Virtual water and input-output framework: an alternative way to assess trade and water consumption in FYR Macedonia

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Poster paper prepared for presentation at the EAAE 2014 Congress
'Agri-Food and Rural Innovations for Healthier Societies'

August 26 to 29, 2014
Ljubljana, Slovenia

Abstract[1]

This study aims to analyse the water consumption of the Macedonian economic sectors and their trade strategies by means of virtual water in an input-output (IO) framework. By analysing the trade balance we determine that as consequence of high virtual water content and significant exports of some sectors, Macedonia is a net exporter of virtual water and lost around 124 million of m^3 water at 2005 level or 18% of the total water consumption. Considering a policy option of export nullification for the most water-intensive products with significant net positive exports, yields a substantial water savings by 42.53% of the total water consumption.
Keywords: virtual water content, trade, Macedonia,

Introduction

The term "virtual water" indicates the water that is "embodied" during the process of production and was first introduced by Allan (1996). This embodied water does not capture the physical content of the water in the product, but the water that has been consumed during the process of production (Dietzenbacher and Velazquez, 2007). This newly defined concept in recent years became relevant to study the international flows of virtual water (among others Hoekstra and Hung, 2003; Velazquez, 2007; Dietzenbacher and Velazquez, 2007) and provide explanation of the water demand management with different alternatives for reducing its use.

Macedonia is currently rich in fresh water with a total estimated endowment of surface and groundwater of around 6.4 and 0.94 billion m^3 (UNECE, 2011). However, there is an uneven spatial, quality and time distribution of water resources throughout the country with more favourable supply conditions in the western part which combined with the more evident climate change effect brings to a scarcity issue, especially in the summer months. In addition, the country exhibits a high Water Exploitation Index (WEI) of 34%[2], similar to the one in Spain and Italy (EEA, 2009) which emphasises the scarcity and availability issue even more. In the long-run agriculture as key water consuming sector will have to compete with the other economic sectors especially during the summer period when irrigation is necessary. The irrigation requirements for most agricultural products convey a high quantity of embodied water, which then are incorporated as intermediate products in other sectors or traded abroad.

This study aims to assess the direct and indirect relationships of water consumption of the Macedonian economic sectors by means of virtual water in an input-output framework and to provide deeper insights of the traded virtual water content. The agricultural sector is disaggregated into 7 crop and 4 livestock sub-sectors (see Figure 1). The input-output model attributes a simplified way to track the "virtual water contents of all intermediate inputs to the virtual water content of the final product without the need of reverting to the detailed stages of the production process" (Ip *et al.*, 2007: 1981). Since trading virtual water is an instrument to control and promote sustainable natural resource management as well as reduce the pressure on the existing water resources (Velazquez, 2007), this will enable us to propose water saving policies to enhance more rational use of water.

[1] This document has been produced with the financial assistance of the Swedish International Development Cooperation Agency, SIDA. The views herein shall not necessarily be taken to reflect the official opinion of SIDA.

[2] WEI has a threshold value of 20% indicating a transition from non-stressed to water scarce region. A severe situation occurs when the index is greater than 40%.

Method

Given the definition of virtual water as the water necessary and directly consumed during production, in order to adjust the input-output model for virtual water analysis, it is essential to define direct water input coefficients for each respective sector. Defining the row vector *W* as an annual direct sectoral water consumption in million m^3 and *X* as a vector of output quantities, the new *W** element gives the intensity of water consumption per 1 million of MKD[3] output produced.

$$W^* = \frac{W}{X} \tag{1}$$

The virtual water multipliers are obtained by pre-multiplying the elements from the well know inverse Leontief matrix $(I\text{-}A)^{-1}$ with equation (1).

$$VW = \hat{W}^*(I - A)^{-1} \tag{2}$$

where ^ refers to a vector where the elements W^* are diagonally lined. They indicate the quantity of total water in m^3, directly and indirectly consumed by sector *i* for each additional unit increase of final demand by the respective sector *j*.

