits the highest WF increase (256.41 million m^3 representing 87.46% as a contribution rate in factor and 6.59% as a contribution rate to sector during 1995-2005 and 623.37 million m^3 which represents 86.90% as a contribution rate in factor and 9.01% as a contribution rate to sector during 2005-2015) induced by the technological effect. The second most important sector in terms of WF increase caused by the technological effect is "Food & Beverages". The latter induced an increase of 30.98 million m^3 which represents 10.57% as a contribution rate in factor and 5.75% as a contribution rate to sector during 1995-2005 while it caused an increase of 79.29 million m^3 which equals 11.05% as a contribution rate in factor and 8.35% as a contribution rate to sector during 2005-2015. The increases in WF for other sectors were too small to be indicated (5.79 million m^3 during 1995-2005 and 14.68 million m^3 during 2005-2015, all sectors combined).

3.2.2 The economic system efficiency effect

As shown in Fig. 1, the economic system efficiency effect (Δ**L**) is the only determinant that helps to mitigate Morocco's water pressure during the study period. According to Fig. 1, the economic system efficiency effect decreased WF by 1438 million m^3 during 1995-2005 and 1120 million m^3 during 2005-2015, which accounts for 19.45% of the total absolute effects of all the contributing factors. All sectors in table 2 and table 3 exhibit decreased WF due to the economic system efficiency effect. It is shown that WF decreases due to the economic system efficiency effect are relatively high within the agricultural sector (-1359,61 million m^3 with -34,95% as a contribution rate to sector and 94,56% as a contribution rate in factor during 1995-2005 and -1059,19 million m^3 with -15,32% as contribution rate to sector and 94,60% as a contribution rate in factor during 2005-2015). "Food & Beverages" is the sector with the second most important contribution to WF decrease regarding the economic system efficiency effect (-53,40 million m^3 with -9,91% as a contribution rate to sector and 3,71% as a contribution rate in factor during 1995-2005 while during 2005-2015 it showed a WF decrease of -44,27 million m^3 with -4,66% as a contribution rate to sector and 3,95% as a contribution rate in factor during 2005-2015). The contribution to WF decreases was not considerable to be mentioned for other sectors (-24.78 million m^3 during 1995-2005 and -16.23 million m^3 during 2005-2015, all sectors combined).

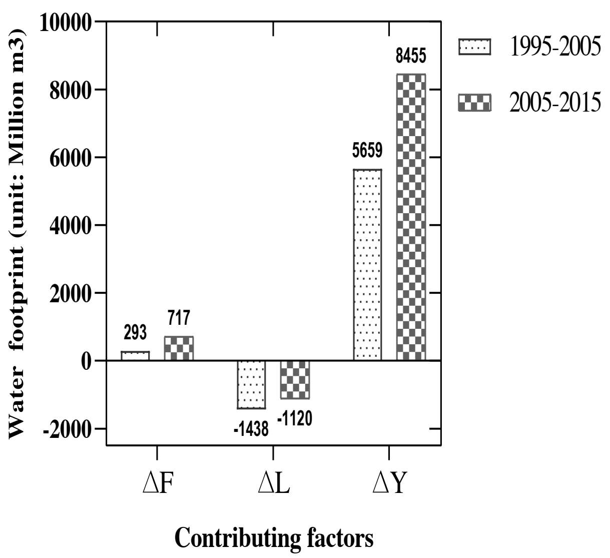

Fig. 1. Contribution of driving factors to Morocco's WF change during 1995-2015 and 2005-2015

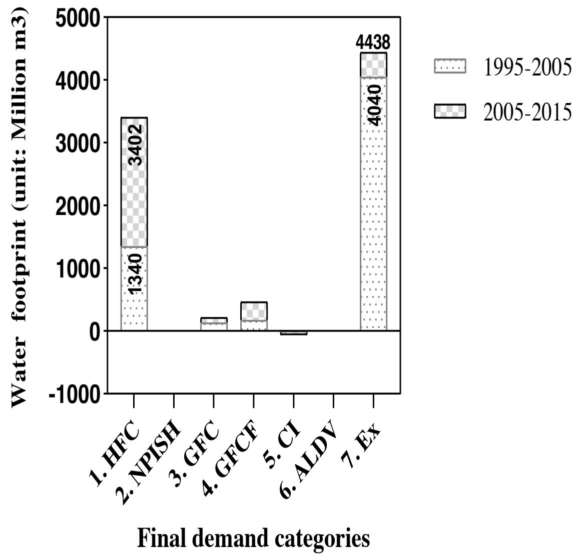

Fig. 2. WF changes from the final demand destination perspective during 1995–2005 and 2005-2015

Table 2. Contribution of the drivers to WF at the sectoral level during 1995-2005

