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WATER AND TRADE IN AGRICULTURE

INVESTIGATING VIRTUAL WATER HYPOTHESIS IN THE EURO-MEDITERRANEAN REGION

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ABSTRACT

Agriculture remains central to Mediterranean economic development. It is also the main user of water as it employs 65% of all water withdrawals in the region. Virtual water is defined as the quantity of water needed to produce a good or a service. In particular, international trade in crops involves virtual transfers from one country to another of the water embedded in the production process of agricultural commodities. Trade liberalization in agriculture might lead to significant water savings whenever trade flows are set out in a way that water efficient countries are favoured.

1. FIRST OBSERVATION

Despite large improvement in water productivity over last fifty years[1], water scarcity still represents one of the chief hindrances that agricultural sector's growth is facing in the developing world. In this line, the Mediterranean region suffers from the consequences of asymmetrical distribution of fresh water resources between countries and brings together more than half of the world *water-poor* population.

Today, agriculture uses large amounts of water. Withdrawals for agricultural purposes account for 65% of total resources available in the Mediterranean basin. In particular, the development of Southern and Eastern Mediterranean Countries (SEMC) is largely depending on the agricultural sector's perspectives of integration into the international trading system. Thus, the specific link between international trade in crops and water usages ought to be clearly identified so as to assess the impact of current trend of trade liberalisation.

The concept of virtual water enables to shed light on this relationship. Virtual water is by definition the quantity of water used in the production process of each agricultural commodity. Agricultural trade flows may then be *mapped* in terms of water contents implicitly exchanged. According to last estimations, the volume of virtual water being traded internationally and associated with agriculture amounts to 1250 km^3 per year (Renault & Zimmer 2002). This quantity is about a third of all the water used in agriculture in a year. Inciting savings depends on policy decision maker's ability to organise agricultural trade flows between *water-poor* and *water-rich* nations. This argument is obviously applicable to the Mediterranean basin where virtual water imports reached 77 km^3 per year at the end of the last decade. In other words, international trade could substitutes direct water transfers and therefore contribute to compensate water endowment imbalances between nations.

2. MEDITERRANEAN FRESH WATER

Stress and tension

The Mediterranean region accounts for 7.3% of the world population though it merely owns 3% of the world water resources (Rosegrant *et al.* 2002b). Besides, SEMC gather almost 60% of worldwide water-*poor* inhabitants each of them collecting less than 1000 m^3 of water on a yearly basis. Adding up to their average scarcity, annual water supplies are geographically very unevenly distributed: the northern part of the region getting 80% of them, while the south and the east only get

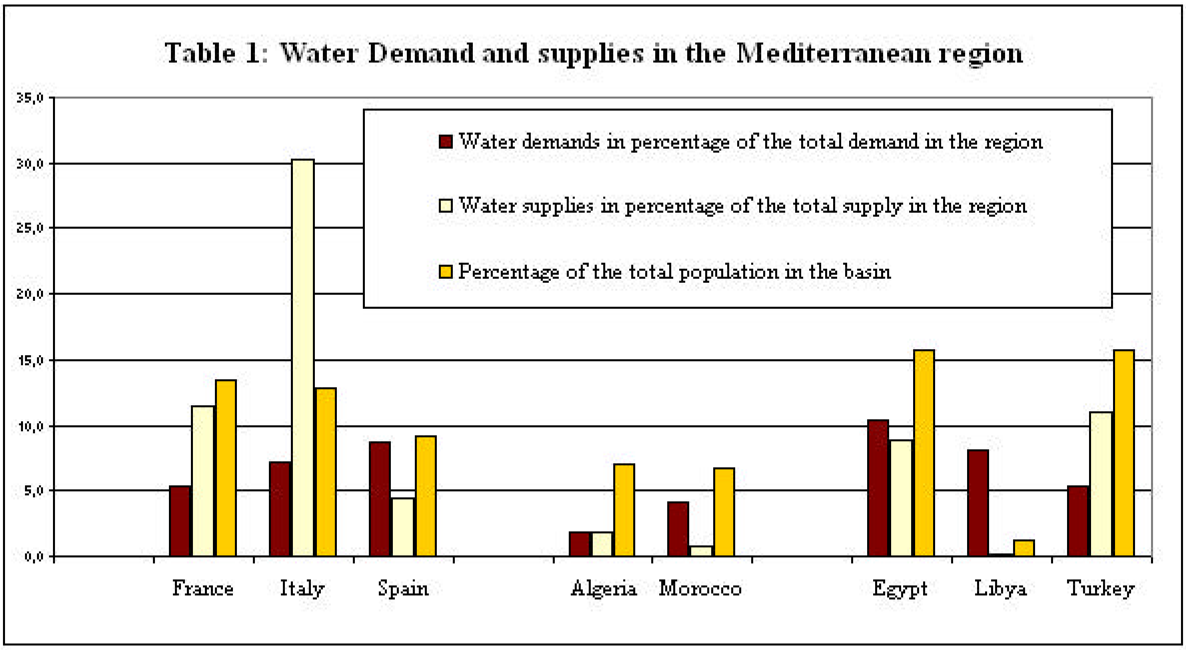
[1] According to *United Nation*'s *Food and Agriculture Organization* (FAO), water productivity in agriculture doubled between 1961 and 2001.