Considering the trade components in the input-output framework we are able to calculate and quantify the virtual water content associated with exports (F_e) and imports (M):

$$VW_e = \hat{W}^*(I - A)^{-1}F_e \quad \text{and} \quad VW_m = \hat{W}^*(I - A)^{-1}M \tag{3}$$

The difference between the two expressions in (3), defines the net export virtual water content, distinguishing if the respective sector is net exporter or importer of virtual water.

The described methodology was applied to the Macedonian economy and trade in 2005. The disaggregation of the agricultural sector in the officially published 2005 input-output table for Macedonia (SSO, 2008) was conducted using the Lindberg and Hansson (2009) procedure. The model was constructed by using several relevant sources of data: the sectoral Common Agricultural Policy Rationalised Impact (CAPRI) 2005 dataset for Macedonia, EUROSTAT data on economic accounts in agriculture, Farm Monitoring Survey (FMS) on farm performance, and reports published by the State Statistical Office (SSO) in Macedonia. The agricultural sector of the water accounts was disaggregated using data on irrigated area from the 2008 Annual Agricultural Report (MAFWE, 2009), as well as the combined figures on crop water requirements (CWR) calculated specifically for Macedonia by Hoekstra and Hung (2003), and Iljoski's crop level estimates (1990).

Results

Figure 1 gives an indication of the most significant Macedonian economic sectors with respect to the water technological coefficients as well as the total embodied virtual water. There is a huge variation of the water use intensity but in particular, the rice and the other crops (fodder production) require large amounts of direct water with around 28855 m^3 and 13177 m^3, respectively. Grape and fruit water consumption for irrigation purposes, as well as sheep/lamb water needs, are less intense (9048 m^3, 6343 m^3 and 5509 m^3, respectively per unit production), but should not be neglected because these are major exported goods from Macedonia. Regarding the manufacturing and service sectors few are following similar patterns as discussed agricultural sub-sectors; mining, other mining and the production of electrical equipment have coefficient with per unit output produced of 27778 m^3, 7262 m^3 and 8301 m^3, respectively.