Sector	ΔF			ΔL			ΔY			ΔWF	
	Volume (10^6 m^3)	CRS	CRF	Volume (10^6 m^3)	CRS	CRF	Volume (10^6 m^3)	CRS	CRF	Volume (10^6 m^3)	CRF
1.Agriculture	256.41	6.59	87.46	-1359.61	-34.95	94.56	4993.63	128.36	88.25	3890.43	86.19
4. Food & Beverages	30.98	5.75	10.57	-53.40	-9.91	3.71	561.22	104.16	9.92	538.80	11.94
12. Recycling	1.70	5.83	0.58	-3.20	-10.99	0.22	30.65	105.16	0.54	29.15	0.65
11.Other Manufacturing	2.06	7.11	0.70	-7.70	-26.52	0.54	34.66	119.41	0.61	29.02	0.64
2. Fishing	0.65	15.50	0.22	-8.88	-213.05	0.62	12.40	297.55	0.22	4.17	0.09

Note: Eight sectors were deleted from table 1. And table 2. as they contain only zero values and so there is no reason to include them in the tables. In addition, and to be more concise and focus on the most substantive information, we decided to remove all the sectors with a contribution to the WF less than 0.1% during 1995-2005 and 2005-2015 simultaneously. Finally, the sectors are sorted based on their contribution to WF changes from largest to smallest. CRS (contribution rate to sector) show the proportion of drivers of WF in each sector. CRS = Volume/ (ΔWF) × 100. CRF (contribution rate in factor) shows the proportion of each sector's driving factor in the total volume of the same driving factor. CRF = (Volume/Total Volume) × 100.

Table 3. Contribution of the drivers to WF at the sectoral level during 2005-2015

Sector	ΔF			ΔL			ΔY			ΔWF	
	Volume (10^6 m^3)	CRS	CRF	Volume (10^6 m^3)	CRS	CRF	Volume (10^6 m^3)	CRS	CRF	Volume (10^6 m^3)	CRF
1. Agriculture	623.37	9.01	86.90	-1059.19	-15.32	94.60	7351.0 7	106.30	86.94	6915.25	85.87
4. Food & Beverages	79.29	8.35	11.05	-44.27	-4.66	3.95	915.10	96.31	10.82	950.12	11.80
12. Recycling	4.26	8.84	0.59	-11.15	-23.14	1.00	55.07	114.30	0.65	48.18	0.60
11. Other Manufacturing	5.30	7.43	0.74	-4.41	-6.17	0.39	70.51	98.74	0.83	71.41	0.89
2. Fishing	1.52	7.27	0.21	2.03	9.72	-0.18	17.32	83.01	0.20	20.87	0.26

3.2.3 The structural effect

3.2.3.1 Analysis from the final demand composition perspective

In comparison with the technological effect, the structural effect plays a dominant role in increasing the WF. Fig. 1 shows that changes in the final demand composition led to Morocco's WF increase by 5659 million m^3 during 1995-2005 and 8455 million m^3 during 2005-2015, which accounts for 76.57% and 82.15%, respectively, of the total absolute effect of the drivers.

At the sectoral level, the structural effects have contributed to the WF increases in all sectors. Table 2 and table 3 clearly show that relatively high WF increases are caused by the agricultural sector with over 4993,63 million m^3, 128,36% as a contribution rate to sector and 88,25% as a contribution rate in factor during 1995-2005. While during 2005-2015 "Agriculture" induced an increase in WF of 7351,07 million m^3 with 106,30% as a contribution rate to sector and 86,94% as a contribution rate in factor, which is the highest contribution to WF increase among all factors and sectors. The increases in WF for other sectors were relatively small to be mentioned (103.76 million m^3 during 1995-2005 and 188.92 million m^3 during 2005-2015, all sectors combined).

3.2.3.2 Analysis from the final demand destination perspective

The changes in WF from the final demand destination perspective during 1995−2005 and 2005-2015 are shown in Fig. 2. This study uses seven categories of final demand, including household final consumption (1. HFC), Non-profit institutions serving households (2. NPISH), Government final consumption (3. GFC), gross fixed capital formation (4. GFCF), Changes in inventories (5. CI), acquisitions less disposals of valuables (6. ALDV) and exports (7. Ex) to reveal their specific effects on WF changes. According to Fig. 2, and during both periods, the increments in WF were mainly attributed to water withdrawal for household final consumption and virtual water embodied in exports.