6% and 12% respectively. Globally, SEMC are subjected to constant and repeated situations of *water stress*[2].

These facts depict a profound trend observable in the southern part of the basin: these countries cannot expect any increase in their water supply capacities. Firstly, because differences between annual renewable resources and resources effectively exploited are minimal. Secondly, as rainfalls are very low and losses by evaporation are very high, precipitations' intensity and regularity do not tolerate balancing fluctuations in water demands, binding countries to implement more and more irrigation infrastructure. Egyptian case is striking as 97% of cultivated areas are irrigated and represent 15% of the total cultivated area of the Mediterranean basin. In the same way, Israel and Lebanon use irrigation on more than half their cultivated area. Thirdly, all southern countries are constantly developing their irrigation systems on a large scale contributing to increase water stress.

Water for agriculture

Like available resources, water demands in Mediterranean countries are very unevenly distributed and hardly ever match the size of their respective population. Asymmetries can sometimes be astonishing. For instance, Libya gathers 1.2% of the region's population and more than 8% of the total demand for water (Table 1).



Source: Plan Bleu, 2004

[2] M. Falkenmark (1995) gave interpretation thresholds: from 1000 and up to 2000 inhabitants per hm^3 per year, the populations are under water stress and qualified as poor-water population. From 2000 inhabitants per hm^3 per year, it can be considered that the population is submitted to a durable and sustainable water shortage.

Somehow, agriculture constitutes the first user of water and especially in areas where irrigation are widely spread. The southern part of the region soaks up 41% of all the water consumed for agricultural purposes in the entire basin against 26% for the eastern and 32% for the northern part. Indeed, it is in the SEMC (especially Egypt, Libya and Syria) that irrigated agriculture is most spread. Conversely, the northern part of the region is the most important user of water for domestic purposes: Europeans engulf 57% of all the volume of water devoted to domestic uses in the region and the industrial sector constitutes 39% of the total northern demand for water[3].

Water shortage will probably affect 60 million peoples from now on to 2025 especially in countries that have difficulties to mobilize additional exploitable resources to satisfy growing needs (Rosegrant *et al.* 2002a). As scarcity leads in general to increasing operating costs, discrepancies in water endowments require structural adjustment for those countries. Responses to these situations and prospects habitually entailed policies aiming at increasing mobilization of additional resources. Numerous water transfers have been put in place among Mediterranean countries in particular in SEMC where they have “a major structuring role of water savings” and usually provide a balance between “basin in surplus and in deficit” (Burak 2002). Yet, a growing number of studies shows that supply’s increases, a traditional policy making tool, has reached a certain limit notably in arid and semi-arid countries. Shifting from a supply-oriented approach to a demand-oriented approach opens a wide array of opportunities and perspectives. This type of approach aims at cutting back losses (leaks and wastes) and improving efficiency in the water use by focusing on the user/consumer. This involves the coordination and the persuasion of individual actions through several mechanism or institutions.