[3] 61.5 MKD (Macedonian Denar) = 1 €; National Bank of R. Macedonia

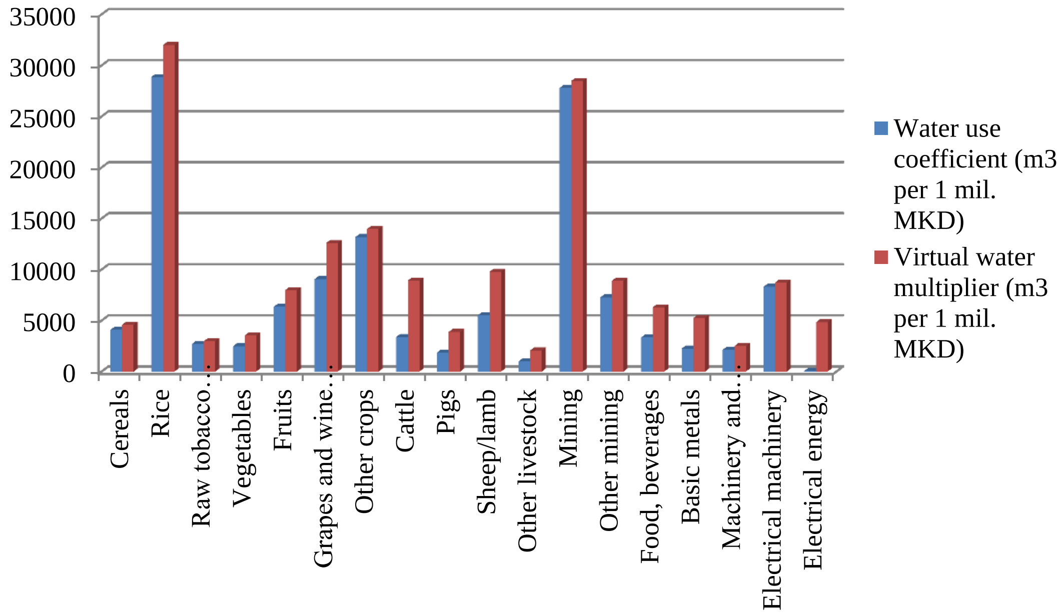

Figure 1. Sectoral water use and associated virtual water content

The distinction between the agricultural sector and the remaining sectors is again noticeable when the multipliers are considered (equation 3), since the indirect water consumption is captured. For instance, the livestock sub-sectors consume almost double than the respective direct water coefficient *i.e.* indirectly large amount of water is embodied in the products used as input in the livestock production. The high direct water coefficient (13177 m^3) and virtual water multiplier (13956 m^3) of other crops sector dominated by fodder production is obvious given this relationship. Sectors such as food and beverages as well as basic metal products followed by the electrical energy sector also display a pattern of driven indirect consumption as the livestock sub-sectors.

The defined virtual water multipliers enable creation of policy scenario through a cost-push model, hence assessing the price changes in the products (Dietzenbacher and Velazquez, 2007). By setting the price of water per m^3 at the same level as other product prices, *i.e.* one unit of output produced, we were able to identify how much the price for a specific good would increase if the price for 1 m^3 increases by one unit[4]. This assumption is arbitrary given the linearity property in the input-output model, but nevertheless implies that the cost of production will increase proportionally to the new water costs. For example, if the water price increases by one unit, then the price of cereals will increase consequently by 4.58%. The virtual water multipliers display that given such cost-push changes, the most price sensitive sub-sectors will be rice, grapes, and other crops (mostly fodder), with around 31.98, 12.50, and 13.90 per cent, respectively. The most price sensitive manufacturing sector will be mining with an 28.46% increase in the prices. Such sensitivity in the price of production indicates that the water pricing policy may be used as a tool to promote water savings policies to enhance a rational use of water.

Since the study also investigates the Macedonian trade strategies in terms of water content, the obtained virtual water multipliers provided the tool to quantify virtual water exports and imports *i.e.* virtual water that exits or enters in Macedonia as a consequence of commercial trade. Figure 2 shows that in general the Macedonian economy is, on one hand, characterized by large virtual water exports, but taking into consideration the water that enters

[4] The price of the new product (w_i) is calculated by dividing the virtual water multipliers (vwm_i) divided by 1000, i.e. $w_i = vwm_i/1000$ (Dietzenbacher and Velazquez, 2007)

the country, the net export of virtual water is estimated at around 124.84 million of m^3 water on 2005 level (18% of total water use).

