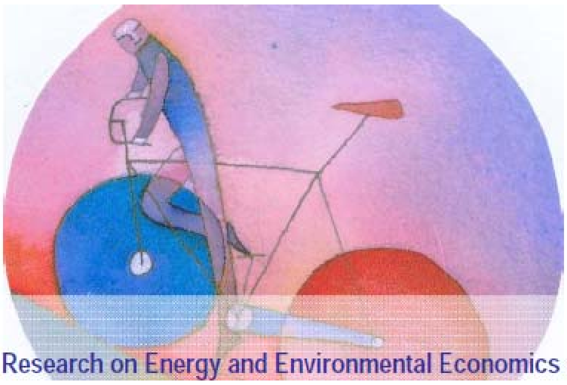

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IEFE
Centre for Research on Energy and Environmental Economics and Policy

Working Paper Series - ISSN 1973-0381

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Working Paper n. 75
December 2014

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Determinants of virtual water flows in the Mediterranean

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Abstract

The aim of the paper is to investigate the main determinants of the bilateral virtual water 'flows' associated with international trade in agricultural goods across the Mediterranean basin. *Virtual water* refers to the volume of water used in the production of a commodity or a service. The exchange of water as embedded in traded goods brings about the so-called *virtual water 'trade'*. We consider the bilateral gross 'flows' of virtual water in the area and study what export-specific and import-specific factors are significantly associated with virtual water 'flows'. We follow a sequential approach. Through a gravity model of trade, we obtain a "refined" version of the variable we aim to explain, one that is free of the amount of flows due to pair-specific factors affecting bilateral trade flows and that fully reflects the impact of country-specific determinants of virtual water 'trade'. A number of country-specific potential explanatory variables is presented and tested. To identify the variables that help to explain the bilateral 'flows' of virtual water, we adopt a model selection procedure based on model averaging.

Our findings confirm one of the main controversial results in the literature: larger water endowments do not necessarily lead to a larger 'export' of virtual water, as one could expect. We also find some evidence that higher water irrigation prices reduce (increase) virtual water 'exports' ('imports').

Keywords: virtual water 'trade', Mediterranean countries, Bayesian model averaging, weighted average least square

JEL codes: F18, Q25

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1. Introduction

Water plays a key role in sustaining the survival of any ecosystem and underpinning the development of any society. Unlike other natural resources, water fulfils a high number of functions for which there is no substitute. Water scarcity is one of the most concerning environmental issue the world faces today and will continue to face in the near future (FAO, 2013), especially in the arid and semi-arid regions of the world where water shortage is a limiting factor (or even a constraint) to economic development, and where water-food challenges are particularly urgent.

Despite water being a renewable resource, its availability is dictated by a variety of exogenous and endogenous factors, which are subject to considerable variability: diverse water endowments over time and space, diverse climatic conditions, erratic rainfall patterns, and the like. The Mediterranean region, in particular, shows substantial imbalances between water supply and water demand, and several factors may justify an unprecedented pressure on water resources: climate change and variability, rapid demographic growth, rapid economic development, massive urbanization and widespread pollution, as well as unwise agricultural policies (FAO, 2012). According to the UNEP (2006), water demand in the area has increased twofold during the second half of the 20th century, reaching 280 km^3/year. The situation is likely to get worse in the next future, as water extraction already exceed the limit threshold of renewable resources in some countries.

The climatic variability and different rainfall patterns in the Northern, Southern and Eastern parts of the Mediterranean contribute to worsen the already notable disparities in the resource availability. Forecasts, produced within the three-years European research project WASSERMed[1], suggest that precipitations will decrease in the Mediterranean basin in the period 2000-2050, particularly in France (-13%), Morocco (-18%) and Tunisia (-10%), whereas the average temperature is expected to increase of about 2°C (Pizzigalli et al., 2011). Elaborating on these estimates, Roson and Sartori (2014b) find that water supply is expected to be lower in all countries, with the exception of Egypt, where it is projected to remain approximately constant. The largest reduction is predicted for Morocco, with a drop of 438 m^3 of water per capita, annually, which corresponds to -20%. Other significant variations occur for France (-12%), Tunisia, Croatia and Italy (all around -9%).

According to FAO (2002), agriculture is by far the most intense water user in the region, accounting for 63% of total water withdrawal (reaching 42% in the North, and 81% in the South and East). Irrigated surface is likely to increase by 38% in the South and 58% in the East by 2030, as well as the demand for drinking water. The agricultural sector is probably the least efficient sector in terms of water usage and this contributes to explain the intensity of withdrawals. Despite the rapid expansion of irrigated areas throughout the whole region, average losses of water in irrigation systems account for 55%, and inadequate technologies and mismanagement are commonplace. In addition, water is free or under-priced in most countries (FAO, 2004), often because of public subsidies to farmers. This factor contributes to explain the intense water usage in the region and suggests that the allocation of water is unlikely to be influenced by market-based incentives, as prices do not reflect the social marginal value of water. Additional pressure on water resources in the region arises from other industries as well, such as tourism, which concentrates in urban agglomerations and significantly peak in the summer. Tourism, which plays an important role in the economy of the region, is conducive to additional demand of water because of the numerous related services (Roson and Sartori, 2014a).