3. VIRTUAL WATER AND MEDITERRANEAN AGRICULTURE

Water dependence and transfers

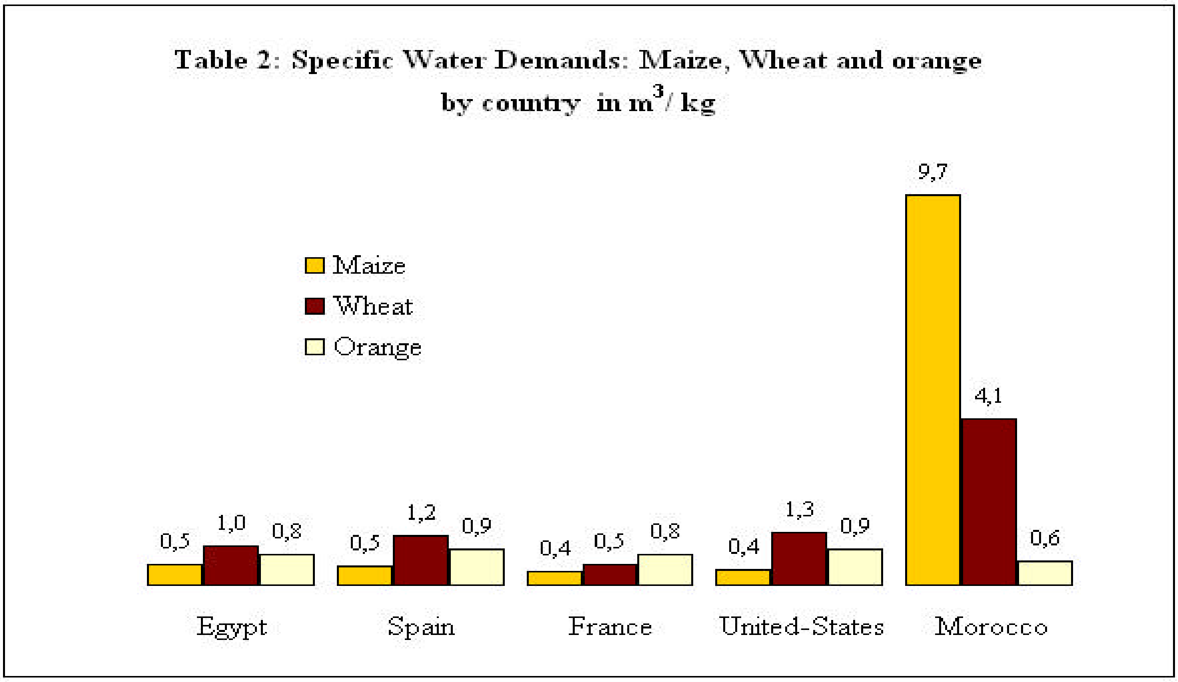
Discrepancies between water uses and resources sometimes lead to a deficit generally filled by *water imports*. The *dependency ratio* measures the degree of autonomy in water resources of a territory *vis-à-vis* a country located upstream. Theoretically, this ratio ranges from 0% to 100% depending on the country ability to receive all or none of the water from abroad. It is worth mentioning that Southern countries are not, on average, more dependent than their Eastern and Northern counterpart. However, gaps are less likely to be compensated in the South and in the East where values are somewhat extreme: in the South, Egypt is dependent for about 37% of its water needs whereas Algeria, Morocco and Libya are close to absolute independency. In the East, Syria and Israel are not very autonomous regarding their water resources.

[3] This last percentage includes the water used for cooling energy plants; a sector that’s considerably less developed in the southern and eastern part of the region.

This state of affairs echoes in the implementation of transfers project, though it does not constitute a management *per se* as it only moves resources from one place to an other without creating global savings and may even lead to losses due to the poor state of infrastructure. Water savings could be put into practice regionally, inter-regionally or internationally through a management tool that ensures the adequacy between relative scarcity of water resources and agricultural trade objectives in the Mediterranean region. Here, the concept of *virtual water* appears to be central.