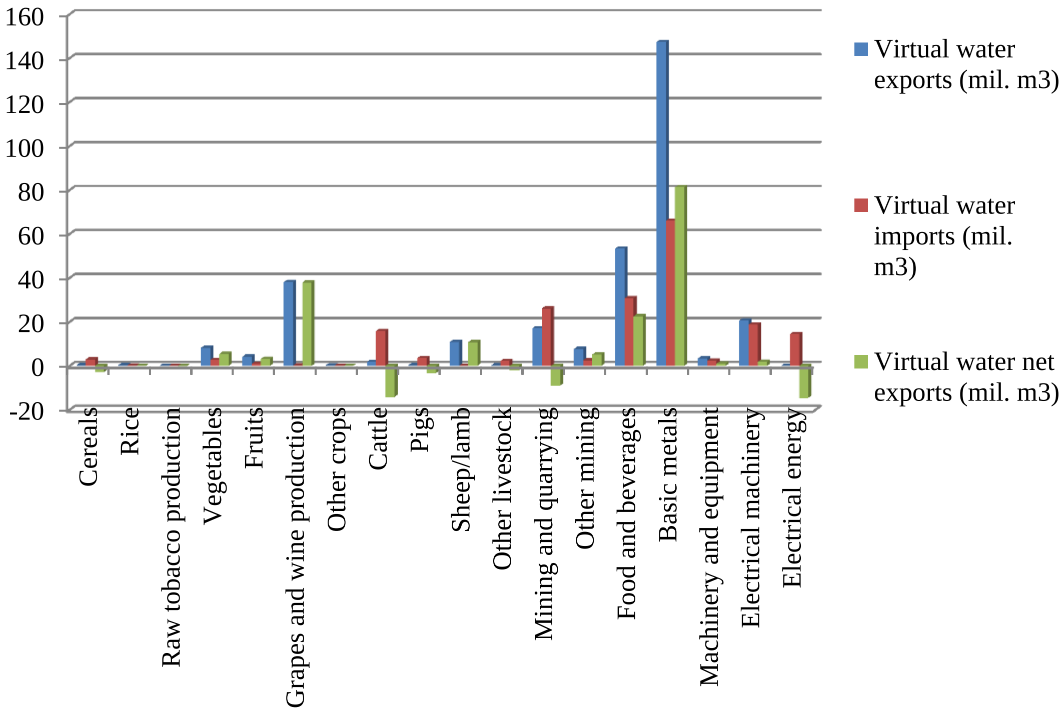

Figure 2. Virtual water trade of Macedonia in 2005

At sectoral level, almost all agricultural sub-sectors, except for grape production and sheep/lamb breeding, display negative or marginally positive net exports. The manufacturing and service sectors have significant exports but also imports of virtual water by the mining, food industry as well as basic metal and production of electrical energy.

If we propose an alternative way of saving water by nullification of the foreign trade for the sectors that display significant net exports in terms of virtual water, the total amount saved would be 290.78 million m^3 or around 42.53%. If the exports are nullified following the Dietzenbacher and Velazquez (2007) method, the trade balance and the Macedonian economy deteriorates by only only 3.26%[5] from the total output in 2005. This exercise is rather hypothetical since the country would not quit the most important exporting products which are driving the economy and contribute with 35.5% of the total export. However, from an environmental point of view, it is just an attempt to display the consequences over the natural resources and what may be done in future at policy level to promote substantial savings in water consumption and mitigate the scarcity issue.

Conclusion

Although the virtual water trade is still a new concept in the existing literature, its importance becomes central in defining policies for enhancement of rational use of water. Our findings reveal that in general due to the significant exports of the agricultural sub-sector, followed by the food and basic metal products, from the manufacturing group of sectors, Macedonia is a net exporter of virtual water. As a consequence of such trade pattern, based on the 2005 input-output framework, a net quantity of 124 million of m^3 water exited the country. At the moment the country is relatively abundant in water, but if such intensive use

[5] Total output of the economy in Macedonia in 2005 was 773759 million MKD (SSO; 2008).

and trade pattern is practiced over the years, combined with the climate change effect, there will be significant impact upon the environment and economy.

We also explore options that may provide insights for future changes in more environmental sustainable economy. If the exports that display significant net export of virtual water are nullified, the trade balance deteriorates by 3.25%; from an environmental perspective the total water consumption may be reduced by 42.5%. Thus, the environmental benefits in the long-run if Macedonia decides to reduce or redefine these exports are much more valuable compared to the economic trade deterioration. We displayed how sensitive the products may become given a cost-push in the water prices. This increase may also stimulate the producers of the water intensive goods to use water more efficiently and result in cost decline of their products. Anyway, though it is unexpected that such measures will be accepted in the long-run, still from our point of view the most realistic option to overcome the issue of water scarcity in the long-run, is investment in technological change to reduce the intensity of the water coefficients. Agriculture at national level accounts as the biggest water consuming sector, thus technological changes in more efficient irrigation practices such as drip irrigation combined with capital investments in reconstruction and development of the irrigation schemes are the most desirable policy option.

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