In sum, there seems to be a widespread consensus that the situation is likely to worsen in the near future, and that it is reasonable to envisage more competition for water resources in the area (FAO, 2002). Indeed, elaborating on estimates of national income growth provided by the World Bank[2], and population growth forecasted by the World Population Prospect (United Nations Secretariat, 2010), Roson and Sartori (2014b) predict an average increase of 19% and 46% in the period 2000-2050 in water demand for industrial activities and urban needs, respectively. With water withdrawal increasing

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[1] WASSERMed (Water Availability and Security in Southern Europe and the Mediterranean Region) is a research project funded by the European Commission in the 7th Framework Program (contract no. 244255). For more information, see http://www.wassermed.cmcc.it

[2] GDP forecasts have been obtained from estimates realized by DEvelopment Prospect Group (DEPG) at the World Bank.

rapidly and exceeding the internally renewable resources, water scarcity and its implication for food security is a primary concern in most countries of the Mediterranean region (Antonelli, 2014).

All these facts, data, estimates and predictions make the Mediterranean region an interesting and policy-relevant case of study, and explain why the Mediterranean is the object of a flourishing literature on the issues of water scarcity and food security. Among the many studies, Iglesias et al. (2011) quantify the effects of climate change on water resources and discuss water policy priorities for climate change adaptation in the Mediterranean, suggesting to link water scarcity indicators to relevant adaptation strategies; Yang and Zehnder (2007) study the link between water scarcity, economic performance and trade in agricultural products and conclude that intensification of water scarcity is an important factor in explaining the increase in food import in Southern an Eastern Mediterranean countries during the past two decades; Roson and Sartori (2014b) evaluate the structural consequences of alternative water availability scenarios, due to different forecasts regarding future climatic and socio-economic conditions, and argue that water scarcity is likely to become a serious problem in the Mediterranean, with sizeable economic consequences, particularly for the Southern countries.

A relevant economic consequence of the increasing water demand on the limited and unevenly distributed water resources is that a substantial portion of the domestic water-intensive food supply in various Mediterranean countries has to rely on imports. Availability of water resources thus affects international trade and the relative competitiveness of countries and industries. In this context, arid and semi-arid countries, including some Mediterranean economies, have managed to cope with water scarcity through a market-mediated water saving effect that Allan (1993) conceptualized as *virtual water 'trade'*. The term *virtual water* (VW) refers to the amount of water embedded in internationally traded products and virtual water 'imports' ('exports') reflect the virtual 'transfer' of water to (from) the commodity importing (exporting) country. A large literature on VW and VW 'trade' is now available (for a critical review, see Yang and Zehnder, 2007; Antonelli and Sartori, 2014) and several studies have investigated the Mediterranean region's water and food challenges through the lens of VW 'trade'.

According to Allan (2001; 2003a; 2003b), the countries experiencing water scarcity may partially reduce the pressure on water resources by importing water-intensive food commodities from abroad, substituting the use of domestic water for agricultural production with "imported" water and preserving their limited or insufficient water resources for alternative domestic needs. For instance, De Fraiture et al. (2004) is among the few studies that show empirically that cereals are exported from more to less water productive countries in the Middle East region, subsequently resulting in local (and global) water saving. VW 'imports' thus become a fundamental alternative source of water for water-scarce countries (Haddadin, 2003). However, a number of recent contributions have questioned the empirical validity of such argument, highlighting the limited impact of water endowments on food production and trade strategies. Ansink (2010) and El-Fadel and Maroun (2003) bring evidence that water-scarce countries do often 'export' high amounts of VW.

From a theoretical perspective, water availability should be considered neither the main nor the unique determinant of VW 'flows'. Kumar and Singh (2005), for instance, show that water endowments should be considered in relative terms with respect to the amount of arable land. Indeed, if one investigated the impact of water scarcity on VW 'flows', in line with the concept of relative factor abundance encompassed in the Hecksher-Ohlin international trade theory, she would need to focus on the relative endowments of all productive factors across countries and on the relative factor-intensities of all (traded and non-traded) products (see Debaere, 2014 and Fracasso, 2014). While Debeare (2014) finds evidence that water availability affects the composition of trade flows in a way consistent with the Hecksher-Ohlin paradigm, Fracasso (2014) concludes that bilateral VW 'flows' are affected both by the classical determinants of trade and by national water endowments as well as by the level of pressure on water resources.

Using a gravity model of trade Delbourg and Dinar (2014) find that, on the one hand, exporter-importer asymmetries in water endowments do have a positive effect on VW 'trade' but, on the other hand, asymmetries in water footprint have a strong non-linear impact on food trade, mostly because of demand effects. Differently from Fracasso (2014) and Delbourg and Dinar (2014), the majority of the works in this strand of the literature focus on aggregated trade flows (net imports/exports) rather than on the bilateral 'exchanges' of VW (see, among others, Lenzen et al., 2012). Investigating the determinants of aggregated flows prevent from identifying all the country-specific bilateral determinants of VW 'flows'.

The aim of the paper is thus to investigate the main determinants of the bilateral VW 'flows' associated with international trade in agricultural goods across the Mediterranean basin. Following Fracasso (2014), we consider the bilateral gross 'flows' in the area and investigate which export- and import-specific variables significantly affect VW 'flows'. Lacking a well-defined theoretical framework, the determinants of VW 'flows' are surrounded by a high level of uncertainty. To cope with this, we adopt a model selection procedure based on model averaging, which incorporates model uncertainty into the analysis, averaging across all possible model specifications, given a set of possible explanatory variables. Hence, instead of drawing conclusions on the relevance of any candidate covariates on the basis of just one model, this approach explores the entire set of possible combinations of regressors.

The remind of the paper proceeds as follows. Section 2 outlines the methodology followed and Section 3 presents and discussed our empirical results. A final Section discusses the significance of the research and draws some conclusions.

