WATER SECURITY OF NATIONS: HOW INTERNATIONAL TRADE AFFECTS NATIONAL WATER SCARCITY AND DEPENDENCY

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Abstract. Import of water in virtual form, i.e. in the form of agricultural and industrial commodities, can be an effective means for water-scarce countries to preserve their domestic water resources. On the other hand, export of water-intensive commodities will increase the use and thus the scarcity of water in the exporting countries. Another likely effect of international trade is that it increases dependency of nations that are net importers of water-intensive commodities on net exporters. This paper reviews the following questions: how relevant is international trade in magnifying water scarcity in some nations and in alleviating water scarcity in other nations, and to which extent does international trade contribute to national water dependency?

It is shown that the current global trade pattern significantly influences water use in most countries of the world, either by reducing domestic water use or by enhancing it. In the period 1997–2001, 16% of the water use in the world was not for producing products for domestic consumption but for making products for export. Many of the water problems in the export countries are partially related to their export position. On the other hand, domestic water savings can be enormous for the import countries, i.e. the countries that have partly externalized their water footprint. Jordan annually imports a virtual water quantity that is five times its own yearly renewable water resources. Although saving its domestic water resources, it makes Jordan heavily dependent on other nations, for instance the United States. Other water-scarce countries with high virtual water import dependency (25–50%) are for instance Greece, Italy, Portugal, Spain, Algeria, Libya, Yemen and Mexico.

It is suggested that future national and regional water policy studies include an assessment of the effects of trade on water security. For water-scarce countries, it would also be wise to do the reverse: study the possible implications of national water scarcity on trade. In water-scarce countries a trade-off is to be made between (over)exploitation of the domestic water resources in order to increase water self-sufficiency (the apparent strategy of Egypt) or virtual water import at the cost of becoming water dependent (Jordan).

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1. Introduction

The relation between international trade and water security is generally not something that government officials think about. The reason is that water is hardly traded internationally, due to its bulky properties. Besides, there is no private ownership of water so that it can also not be traded as in a market. It is often forgotten, however, that water is traded in virtual form, i.e. in the form of agricultural and industrial commodities. Although invisible, import of 'virtual water' can be an effective means for water-scarce countries to preserve their domestic water resources (Allan, 2001a). Import of water-intensive commodities can thus relieve the pressure on the domestic water resources. This is a mechanism that makes many countries in the Middle East survive. These countries meet their demand for food and save their scarcely available water resources through food imports from overseas. Mediterranean countries will expectedly experience increased water scarcity due to climate change, forcing them into the direction of increased import of water-intensive products.

Where food import can alleviate national water scarcity, export of water-intensive goods will increase the use and thus the scarcity of water in the exporting countries. Many water problems bear an international trade component (Hoekstra and Hung, 2005; Hoekstra and Chapagain, 2008). Subsidized water in Uzbekistan is overused to produce cotton for export; Thailand experiences water problems due to irrigation of rice for export; Kenya depletes its water resources around Lake Naivasha to produce flowers for export to the Netherlands; Chinese rivers get heavily polluted through waste flows from factories that produce cheap commodities for the European market.

International trade magnifies water scarcity in some places and relieves water scarcity in other places. Another likely effect of international trade is that it increases interdependences between nations, with as a net effect that net importers of water-intensive commodities are dependent on the net exporters. Water is like oil in this respect. Many countries that do not have oil depend on countries that do have oil. Similarly, countries that do not have much water and therefore import water-intensive commodities depend on countries that have more water and apply that for producing water-intensive export goods.

This paper reviews current knowledge with respect to the three issues raised above:

- How relevant is international trade in magnifying national water scarcity?
- How relevant is international trade in alleviating national water scarcity?
- To which extent does international trade contribute to national water dependency?

The chapter will be concluded with a discussion of risks and opportunities associated with the intensification of international trade in water-intensive commodities.