Definition

Virtual water is the volume of water required for the production of a good or a service (Allan 1993 & 1994). In particular, international trade in crops involves virtual transfers from one nation to another of the water used in the production process of this good or service. This water is said to be *virtual* since it is not present *per se* in the envisaged traded product. The *specific water demands* for a crop (measured in m^3 per kilogram) varies accordingly to production conditions in time and place and accordingly to water use efficiency, say: water productivity. Hence, a country may save resources when it decides to import a product rather than produce it. Savings do not amount to the quantity of virtual water embedded in the imported product but to the volume of water the importers would have required to produce the same quantity of product. On the one hand, the production of a kilogram of wheat, cultivated in favourable conditions, like in France, requires on average half a cubic meter of water. On the other hand, in an arider country like Egypt or Morocco, the amount of water needed to produce the same quantity of wheat is two to eight times higher. Disparities are even more astounding for maize:



Sources: FAO, Aquastat, CropWat

Most recent studies assert that 67% of total virtual water flows are associated with international trade in crops, 23% with international trade in livestock and livestock products and 10% with trade in industrial goods (Hoeskstra *et al*. 2002). In principle, virtual water flows can be understood as comparative advantages between nations owning relatively more or less water resources (Hakimian 2003; Lant 2003). Thus, a *water-poor* country should implement a strategy aiming at producing and exporting products that are less water demanding and importing those containing more virtual water on the basis of its relative *water endowments* to its trading partners.

Virtual water trade in the Mediterranean region: the state of play

Among first thirty world net exporters of virtual water associated to agriculture, four of them are European countries: France, Greece, United-Kingdom, Sweden and only one SEMC Syria[4]. Among major thirty world net importers of virtual water associated to agriculture, six of them are European countries: The Netherlands, Spain, Germany, Italy, Belgium and Portugal and six of them are SEMC: Egypt, Algeria, Morocco, Israel, Jordan and Tunisia. Net imports of virtual water in the region amounted to 77 km^3 per year for the 1995 – 1999 period and about 48 km^3 for the SEMC. Discrepancies in the region are very significant; the Southern part is accountable for half the total net imports whereas the southern and eastern part are respectively accountable for 37% and 10%.

4. INTERNATIONAL TRADE AND WATER SAVINGS

Can positive impacts of virtual water imports be strengthened through adequate and well-considered choices of trade policy?

Issues at stake

The question of Euro-Mediterranean agricultural trade and the one of water management are tightly intertwined. In line with first studies on virtual water flows between nations associated with agriculture, almost 13% of the water used by the agricultural sector is exported as virtual water (Renault & Zimmer 2002). The assumption at the heart of this paper is that the allocation of water resources to different agricultural productions in the Mediterranean region is neither efficient nor sustainable. Could these inefficiencies of usage be alleviated by trade liberalization?

In the up-coming decades, agricultural production will steadily grow in response to the increase of population and to the slight raise in prices especially in developing countries (OECD 2002;

[4] The ranking is available in the following study: Hoekstra *et al* – 2002.

Rosegrant *et al*. 2002*a*). These trends will most probably spark off the creation additional arable soil areas and further investments in irrigation infrastructures. Consequently, new water resources will be needed and allocated to agricultural production. Prospects to 2025 show that annual withdrawals in North Africa and in the Middle East will grow by 20%, being the 3rd most important increase among the 10 regions compared in the forecast (Rosegrant *et al.* 2002*b*). Nevertheless, potentially available and effectively exploitable resources will not be sufficient enough to allow such an increased pressure by demand in the SEMC. Despite imagining further water transfers or increased water productivity through technical innovation, countries will have to implement strategies using the concept of virtual water to ensure global water savings. The effectiveness of this approach can be estimated throughout the evaluation of the following hypothesis:

1ST HYPOTHESIS: As it was shown internationally (De Fraiture et al. – 2004), can it be verified at the Mediterranean region level that international trade in crops saves water? Put differently, is a chosen product effectively produced and exported by the country that uses relatively less water than its trading partner in the region?

2ND HYPOTHESIS: Does international trade involves that virtual water flows are reallocated in order to favour countries using rainfed agriculture? If this were the case, water savings and water productivity would then be upgraded locally or regionally.