2. Methodology

We investigate the main determinants of bilateral VW 'flows' associated with international trade in agricultural goods across the Mediterranean basin, following a sequential approach (Figure 1), that includes four main components. We first build a cross-sectional database (see Section 2.1), composed of 110 bilateral VW 'flows' among eleven Mediterranean countries (Albania, Croatia, Cyprus, Egypt, France, Greece, Italy, Morocco, Spain, Tunisia and Turkey), in the year 2004. Through a gravity model of trade (see Section 2.2), we obtain a "refined" version of the dependent variable to explain, one that is free of any pair-specific factors affecting bilateral trade flows and that instead fully reflects the impact of all country-specific determinants of VW 'trade'. A list of country-specific potential determinants is selected and presented in Section 2.3. Finally, to isolate the variables that are statistically significant in explaining the bilateral 'flows' of VW, we adopt an empirical strategy that accounts for model uncertainty (Section 2.4).

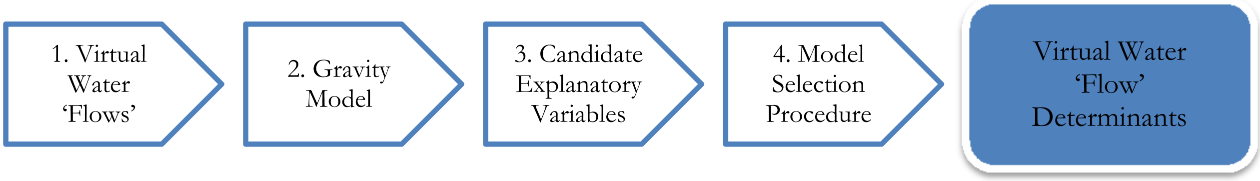

Figure 1. Methodological approach.

In what follows, each step of the analysis is explained in greater details.

2.1 Virtual water 'flows' in the Mediterranean basin

Data on VW 'flows' refer exclusively to trade in agricultural goods in the year 2004. These 'flows' are not observable and are instead estimated through a complex methodology developed within the European project WASSERMed by Antonelli et al. (2012), to which we refer for a detailed explanation of the computations. Here, it suffices to say that the 'flows' of VW (m^3/yr) are obtained multiplying the water usage per unit of output (in monetary terms, m^3/\$) by the value of production (\$/yr). The water usage per unit of output considers both the direct and indirect (systemic) use of water, according to the Leontief Input-Output model, as described in Antonelli et al. (2012). While estimates of direct water consumption per crop and per country are provided by Chapagain and Hoekstra (2004), data on agricultural production are taken from the GTAP database[3].

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[3] GTAP is a research consortium providing data on the social accounting matrix for 109 countries and 20 macro-regions. For more information, see www.gtap.org

Figure 2 provides a graphical overview of VW 'flows' in the area, where the thickness of each line depends on the magnitude of the 'flow'[4]. One can easily identify a small number of very strong links together with a large fraction of smaller connections. The most significant 'exchanges' of VW are found between the largest North-Mediterranean economies. France and Spain are the greatest traders of agricultural goods and an important role is also played by Italy, which is a substantial importer of agricultural products. Notable, a number of North African countries, such as Morocco and Tunisia, but also Turkey, are engaged in non-negligible 'exchanges'.

As argued before, the figure highlights the presence of a few very strong links among the largest and most advanced countries in the area, alongside a vast majority of smaller flows. This observation suggests that while country-size and distance influence the exchange of commodities and VW, as it is typically the case in the trade literature, other factors may be at play. These can be either pair-specific (e.g., a common language or legal system) or country-specific (e.g. water endowment). Accordingly, in what follows, we shall develop a two-step procedure to deal with pair-specific and country-specific determinants separately.

Figure 2. Largest 'flows' of VW 'trade' in the Mediterranean. Source: elaboration of the authors.

2.2 Empirical strategy

The gravity model of trade is an empirical specification that helps to account for and to predict bilateral trade relationships. This model takes its name after the gravitational interaction, whereby two bodies are attracted one to each other by a force proportional to their masses and inversely related to their distance. In the case of international trade, GDP is normally used to capture economic "mass", while distance proxies for trade costs. The gravity equation has gained prominence in the applied trade literature for its ability to correctly account for bilateral flows and for its stability across hundreds of empirical exercises (see for instance Anderson, 1979; Feenstra et al., 2001; Anderson and van Wincoop, 2003; Head et al., 2010; Anderson, 2011; and Head and Mayer, 2014).

In its most basic form the gravity equation can be represented as:

$$X_{ij} = G\frac{Y_i^{\alpha} Y_j^{\beta}}{D_{ij}} \qquad (1)$$

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[4] Data on bilateral VW 'flows' are provided in the Appendix (Table A1).

where X_{ij} is the bilateral directed flow from country *i* to country *j*, Y_i and Y_j measure the mass of the trading countries, D_{ij} is the distance between *i* and *j*, and *G* is the gravitational constant.

This specification, however, does not consider that trade flows can be affected by country-specific factors other than the mass of the country, and by pair-specific factors other than the geographical distance. A more general specification of the gravity model accounts for all these various determinants:

$$X_{ij} = G\frac{F_i^{\alpha}F_j^{\beta}}{\Theta_{ij}^{\ \tau}} \qquad (2)$$

where F_i represents all the features that affect the exporter *i* as a supplier (vis-a-vis all destinations), F_j captures all features of *j* as a destination from all the exporters, and Θ_{ij} stands for the degree of accessibility of market *j* for the producers in country *i*. Clearly, Θ_{ij} does include geographical distance but also other pair-specific factors that influence bilateral exchanges between *i* and *j*.