2. International trade amplifying national water scarcity

In the period 1997–2001, 16% of the water use in the world was not for producing products for domestic consumption but for making products for export (Hoekstra and Chapagain, 2007, 2008). The nations with the largest net annual water use for producing export products were the USA (92 billion cubic meters), Australia (57 billion cubic meters), Argentina (47 billion cubic meters), Canada (43 billion cubic meters), Brazil (36 billion cubic meters), and Thailand (26 billion cubic meters). The main products behind the national water use for export from the USA were oil-bearing crops and cereal crops. These products are grown partly rain-fed and partly irrigated. In Australia and Canada, the water use for export was mainly related to the production of cereals and livestock products. In Argentina and Brazil, water use for export was primarily for producing oil-bearing crops. The national water use for export in Thailand was mainly the result of export of rice. Much of the rice cultivation in Thailand is done during the rainy season, but irrigation is widespread, to achieve two harvests per year. In the period 1997–2001, Thailand used 27.8 billion cubic meters per year of water (sum of rainwater and irrigation water) to produce rice for export, mostly grown in the central and northern regions (Maclean et al., 2002). The monetary equivalent of the rice export was US$1,556 million per year (ITC, 2004). Hence, Thailand generated a foreign exchange of 0.06 US$/$m^3$.

Let me repeat that currently 16% of the water use in the world is not for producing products for domestic consumption but for making products for export and let us assume that, on average, agricultural production for export does not cause significantly more or fewer water-related problems (such as water depletion or pollution) than production for domestic consumption. That means that roughly one sixth of the water problems in the world can be traced back to production for export. Consumers do not see the effects of their consumption behaviour due to the tele-connection between areas of consumption and areas of production. The benefits are at the consumption side, but since water is generally grossly under-priced, the costs remain at the production side. From a water-resources point of view it would be wise for the exporting countries in the world to review their water use for export and see to which extent this is good policy given the fact that the foreign income associated with the exports generally does not cover most of the costs associated with the use of water. The construction of dams and irrigation schemes and even operation and maintenance costs are often covered by the national or state government. Negative effects downstream

and the social and environmental costs involved are not included in the price of the export products as well.

3. International trade alleviating national water scarcity

An obvious effect of international trade in water-intensive commodities is that it generates water savings in the countries that import those commodities. This effect has been discussed since the mid-1990s (Allan, 2001b; Hoekstra, 2003; Oki and Kanae, 2004; De Fraiture et al., 2004; Chapagain et al., 2006; Yang et al., 2006). The national water saving associated with import can be estimated by multiplying the imported product volume by the volume of water that would have been required to produce the product domestically.

In many countries international trade in agricultural products effectively reduces domestic water demand (Table 1). These countries import commodities that are relatively water-intensive while they export commodities that are less water-intensive. In the period 1997–2001, Japan, the largest (net) importer of water-intensive goods in the world, annually saved 94 billion cubic meters from its domestic water resources. This volume of water would have been required, in addition to its current water use, if Japan had produced all imported products domestically. In a similar way, Mexico annually saved 65 billion cubic meters, Italy 59 billion cubic meters, China 56 billion cubic meters, and Algeria 45 billion cubic meters (Chapagain et al., 2006).

One of the water-scarce countries that most heavily depend on imports of water-intensive commodities is Jordan. It imports 5 to 7 billion cubic meters of water in virtual form per year, which is in sharp contrast with the 1 billion cubic meters of water withdrawn annually from domestic water sources (Haddadin, 2003; Hoekstra and Chapagain, 2007, 2008). People in Jordan thus survive owing to the fact that their ‘water footprint’ has largely been externalized to other parts of the world, for example the USA. Intelligent trade largely covers up Jordan’s water shortage: export of goods and services that require little water and import of products that need a lot of water. The good side of Jordan’s trade balance is that it preserves the scarce domestic water resources; the downside is that the people are heavily water dependent.

For countries that depend on the import of water-intensive products, it is important to know whether the water thus saved has higher marginal benefits than the additional cost involved in importing these products. Let us consider the example of Egypt, a country with a very low rainfall – the mean rainfall is only 18 mm/year – and with most of its agriculture being irrigated. The import of wheat in Egypt implies a saving of their domestic water resources of 3.6 billion cubic meters per year, which is about 7% of the total volume of water Egypt is entitled to according to the 1959 agreement on the use of the Nile River. The national saving is made with the investment of foreign exchange of US$593 million per year (ITC,

2004), so that the cost of the virtual water is 0.16 US$/m^3 at most. In fact, the cost will be much lower, because the costs of the imported wheat cover not only the cost of water, but also the costs of other input factors such as land, fertilizer, and labour. In Egypt, fertile land is also a major scarce resource. The import of wheat not only releases the pressure on the disputed Nile water, but also reduces pressure to increase the area of land under agriculture. Greenaway et al. (1994) and Wichelns (2001) have shown that in the international context Egypt has a comparative disadvantage in the production of wheat, so that the import of wheat into Egypt implies not only physical water saving, but also an economic saving.