3RD HYPOTHESIS: Following the *Lant hypothesis* (2003) and international trade theory, *poor-water* countries should import food from *water-rich* countries and save this water for other purposes: domestic, industrial or environmental purposes.

Scenarios and first results

Our study relies on three scenarios affecting three products chosen among respective comparative advantages of both bank of the Mediterranean sea, say: *wheat, oranges and olive oil.*

Wheat constitutes a comparative advantage for the European Union (EU). In 2002, EU produce about 20% of the world wheat production: more than 104 millions tons. The sample of 10 SEMC chosen for the study produce 36 millions tons of wheat amounting to 6% of the world production. In 2002, Morocco is Europe's first orange supplier in the region, exporting almost 205 thousands tons. Egypt, Tunisia and Turkey ensure also part of Europe supply of oranges. Olive oil is a sensitive product (FEMISE 2003) as it is considered to be a potential source of high competition between EU and the SEMC. However, world production amounting to 3 millions tons, EU provides 87% of it.

Each scenario assigns a change in trade policy and draws the effects on 11 countries or country group and on the three selected products in term of virtual water trade. Besides, all three assumptions are tested for each scenario:

1ST SCENARIO: EU liberalizes unilaterally its trade vis-à-vis its Mediterranean trading partners and consequently applies a zero tariff to all three products entering its market. Conversely, SEMC partners keep their trade protections.

2ND SCENARIO: EU liberalizes vis-à-vis its SEMC partners and SEMC do the same bilaterally vis-à-vis the EU. SEMC keep their protections among them.

3RD SCENARIO: Liberalization is widespread in the region.

The third hypothesis expects that international trade in crops and agricultural products, according to economics theory, will reallocate virtual water flows in accordance with relative water scarcity. Then again, countries involved in this study use in a different way their water resources (rainfed or irrigated agriculture), be given the type of crops grown and their climate, hydrologic and geographic characteristics. Consequently, the third hypothesis will be proven to be valid provided that the first two are corroborated. Results gathered from simulations are summarized in the following table. It shows the evolution of tests on all hypotheses according to the level of liberalization[5]:

	1st Scenario			2nd Scenario			3rd Scenario		
	Wheat	Olive oil	Orange	Wheat	Olive oil	Orange	Wheat	Olive oil	Orange
1st Hypothesis	NO	NO	YES	YES	NO	YES	YES	YES	YES
2nd Hypothesis	NO	YES	YES	YES	YES	YES	YES	YES	YES
3rd Hypothesis	NO	Undeterminable	YES	YES	Undeterminable	YES	YES	YES	YES

The more trade is liberalized, the more hypotheses are validated. Notably, for wheat and oranges, a simple reciprocal liberalization (2nd scenario) proves the 3rd hypothesis to be verified. Whereas in the first scenario, EU's virtual water imports associated with wheat register a 45% increase, when the

5 The appendix provides a description of the model used in this study. An in-depth study has been previously conducted: Le Vernoy A., 2005, "Les échanges internationaux d'eau virtuelle: le cas de la libéralisation du commerce agricole dans la région Euro-Méditerranéenne". Master Thesis in Economics of International Relations. Institute of Political Studies, Sciences-Po Paris. Contact : alexandre.levernoy@sciences-po.org

liberalization is reciprocal, EU's virtual water exports grow by 13hm^3 per year. In particular, this scenario enables Libya to increase its virtual water imports of 32%.

In the third scenario, trade liberalization accentuates its effect notably for olive oil. Trade between SEMC increases sharply and then can contribute to assess the possible positive effect of the creation of an *Arab Free-Trade Area*. For instance, Libya and Algeria's virtual water imports associated with wheat doubled amounting respectively to 23 hm^3 and 2,4 hm^3. These imports are largely coming from the EU, Tunisia and Morocco. Given irrigation practices and specific water demands in those countries, first and second hypothesis are largely verified. Concerning olive oil and oranges, virtual water imports are well reallocated from SEMC (particularly Morocco) using relatively less water to SEMC (Israel, Jordan, Lebanon) using relatively more water. Hypothesis 1 and 2 are well verified for these two products.