This work focuses on the role played by country-specific determinants of VW 'flows', which can be included in F_i and F_j. To estimate correctly the impact of country-specific factors on the bilateral 'flows' of VW, one has first to identify the impact of the pair-specific factors. In particular, following the literature (see Head et al., 2010, among others), one needs to isolate the impact of the geographical distance between the trading countries, the presence (or lack) of a common legal system and of a common official language. These two variables capture important aspects of cultural and institutional similarity, which impacts heavily on bilateral trade relationships.

A log-linear expression of the gravity equation to identify these pair-specific factors can be written as:

$$x_{ij} = \varphi^d dist_{ij} + \varphi^g cle_{ij} + \varphi^l cla_{ij} + \eta_i + \eta_j + \epsilon_{ij} \qquad (3)$$

Where x_{ij} is the logarithm of the amount of VW 'embodied' in the exports from *i* to *j*, $dist_{ij}$ is the logarithm of the geographical distance between *i* and *j*, cla_{ij} is a dummy variable taking value 1 when countries *i* and *j* share the same official language (and 0 otherwise) and cle_{ij} is a dummy variable taking value 1 when the countries exhibit the same legal system (and 0 otherwise)[5]. The terms η_i and η_j are country-specific dummy variables and serve to capture all the possible country-specific factors in F_i and F_j. The results, reported in Table 1, are in line with the literature: distance has a negative effect on trade (the value of the coefficient is relatively large, reflecting the fact that some agricultural goods are perishable and therefore relatively more sensitive to transport than manufactured goods), whereas sharing a common language and having a common legal system exert a positive effect via a reduction in trade barriers and costs.

Table 1. Estimation results for the gravity model specified in equation (3). Export- and import- specific fixed effects not reported.

Variables	Coefficients and t-ratio
distance	-1.218
	(-5.838)
common legal system	0.876
	(2.379)
common language	1.334
	(2.779)
Observations	*110*
R-squared	*0.998*

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[5] Data are made available from the CEPII database. See www.cepii.fr.

Using the estimated coefficients $\widehat{\varphi^d}, \widehat{\varphi^g}$ and $\widehat{\varphi^l}$, we derive the component of the bilateral VW 'flows' that is not ascribable to pair-specific factors, which we call r_{ij}:

$$r_{ij} \equiv x_{ij} - \widehat{\varphi^d} dist_{ij} - \widehat{\varphi^g} cle_{ij} - \widehat{\varphi^l} cla_{ij} \tag{4}$$

To uncover the impact of the various country-specific factors on the component of observed VW 'flows' that cannot be ascribed to pair-specific factors, we regress the variable r_{ij} on a number of country-specific determinants. For the sake of brevity, we propose here a synthetic version of the specification to estimate and we refer to the next Section for a discussion of the individual variables included:

$$r_{ij} = c + \lambda^o y_i + \lambda^d y_j + \boldsymbol{z}_i' \boldsymbol{\Delta}^o + \boldsymbol{z}_j' \boldsymbol{\Delta}^d + v_{ij} \tag{5}$$

where y_i and y_j measure the mass of the trading countries (logarithms of the population), and $\boldsymbol{z_i}$ and $\boldsymbol{z_j}$ are matrices including various country-specific determinants of VW 'flows' for, respectively, the country of origin *i* (i.e., the exporter) and the country of destination *j* (i.e., the importer).

As the number of potential candidates in $\boldsymbol{z_i}$ and $\boldsymbol{z_j}$ is large and the literature does not allow to form any strong prior, we shall adopt an estimation methodology that deal with model uncertainty. This will be discussed in Section 2.4, after the introduction of the candidate country-specific factors.

2.3 ***The candidate explanatory variables***

The number of variables potentially explaining the bilateral 'flows' of VW in the Mediterranean basin is very large. Among the many, we identify four categories, some of which have been used by other studies investigating similar issues, at regional or global scale, by applying a gravity model of trade or different methodologies (as instance, see Yang, et al., 2003; Lenzen et al., 2012; De Fraiture et al. 2004; Ramirez-Vallejo and Rogers 2004; Yang and Zehnder 2007; Debaere 2014; Fracasso 2014; Novo et al. 2009).

A first group of candidates is composed by the variables expressing the mass of the countries involved in trade, that is the population of both the exporting and importing country, taken in logs. We expect a positive influence of the country dimension on the bilateral 'flows' of VW, in line with the empirical literature on international trade, as larger countries feature larger trade flows due to sheer size. Data are retrieved from the FAOSTAT database.

A second group of explanatory variables refers to water endowments. While it is intuitive to imagine that water-rich countries tend to 'export' more VW than arid ones, the literature has found only partial support for this claim. On the one hand, various studies show that countries endowed with scarce water resources are net 'exporters' of VW (see, e.g., De Fraiture et al., 2004, Ramirez-Vallejo and Rogers 2004; Yang and Zehnder 2007; Verma et al., 2009; Roson and Sartori, 2010, 2013). On the other hand, Kumar and Singh (2005) find no statistically significant relationship between net VW 'flows' and water scarcity. Finally, Yang et al. (2003) find that the positive relationship between scarce water endowments and net VW 'imports' holds only below a certain level of water endowment.

Among the variables capturing water endowments, we select four possible candidates, referring to both the exporting and importing country. The first variable is the total amount of water available for agricultural purposes, taken in logs and in per capita terms. From a theoretical perspective, total water is the sum of two components: green water, which indicates the return flow of water to the atmosphere as evapotranspiration and whose supply depends on rainfall (Falkenmark, 1995); and blue water, which refers to water stored in lakes, rivers, reservoirs, ponds and aquifers (Rockström et al., 1999). In our case, the total amount of available water is computed as the sum of 40% of the total blue water (as 60% is assumed to be absorbed for other uses) and the entire amount of green water. The second variable we consider is the total amount of green water, taken in logs and in per capita terms[6]. A third variable we include in this category is a proxy of the water pressure, that is the water availability ratio, computed as the ratio between the total amount of water available over the total country-specific dietary requirement. Data on these three variables are made available by Gerten et al. (2011). Finally, we also test the significance of the mean annual temperature, computed as an average of the values registered over the period 1961-1999. Data on this last variable are obtained from the Climate Change Knowledge Portal[7].