TABLE 1. Examples of nations with net water saving as a result of international trade in agricultural products. Period 1997–2001

Country	Total use of domestic water resources in agricultural sector[a] (10^9 m^3/year)	Water saving as a result of import of agricultural products[b] (10^9 m^3/year)	Water loss as a result of export of agricultural products[b] (10^9 m^3/year)	Net water saving due to trade in agricultural products[b] (10^9 m^3/year)	Ratio of water saving to water use
China	733	79	23	56	8%
Mexico	94	83	18	65	69%
Morocco	37	29	1.6	27	73%
Italy	60	87	28	59	98%
Algeria	23	46	0.5	45	196%
Japan	21	96	1.9	94	448%

[a]Hoekstra and Chapagain (2008).
[b]Chapagain et al. (2006a). Agricultural products include both crop and livestock products.

4. How international trade can enhance national water dependency

Nations can be 'water dependent' in two different ways. Most writings about national water dependency are concerned with the dependency of down-stream nations on the inflow from water from upstream basins or the mutual dependency of nations sharing a border river. This type of water dependency is sometimes quantified by considering the ratio of external to total renewable water resources of a country. FAO (2007) defines the 'external renewable water resources' of a country as that part of the country's renewable water resources which is not generated in the country. It includes inflows from upstream countries (groundwater and surface water) and part of the water of border lakes or rivers. The 'internal renewable water resources' of a country concern the average annual flow of rivers and recharge of aquifers generated by endogenous precipitation. The total renewable water resources of a country are the sum of internal and external renewable water resources. Table 2 shows the 'external water resources dependency' for a number of selected downstream countries. For a country like Egypt the

dependency is extremely high, because the country receives hardly any precipitation and thus mostly depends on the inflowing Nile water. Similarly, but to a lesser extent, Pakistan strongly depends on the water of the Indus, Cambodia on the water of the Mekong and Iraq on the Tigris and Euphrates. In all these cases water is an important geopolitical resource, affecting power relations between the countries that share a common river basin. In a country like the Netherlands external water resources dependency is high but less important, because water is less scarce than in the previous cases. Nevertheless, here too there is a dependency, since activities within the upstream countries definitely affect downstream low flows, peak flows and water quality.

The political relevance of 'external water resources dependency' of nations makes water a regional geopolitical resource in some river basins. The other type of water dependency, virtual water import dependency, makes water a global geopolitical resource. The fundamental reason is the combination of increasing scarcity of water, its unique character that prevents substitution and its uneven distribution throughout the world. Where water-abundant regions did not fully exploit their potential in the past, they now increasingly do so by exporting water in virtual form or even in real form. The other side of the coin is the increasing dependency of water-scarce nations on the supply of food or water, which can be exploited politically by those nations that control the water.

TABLE 2. Dependency on incoming river flows for selected countries

Country	Internal renewable water resources[a] (10^9 m^3/year)	External (actual) renewable water resources[a] (10^9 m^3/year)	External water resources dependency[b] (%)
Iraq	35	40	53
Cambodia	121	356	75
Pakistan	52	170	77
Netherlands	1.1	80	88
Egypt	1.8	56.5	97

[a] FAO (2007).
[b] Defined as the ratio of the external to the total renewable water resources.

From a water resources point of view one might expect a positive relationship between water scarcity and virtual water import dependency, particularly in the ranges of great water scarcity. Virtual water import dependency is defined as the ratio of the external water footprint of a country to its total water footprint. As Hoekstra and Chapagain (2008) show, countries with a very high degree of water scarcity – e.g. Kuwait, Qatar, Saudi Arabia, Bahrain, Jordan, Israel, Oman, Lebanon and Malta – indeed

TABLE 3. Virtual water import dependency of some selected countries. Period: 1997–2001

Country	Internal water footprint[a] (10^9 m^3/year)	External water footprint[a] (10^9 m^3/year)	Water self-sufficiency[b] (%)	Virtual water import dependency[c] (%)
Indonesia	242	28	90	10
Egypt	56	13	81	19
S. Africa	31	9	78	22
Mexico	98	42	70	30
Spain	60	34	64	36
Italy	66	69	49	51
Germany	60	67	47	53
Japan	52	94	36	64
U.K.	22	51	30	70
Jordan	1.7	4.6	27	73
Netherlands	4	16	18	82

[a]Hoekstra and Chapagain (2008).
[b]Defined as the ratio of the internal to the total water footprint.
[c]Defined as the ratio of the external to the total water footprint.

have a very high virtual water import dependency (>50%). The water footprints of these countries have largely been externalised. Jordan annually imports a virtual water quantity that is five times its own yearly renewable water resources. Although saving its domestic water resources, it makes Jordan heavily dependent on other nations, for instance the United States. Other water-scarce countries with high virtual water import dependency (25–50%) are for instance Greece, Italy, Portugal, Spain, Algeria, Libya, Yemen and Mexico. Table 3 presents the data for a few selected countries. Even European countries that do not have an image of being water-scarce, such as the UK, Belgium, the Netherlands, Germany, Switzerland and Denmark, have a high virtual water import dependency. In those cases where large virtual water imports go together with national water abundance, the import is obviously not related to water scarcity but must be explained from other factors.