Water withdrawal for exports, defined by Hoekstra et al. 2011 as exported VW, makes the greatest contribution to WF increments from the final demand destination perspective, with an increase of over 4040 and 4438 million m^3 during 1995-2005 and 2005-2015, respectively. The increased household final consumption caused increases in WF by 1340 and 3402 million m^3 during 1995-2005 and 2005-2015, respectively. The third most important final demand category in terms of WF increases is gross fixed capital formation, followed by Government final consumption. Non-profit institutions serving households, Changes in inventories and acquisitions less disposals of valuables contributions to WF increases are negligible.

4 Discussion

During 1995-2005 and 2005-2015, the technology effect in Morocco does not offset WF growth in contrast to what the literature suggests [33]. The structural effect also contributed to WF growth. Conversely, the economic system efficiency effect caused a decrease in total water withdrawal. The absolute change in WF resulting from the structural effect was the largest absolute change in WF caused by any of the three factors.

The agricultural sector is the highest contributor to WF increments regardless of any contributing factor and any period considered, while, on average between 2008 and 2018, it produced only 12.8% of Morocco's total GDP [34]. This indicates a clear disagreement between water use and value-added. This disagreement will necessarily restrict the development of the secondary and service sectors, which are crucial for Morocco's economic development. The agricultural sector should be at the center of Morocco's strategies in tackling water scarcity.

The improvement of water-saving technologies should be highly emphasized, especially as part of the green Morocco plan. The WF growth due to the technological effect was primarily caused by the increased water use intensity of agriculture. Since agricultural water withdrawal is mainly used for irrigation for crop production, there is a large room to improve the water use efficiency by the promotion of technological development in the irrigation system and agronomic techniques which may lead to a considerable drop in Morocco's WF. Adjusting water use intensity in the agricultural sector and emphasizing more profitable sectors with low water intensity such as high-tech industries can not only reduce the total WF but also increase the GDP.

The economic system efficiency effect made a considerable contribution to Morocco's WF decrement during both periods. The economic system efficiency changes are induced by the dynamics of the intersectoral connections based on product supply and demand. WF decreases in this regard can be resulted for instance from intermediate product substitution caused by technique modification, a decreased demand of intermediate products caused by scale effects or superior management practices leading to economized raw material input, etc [35]. Thus, it is necessary to pay greater attention to such practices, given their inhibitory effects can make WF saving possible.

Morocco does not only need to control its WF from the production perspective but also needs to promote WF saving from the final demand perspective. The focus should be on the issue of WF growth caused especially by the household final consumption and the VW embodied in exports. It is vital to implement appropriate measures to improve water conservation within the former through better water-saving pricing structures and improving public awareness of water conservation, among others. When it comes to VW embodied in exports, and since it is larger than WF of domestic consumption, we can fairly say that Morocco exports water in the form of commodities, mainly agricultural ones. From the importing countries' perspective, they import commodities instead of producing them domestically which contributes to saving domestic water resources when externalizing the negative effects of water withdrawal. This is advantageous provided that the country in question exports in return higher value-added and lower water intensity commodities. From a pure economics point of view, it would be worth checking whether Morocco's exported agricultural products yield a higher income of foreign currency per unit of water used relatively to other potential alternative commodities. We are convinced that restructuring Morocco's agricultural exports by avoiding water intense crops, such as watermelon and citrus, and focusing on lower water intense and higher value-added products will help to address water stress.

Finally, and despite the progress made, there is still a lot of work to be done in terms of water policy in Morocco. The impacts of the political and institutional reforms launched are clearly limited. Especially the conversion to drip irrigation promoted by the national program for water saving in irrigation (2007), and the green Morocco plan (2008). The latter advocates modern agriculture, high value-added and productivity, as well as developing Moroccan agricultural sector exports which increases agricultural production and exports but at the expense of Morocco's water resources.

5 Conclusion

This paper quantified Morocco's major WF changes drivers during 1995-2005 and 2005-2015 at the sectoral level. We decomposed the driving factors that affected WF with SDA. Technological, economic system efficiency, and structural effects were analyzed. Internal WF and exported VW were considered. The exported VW has been specifically quantified to evaluate the impact of exports on local water use.

During 1995-2005 and 2005-2015, the results show that Morocco's WF growth was dominated by the structural effect. The latter accounts for 76.57% and 82.15% during 1995-2005 and 2005-2015, respectively, as a contribution proportion to the total absolute effect of the drivers. The exported VW followed by household final consumption are the main contributors to WF increase from the final demand perspective. The technological effect also hindered water conservation. On the contrary, the economic system efficiency effect is the only driver offsetting WF growth. Regardless of any driving factor and any period considered, the dominant economic sector is agriculture, suggesting developing lower water intensity and higher value-added crops. In short, technological innovation and final demand structure adjustment should be the priorities for Morocco in the future to tackle water scarcity.

This study reveals some areas where future researches are needed. For instance, it would be interesting to include more driving factors to WF changes analysis and to analyze extensively VW trade.

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