Water availability should be considered neither the main nor the unique determinant of VW 'flows'. Kumar and Singh (2005), indeed, show that water endowments should be considered in relative terms with respect to the amount of arable land. Therefore, we introduce as potential explanatory variable a measure accounting for the land endowment, that is the surface of the arable land of both the exporting and importing country, taken in logs and in per capita terms, which is the land actually being farmed, at minimum every five years, with crops that are sown and harvested within the same agricultural year.

As suggested by Wichelns (2004), the determinants of VW 'flows' do not depend only on water and water-related endowments, however. Indeed, a large number of forces influence the production, the consumption and the exchanges of agricultural goods and of the water embodied in such goods: production technologies, domestic and international good prices, trade barriers, and other country-specific socio-economic characteristics. We therefore include a number of other candidate covariates. The first refers to the presence of trade barriers and is the simple average of the agricultural import tariffs in force in the importing country in the closest available year, as reported in the WITS dataset of the World Bank. While allowing to capture the average openness of the importing country with respect to the agricultural sector, this variable is not specific to the pair of trading countries as it regards the importer vis-a-vis all the exporters.

A second covariate is represented by water irrigation charges. It should be noted, however, that irrigation prices are often distorted by policy measures, which in general keep prices artificially low; this inevitably affects the way farmers take (water) prices into account while deciding production levels. Data are taken from a FAO Report (FAO, 2004) and from a study conducted by Chohin-Kuper et al. (2003) on this issue.

To account for the productivity level of the agricultural sector, which may affect the quantity of water that virtually flows across borders, we consider two further variables, which are the number of tractors for 100 km^2 of arable land, taken in logs, and the kilograms of fertilizers consumed per hectare of arable land. Clearly, the number of tractors and the kilograms of fertilizers per hectare of arable land may proxy the development of the country. Yet, as they refer specifically to the agricultural sector they more directly capture factors associated with agricultural productivity. In both cases, data are taken from the World Development Indicators database maintained by the World Bank. Finally, we include a variable indicating the level of education of the population, that is the average years of total schooling, as provided by Barro and Lee (2010). This variable is meant to capture the level of socio-economic development in the country[8].

2.4 Estimation methods

To address the high degree of model uncertainty that surrounds the empirical determinants of VW 'flows', and partly originates from the lack of a well-defined theoretical framework, we adopt a model selection procedure based on model averaging.

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[6] The total amount of blue water is excluded to avoid its perfect collinearity with the other variables.

[7] http://sdwebx.worldbank.org/climateportal.

[8] The small sample size we work with (110 bilateral 'flows') constraints the number of possible explanatory variables we can test. Therefore, we only include measures of agricultural technology (use of tractors and fertilizers) for the exporting country, whereas we consider tariffs and schooling for the destination country.

We leave the technical details aside and limit ourselves to a quick intuitive overview of the methodology: the interested reader is referred to the various excellent introductions to the subject (see for instance Raftery 1995; Raftery et al. 1997).

The main feature of model averaging techniques is to incorporate model uncertainty into the analysis, averaging across all possible model specifications, given a set of possible explanatory variables suggested by the researcher. Hence, instead of drawing conclusions on the relevance of any candidate covariates on the basis of just one model or a few of pre-selected models, the model averaging approach explores the entire set of possible combinations of regressors.

There are two main sources of model uncertainty: the first comes from the fact that in most economic domains competing theories exist that suggest different determinants for any phenomenon under investigation; the second, more subtle issue arises from the fact that it is often unclear what empirical measure captures better a given variable or economic concept. To complicate matters, in the case of VW ‘flows’, we lack a clear-cut theoretical framework and the literature offers conflicting views on the relevance of candidate variables, such as water endowments, climatic conditions or water pricing.

Model uncertainty has been recognized as a relevant issue at least since Leamer (1978), who is credited with the first application of model averaging techniques in the context of Bayesian estimation. The development of Bayesian model averaging (BMA) by Raftery (1995) and recent advances such as the weighted-average least square (WALS) technique by Magnus et al. (2010) have made this approach increasingly popular in the growth literature (where it originated) and beyond.

BMA exploits information from each of the possible models defined by the combination of candidate explanatory variables, and then assigns to each model a weight that reflects its likelihood or, more intuitively, its fit[9].

The methodology provides unconditional standard errors, i.e. standard errors that do not depend on a specific model being chosen. Furthermore, BMA also assigns to each candidate variable a “posterior inclusion probability” (pip), which summarizes the importance of that variable in explaining the data (and it is computed as the sum of posterior model probabilities for all models in which that covariate has been included). The rule of thumb for considering a variable as a relevant regressor is a pip>0.5, which corresponds to an unconditional t-value larger than 1 (in absolute value).

Magnus et al. (2010) distinguish between "focus" and "auxiliary" regressors: the former are included in all models because there is no uncertainty about their relevance, whereas model averaging takes place among all possible combinations of auxiliary covariates. Hence, given a set of k auxiliary regressors, there are 2^k possible models. In fact, the computational burden associated with BMA can be substantial even for a relatively small set of auxiliary variables. Weighted-average least square, an alternative model averaging technique developed by Magnus et al. (2010), addresses this issue (as well as others related to the choice of the most adequate prior) and provides a much faster procedure to explore the model space.