In most water-scarce countries the choice is either (over)exploitation of the domestic water resources in order to increase water self-sufficiency (the apparent strategy of Egypt) or virtual water import at the cost of becoming water dependent (Jordan). The two largest countries in the world, China and India, still have a very high degree of national water self-sufficiency (93% and 98% respectively). However, the two countries have relatively low water footprints per capita (China 700 m^3/capita/year and India 980 m^3/capita/year). If the consumption pattern in these countries changes to that of the USA or some Western European countries, they will be facing a severe water scarcity in the future and will probably be unable to sustain

their high degree of water self-sufficiency. A relevant question is how China and India are going to feed themselves in the future. If they were to decide to partially obtain food security through food imports, this would put enormous demands on the land and water resources in the rest of the world.

5. Discussion

International transfers of water in virtual form are substantial and likely to increase with continued global trade liberalization (Ramirez-Vallejo and Rogers, 2004). Intensified trade in water-intensive countries offers both opportunities and risks. The most obvious opportunity of reduced trade barriers is that virtual water can be regarded as a possibly cheap alternative source of water in areas where freshwater is relatively scarce. Virtual-water import can be used by national governments as a tool to release the pressure on their domestic water resources. This import of virtual water (as opposed to real water, which is generally too expensive) will relieve the pressure on the nation's own water resources. For water-abundant countries an argument can be made for export of virtual water. Trade can physically save water if products are traded from countries with high to countries with low water productivity. For example, Mexico imports wheat, maize, and sorghum from the USA, which requires 7.1 billion cubic meters of water per year in the USA. If Mexico were to produce the imported crops domestically, it would require 15.6 billion cubic meters of water per year. Thus, from a global perspective, the trade in cereals from the USA to Mexico saves 8.5 billion cubic meters per year. Although there are also examples where water-intensive commodities flow in the opposite direction, from countries with low to countries with high water productivity, the available studies indicate that the resultant of all international trade flows works in a positive direction. Hoekstra and Chapagain (2008) show that international trade in agricultural commodities reduces global water use in agriculture by 5%. Liberalization of trade seems to offer new opportunities to contribute to a further increase of efficiency in the use of the world's water resources.

A serious drawback of trade is that the indirect effects of consumption are externalized to other countries. While water in agriculture is still priced far below its real cost in most countries, an increasing volume of water is used for processing export products. The costs associated with water use in the exporting country are not included in the price of the products consumed in the importing country. Consumers are generally not aware of – and do not pay for – the water problems in the overseas countries where their goods are being produced. According to economic theory, a precondition for trade to be efficient and fair is that consumers bear the full cost of production and impacts. Another downside of intensive international virtual-

water transfers is that many countries increasingly depend on the import of water-intensive commodities from other countries. Jordan annually imports a virtual-water volume that is five times its own annual renewable water resources. Other countries in the Middle East, but also various European countries, have a similar high water import dependency. The increasing lack of self-sufficiency has made various individual countries, but also larger regions, very vulnerable. If for whatever reason food supplies cease – be it due to war or a natural disaster in an important export region – the importing regions will suffer severely. A key question is to what extent nations are willing to take this risk. The risk can be avoided only by promoting national self-sufficiency in water and food supply (as Egypt and China do). The risk can be reduced by importing food from a wide range of trade partners. The current worldwide trend, however, facilitated by the World Trade Organization, is toward reducing trade barriers and encouraging free international trade, and decreasing interference by national governments.

The current global trade pattern significantly influences water use in most countries of the world, either by reducing domestic water use or by enhancing it. Future national and regional water policy studies should therefore include an assessment of the effects of trade on water policy. For water-scarce countries, it would also be wise to do the reverse: study the possible implications of national water scarcity on trade. In short, strategic analysis for water policy making should include an analysis of expected or desirable trends in international or inter-regional virtual-water flows.

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