5. CONCLUSION

Effects of trade liberalization in agriculture of the selected products over water resources will be positive if two conditions are verified. On the one hand, exporters are using water more efficiently in their production process than importers, meaning that they have higher water productivity. On the other hand, exporters must produce more intensively rainfed-crops rather than irrigated-crops relatively to importers.

Water is central to agricultural trade relationships in the Euro-Mediterranean region. However, stakes are global: like SEMC, other developing countries will increase their withdrawals as a result of their plausible production increase in the years or decades to come. At a multilateral level, some answers to these stakes have been sketched out. Uruguay Round negotiations hatched out the principle of *multifunctionality*: future negotiations will have to take into account various non-trade aspects of agricultural trade. Like food security, (virtual) water should become a key factor to the definition of the concept of *multifunctionality*.

Even so, at the local or regional level, there is no example of policy that including the concept of virtual water as a tool for a sustainable management strategy of water resources.

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7. APPENDIX: THE MODEL

The complete model used in this study is two-fold. On the one hand, changes in trade policy and variations of trade flows are modelled in a partial equilibrium model using *GSIM 25x25*. On the other hand, virtual water contents and international trade volumes variations are modelled thanks to the *CROPWAT* model elaborated by the FAO.

International trade modelling with GSIM 25x25

It is a partial equilibrium model, which allows the analysis of global, regional or unilateral changes in trade policies for a specific product or sector that takes into account trade creation and divergence. It also considers variations in bilateral tariffs (ad valorem equivalent) and production and exports subsidies. The model relies on the *Armington assumption* that allows a degree of imperfect substitution between domestically produced and foreign produced goods. Thus, domestic and imported goods are aggregated into a new composite product using a CES demand function (Francois *et al.* – 1997).

In our simulation, European Union is the one that gather 15 members, before the process of enlargement of May 2004. The simulation includes also the following 10 SEMC: Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Syria, Tunisia and Turkey. Data on crops production for the year 2002 are extracted from the online database of the *Food and Agriculture Organisation* of the United Nation (FAOSTAT)[6]. Concerning Wheat and olive oil, world prices are collected from the UNCTAD database and from the World Bank for Oranges. For all three products, demand, supply and substitution elasticities come from UNCTAD's *TRAINS* database[7]. Bilateral trade for 2002 are from United Nations' *COMTRADE* database. Finally, bilateral tariffs are taken from: *TRAINS* (NPF tariffs) and EU's *Market Access DataBase*[8] (preferential tariffs applied by the EU to imports coming from its Mediterranean trade partners).

Virtual water content calculation

The *CROPWAT* model developed by the FAO and used in this study allows us to reach three objectives:

- estimate water quantity needed to produce each crops in different countries;
- quantify the volume of virtual water flows between nations;