Hence, in the ensuing analysis we primarily adopt the WALS approach, although we do apply also BMA to validate the results and check their robustness. Since WALS does not provide a posterior inclusion probability for each auxiliary regressor, but only unconditional t-values, we will refer to them rather than to pips also in BMA analysis when discussing the relevance of different candidate covariates.

3. Empirical results

3.1 Baseline results

Estimation results are reported in Table 2. The first column of the table distinguishes between the types of regressors: focus variables and auxiliary variables are displayed, respectively, in the upper and the

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[9] More precisely, each model is weighted according to its posterior model probability; this in turn is proportional to the marginal likelihood of the model (the probability of the data given a specific model) times a prior model probability, that -in most applications- is assumed to be uniform across all models to represent lack of prior knowledge.

lower panels of the table. The second column classifies the explanatory variables by category: (i) country size, (ii) water and land endowments, and (iii) socio-economic aspects. For each regressor and for each model specification, the table reports the estimated coefficient of the explanatory variable and the t-ratio, in parenthesis, in order to show, respectively, how the regressor affects the bilateral VW 'flows' and the statistical significance of the estimated parameter. Country size, for both exporting and exporting country, is defined as a "focus variable" and therefore included in all models. Although this does not significantly affect the results, we deem necessary to control for size effects.

Table 2. WALS and BMA model estimates of equation (5); t-ratios in parentheses. Observations: 110.

Type of Regressor	Category	Variables	WALS	BMA
Focus Regressors	Country size	Population (orig)	**0.913**	**1.077**
			(4.820)	**(7.541)**
		Population (dest)	**0.907**	**0.947**
			(9.505)	**(12.622)**
Auxiliary Regressors	Endowments	Availability Rario (orig)	**0.264**	**0.482**
			(1.020)	**(1.927)**
		Availability Ratio (dest)	**0.167**	0.024
			(1.135)	(0.267)
		pc Green Water (orig)	**0.774**	0.403
			(1.403)	(0.677)
		pc Green Water (dest)	0.333	0.006
			(0.797)	(0.076)
		pc Total Water (orig)	**-1.695**	-0.351
			(-1.115)	(-0.322)
		pc Total Water (dest)	**-1.679**	-0.346
			(-1.364)	(-0.631)
		Temperature (orig)	0.084	**0.203**
			(0.613)	**(1.975)**
		Temperature (dest)	-0.039	0.003
			(-0.416)	(0.099)
		pc Arable Land (orig)	**0.652**	0.552
			(1.170)	(0.948)
		pc Arable Land (dest)	-0.307	-0.002
			(-0.565)	(-0.026)
	Socio-economic Aspects	Irrigation Water Price (orig)	**-8.046**	-2.197
			(-1.389)	(-0.391)
		Irrigation Water Price (dest)	1.373	3.580
			(0.245)	(0.975)
		Agricultural Tariffs (dest)	**-0.029**	**-0.050**
			(-2.553)	**(-5.594)**
		Number of Tractors (orig)	**0.466**	**0.445**
			(3.816)	**(3.607)**
		Kg of Fertilizers (orig)	0.004	0.001
			(0.911)	(0.164)
		Total years of Schooling (dest)	**0.298**	0.076
			(2.055)	(0.644)
		Constant	9.506	-7.441
			(0.487)	(-0.599)

As expected, the mass-related variables are positively correlated with the magnitude of the bilateral VW 'flows' and highly significant.

The first group of auxiliary regressors accounts for water endowments. The coefficients for the availability ratio, which captures the pressure on water resources, suggests that the more abundant the resources with respect to the potential dietary needs, the greater the VW 'flows' between countries. While this is expected for the exporting country, it is somewhat counterintuitive for importers. The estimates for the other coefficients of this group of regressors offer ambiguous results. On the one hand, the estimates suggest that a higher per capita availability of green water in the exporting country is associated with larger VW 'exports'. On the other hand, when we look at the total water endowment we find a negative sign for both the exporting and the importing country. Overall, our results confirm that the relationship between water endowments and VW 'flows' is relatively complex and does not obey to a simple mechanism whereby higher/lower water availability translates into larger/smaller VW 'flows'. Indeed, although most of the water is used in the agricultural sector, a number of competing uses are becoming more and more relevant, e.g. tourism or power generation, where threshold effect may exists making them viable only if a large amount of water is available. Another possible explanation of these mixed findings may be found in the relationship between total water endowment and the country's level of development. Indeed, the Mediterranean countries where water is more abundant tend to feature a higher level of income, so that their economic structure revolves around the production of manufactured goods and services, rather than agricultural commodities. Italy, for instance, is one of the richest countries among the Mediterranean economies and is a strong importer of agricultural good (FAO, 2013), despite its relatively rich endowment of water resources.[10]

Average temperature is included in this group to capture the fact that since a warmer climate increases evapotranspiration, the amount of VW associated with a given agricultural production is not constant everywhere. However, the variable turns out to be non significant according to the WALS approach.

The next endowment variable we consider is the per capita amount of arable land. In fact, land and water can be considered as complementary inputs in agricultural production. We find that larger land availability in the exporting country is associated with larger VW 'flows', while the opposite holds for the importing country (as one would indeed expect), although this second coefficient is not statistically significant. These results are consistent with previous findings in the literature (e.g. Kumar and Singh, 2005).

For what concerns the socio-economic variables among the candidate determinants of VW 'flows', we find that the average level of agricultural tariffs in the importing country exerts a negative effect on the 'flows'. Water irrigation prices in the exporting countries are also significantly associated with VW 'flows'. As expected, the relationship is negative: higher water prices give farmers an incentive to economize on this input and therefore reduce the amount of VW embedded in agricultural products (or it may shift production toward less water-absorbing crops). The size of VW 'flows' is positively affected by the agricultural production technology, captured here by the number of tractors employed and kilograms of fertilizer consumed per hectare, although this latter variable is not statistically significant at the standard level (the t-value, at 0.911, falls slightly short of 1). Finally, the level of education in the importing country seems to have a positive effect on VW 'flows'. This can be interpreted as a sign that a more educated population is associated with a lower share of agriculture in the economy, leading to larger imports of agricultural products and of the VW embedded in them.

3.2 Robustness checks

To check the robustness of the results we have repeated the estimations by employing the more traditional BMA approach: results using this alternative methodology are reported in the second column of Table 2. The findings, as well as the overall picture that emerges from BMA analysis, are qualitatively similar to those described in the previous section. The few relevant changes that are worth describing mainly pertain to the water endowment variables. The availability ratio for the importing country becomes smaller and is no longer significant, more in line with the initial expectations; total

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[10] Admittedly, this also suggests, as noticed in Fracasso (2014), that these estimated relationships may suffer of a sample selection bias. In a sample including all countries in the world, for instance, the correlation between economic size and water endowment would not be present and the estimates could possibly be different.

water availability per capita in the exporting country also ceases to be significant, although it keeps a puzzling negative sign; average temperature in the source country becomes significant and exerts a positive effect on VW 'flows'. Notwithstanding less controversial point estimates, it is worth noticing that the t-stat for green-water availability falls below the inclusion threshold normally used to grant inclusion (t-stat=1), and the same applies to total water availability in the importing country. When it comes to water prices, we observe that also the price charge in the exporting country ceases to be significant, while that of the importer features a positive sign (in line with expectations) and a t-stat equal to 0.975 that is very close to the inclusion threshold.

The sets of t-values obtained using the two model averaging methodologies display a high degree of correlation (0.945). Similarly, the ranking of candidate explanatory variables with respect to the absolute value of the t-stat is similar, as reported in Table 3 (Spearman's rank correlation equals 0.622). BMA identifies a smaller set of covariates as relevant, all of them belong to the group of relevant determinants retained by the WALS methodology.

Table 3. Ranking of candidate explanatory variables with respect to the absolute value of the t-stat. Significant variables are listed above the black line.

Variables	t-stat WALS	Variables	t-stat BMA
Population (dest)	9.505	Population (dest)	12.622
Population (orig)	4.820	Population (orig)	7.541
Number of Tractors (orig)	3.816	Agricultural Tariffs (dest)	5.594
Agricultural Tariffs (dest)	2.553	Number of Tractors (orig)	3.607
Total years of Schooling (dest)	2.055	Temperature (orig)	1.975
pc Green Water (orig)	1.403	Availability Rario (orig)	1.927
Irrigation Water Price (orig)	1.389	Irrigation Water Price (dest)	0.975
pc Total Water (dest)	1.364	pc Arable Land (orig)	0.948
pc Arable Land (orig)	1.170	pc Green Water (orig)	0.677
Availability Rario (dest)	1.135	Total years of Schooling (dest)	0.644
pc Total Water (orig)	1.115	pc Total Water (dest)	0.631
Availability Rario (orig)	1.020	Irrigation Water Price (orig)	0.391
Kg of Fertilizers (orig)	0.911	pc Total Water (orig)	0.322
pc Green Water (dest)	0.797	Availability Rario (dest)	0.267
Temperature (orig)	0.613	Kg of Fertilizers (orig)	0.164
pc Arable Land (dest)	0.565	Temperature (dest)	0.099
Temperature (dest)	0.416	pc Green Water (dest)	0.076
Irrigation Water Price (dest)	0.245	pc Arable Land (dest)	0.026

As a further robustness check, we replicate the empirical analysis on a larger dataset comprising the original 11 source countries, but considering now all the European potential destination partners, on a geographical scale, for a total of 39 countries. To do this, we modify the source of the data on VW 'flows' because those computed by Antonelli et al. (2012) cover only the 11 countries of the Mediterranean basin. To this end, we resort to the data computed by Carr et al. (2012). This provides us with a larger sample of 383 observations.

The inclusion of a large number of destination partners in the sample forces us to modify the set of candidate determinants. In particular, as we do not have information on water irrigation prices for all the possible countries in this enlarged set, we keep the source country information; similarly, we lose the information for average schooling and thus we proxy the level of development in the importing country by means of its per capita GDP.

Results, reported in Table 4, confirm the ambiguous effect of water endowments on VW 'flows': the availability ratio for both the exporting and importing country turns negative (but only the latter is in line with expectations), green- and total water availability have opposite signs, as before. The land endowment confirms its relevance, whereas irrigation prices are no longer significant though they keep the correct sign. This last result is probably driven by the very low variability of prices (for which we only have information on the 11 exporting countries considered). The coefficient of average temperature changes its sign with respect to the baseline results in Table 2: this is probably due to the fact that the enlargement of the sample to include many countries outside the Mediterranean basin affects the variability of the variable on which, in any case, we have no strong prior.

Table 4. BMA and WALS model estimates for robustness check.
Coefficients and t-ratios in parentheses. Observations: 383.