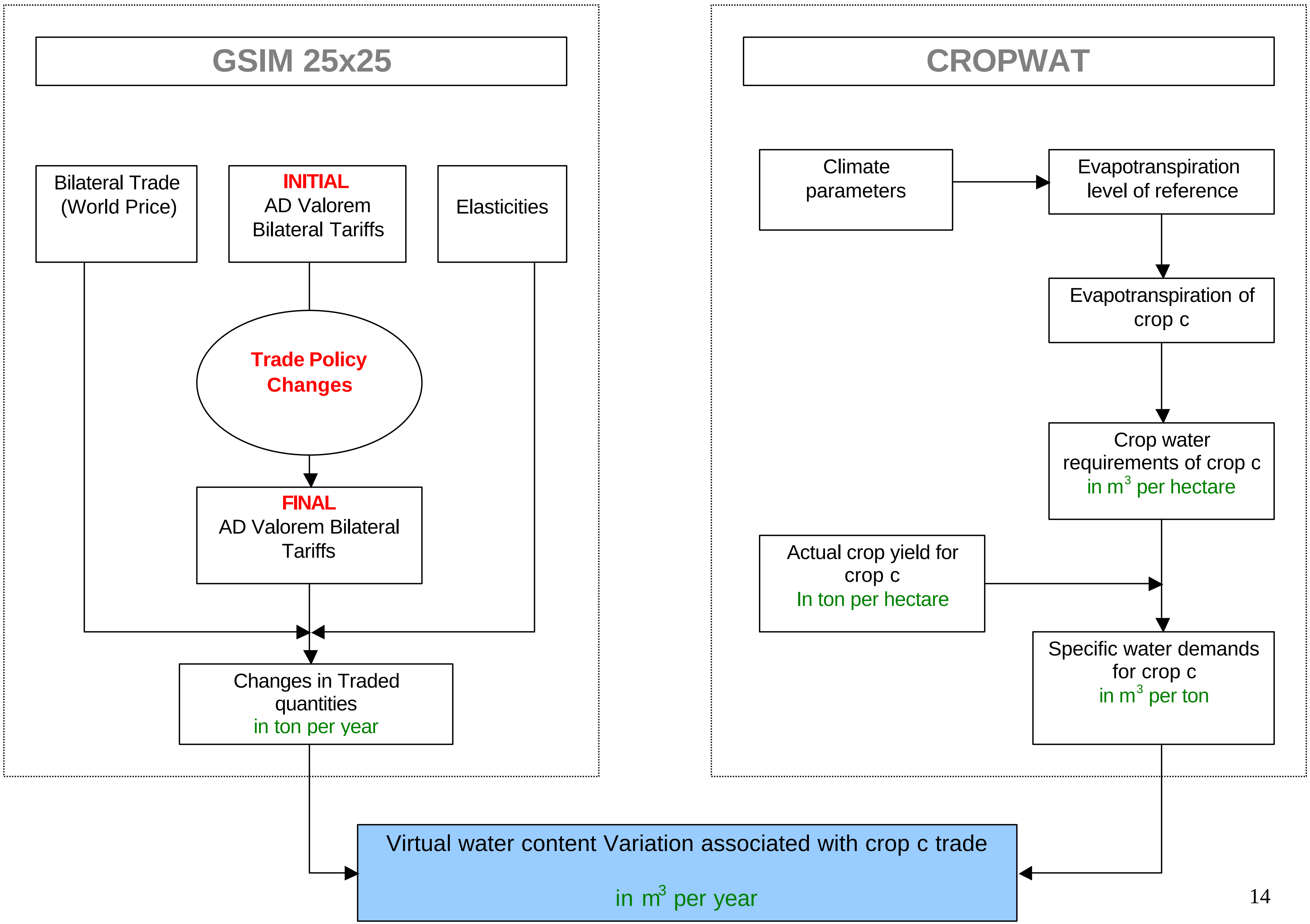
[6] Accessible from http://faostat.fao.org/
[7] Accessible from http://r0.unctad.org/trains/
[8] Accessible from http://mkaccdb.eu.int/mkaccdb2/indexPubli.htm

- studying the effect of a trade policy change on virtual water flow by connecting it to *GSIM*.

Data on water are still relatively scarce quantitatively and when they refer to virtual water flows there is a true lack of data (Hakimian, H. 2003). Somehow, FAO developed several databases that enabled us to pursue our study. Crops yields for 2002 are collect from FAO database. Specific water demands are determined thanks to all available scenarios in the *CROPWAT* model *for Windows*. Data on oranges are assessed from a citrus fruit basket (lemons, oranges, tangerine and grapefruit). Finally, let's recall that the study from A. Y. Hoekstra and P.Q. Hung (2002) was of the utmost value as it contains a lot of data on *specific water demands* for the commodities selected for this study.

Model Diagram

The following diagram summarizes the combination of both models: *GSIM* and *CROPWAT*:


GSIM 25x25
Bilateral Trade (World Price)
INITIAL
AD Valorem Bilateral Tariffs
Elasticities
Trade Policy Changes
FINAL
AD Valorem Bilateral Tariffs
Changes in Traded quantities
in ton per year
CROPWAT
Climate parameters
Evapotranspiration level of reference
Evapotranspiration of crop c
Crop water requirements of crop c
in m3 per hectare
Actual crop yield for crop c
In ton per hectare
Specific water demands for crop c
in m3 per ton
Virtual water content Variation associated with crop c trade
in m3 per year