Type of Regressor	**Category**	**Variables**	**WALS**	**BMA**
Focus Regressors	Country size	Population (orig)	**0.397**	**0.661**
			(1.801)	**(4.585)**
		Population (dest)	**1.070**	**1.076**
			(14.762)	**(13.771)**
		pc GDP (dest)	**0.462**	**0.458**
			(4.412)	**(4.320)**
Auxiliary Regressors	Endowments	Availability Rario (orig)	**-0.313**	-0.014
			(-1.038)	(-0.146)
		Availability Ratio (dest)	**-0.033**	-0.002
			(-1.319)	(-0.168)
		pc Green Water (orig)	**1.831**	**1.286**
			(2.958)	**(1.526)**
		pc Green Water (dest)	-0.072	-0.004
			(-0.325)	(-0.057)
		pc Total Water (orig)	**-5.112**	**-2.515**
			(-2.721)	**(-1.425)**
		pc Total Water (dest)	**0.448**	0.012
			(1.823)	(0.141)
		Temperature (orig)	**-0.285**	-0.033
			(-1.799)	(-0.355)
		Temperature (dest)	**0.061**	**0.064**
			(2.368)	**(1.772)**
		pc Arable Land (orig)	**2.033**	**1.936**
			(3.876)	**(2.562)**
		pc Arable Land (dest)	-0.234	-0.060
			(-0.929)	(-0.400)
	Socio-economic Aspects	Irrigation Water Price (orig)	-1.269	4.643
			(-0.189)	(0.616)
		Agricultural Tariffs (dest)	**-0.021**	**-0.020**
			(-2.153)	**(-1.510)**
		Number of Tractors (orig)	**0.806**	**0.997**
			(6.890)	**(6.997)**
		Kg of Fertilizers (orig)	**0.024**	**0.018**
			(4.103)	**(4.592)**
		Constant	**34.244**	12.749
			(1.741)	(0.913)

As before, the WALS and BMA approaches deliver results that are qualitatively similar, with t-values that are strongly correlated, and with BMA identifying a smaller set of covariates as relevant to explain VW 'flows'.

4. Conclusion

The paper investigates the determinants of VW 'flows' in the Mediterranean basin by testing the relevance of a large set of candidate variables and by using a model averaging strategy that accounts for model uncertainty. Lacking a clear-cut theoretical framework, we draw on general economic theory and the existing literature on trade and on VW to select a number of potential determinants related to water 'flows'.

Our results confirm one of the main controversial results in the literature: larger water endowments do not necessarily lead to larger 'exports' of VW as one could intuitively expect under the assumption that larger water availability may trigger specialization in water-intensive agricultural activities. In fact, there exist many competing uses of water, such as energy production and tourism, that may affect the relationship between water endowments and VW 'trade' in a complex way.

We do find some evidence that higher water prices reduce (increase) VW 'exports' ('imports'), but this must be interpreted as prima facie evidence due to the scant availability of information on prices. Further investigation is warranted, in particular with a view to gathering and mapping data on irrigation prices.

Having a better understanding of the main determinants of VW 'flows' represents an important element in order to assess the potential benefits associated with those flows (for instance in terms of water saving) and to design policies aimed at improving the regional or global efficiency in the use of water resources. Although this work contributes in this direction, the presence of unstable and ambiguous results suggest that further research is indeed warranted.

Acknowledgements

The financial support received through the project "The global virtual-water network: social, economic, and environmental implications" (FIRB - RBFR12BA3Y) funded by the Italian Ministry of Education, University and Research (MIUR) is gratefully acknowledged. The authors are grateful to Marta Antonelli and Roberto Roson for sharing the dataset on virtual water 'flows'.

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Appendix

Data on bilateral virtual water trade 'flows' among the eleven Mediterranean countries are reported in Table A1.

Table A1. Bilateral virtual water 'flows'. Source: Antonelli et al. (2012).

VW flows (m^3)	**Albania**	**Croatia**	**Cyprus**	**Egypt**	**France**	**Greece**	**Italy**	**Morocco**	**Spain**	**Tunisia**	**Turkey**
Albania	0	825,402	108,944	359,549	10,646,310	10,919,614	62,607,499	78,136	2,874,963	43,195	5,496,364
Croatia	10,005,889	0	3,601,331	4,398,746	34,512,960	4,097,727	140,033,075	920,993	2,707,468	275,340	4,281,205
Cyprus	138,863	798,549	0	875,950	3,912,488	10,090,675	11,184,329	43,827	1,755,195	24,170	9,047,023
Egypt	22,797,013	5,177,382	11,325,131	0	135,937,566	129,369,105	428,509,567	42,417,845	126,298,715	52,838,277	174,643,849
France	28,450,755	15,955,189	110,337,295	54,991,242	0	641,089,088	5,285,394,790	905,852,334	4,754,330,892	262,048,381	110,233,379
Greece	111,426,552	21,055,631	87,398,699	18,915,773	84,475,638	0	387,407,552	2,225,669	60,798,063	4,940,411	68,713,861
Italy	38,833,669	96,161,864	13,619,077	15,573,215	1,436,592,645	337,628,328	0	12,016,243	595,908,125	18,709,909	76,669,423
Morocco	1,134,976	6,469,138	1,744,106	15,639,999	2,092,205,018	25,617,957	353,212,138	0	943,379,179	24,739,254	12,257,277
Spain	2,810,004	41,645,166	12,597,720	11,293,548	4,860,466,315	187,745,115	2,167,234,640	76,792,761	0	48,992,961	68,739,768
Tunisia	819,711	3,122,311	2,464,485	4,740,388	484,237,519	14,499,808	735,160,905	78,298,588	300,673,278	0	15,313,948
Turkey	29,938,829	24,463,837	1,066,176	74,018,845	536,895,599	226,500,523	918,043,937	23,433,433	290,104,893	35,326,206	0