WATER IN THE WORLD: THE EFFECTS OF AGRICULTURAL TRADE LIBERALIZATION ON THE WATER ECONOMY OF NATIONS

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1. Introduction. Agriculture is one of the most important sectors in many developing countries, and thus is a key determinant of growth. Increased trade provides economic development, as many developing countries have a comparative advantage in some form of agricultural production. For the least developed countries it represents more than 36% of GDP and 35% of total trade (IFPRI, 2003). Yet, in these countries the ability of agriculture to contribute to growth and development has been heavily circumscribed by global trade protection, much of it originating from OECD countries.

Direct agricultural subsidies in OECD countries amount to over $300 billion every year with the EU leading followed by the US and Japan (EU, 2003). Farmers in the OECD countries typically receive more than one third of their income from government programs. The value of total agricultural support in OECD countries is more than five times higher than total spending on overseas development assistance and twice the value of agricultural exports from developing countries. Payments per cow per day in the EU exceed the generally accepted definition of poverty pegged at $2 per day for hundreds of millions of humans in the developing world. As a result, the reduction of subsidies and liberalization of agriculture will continue to be at the top of the negotiating agenda of future international trade talks. As this paper was being drafted the WTO meeting in Cancun, Mexico, collapsed because of the failure of the OECD countries to address some of these contentious issues. Therefore, the linkages between agricultural trade and water resources need to be identified and analyzed to better understand the potential impacts that a full liberalization, or lack thereof, will have on water resource exploitation under future trade regimes.

Water is one of the most important inputs to agricultural production. Water is embodied in all products to a greater or lesser degree, but the amounts used in production generally exceed the embodied water by orders of magnitude. This is particularly true with agricultural products. For example Hoekstra and Hung (2002) claim that 16,000 cubic meters of water are required to produce one ton of beef, compared with 1,200 per ton of wheat. The supply of water to agriculture can be from natural sources of rain or snow or from human controlled sources by irrigation. The total amounts of water from all sources used to produce a crop and including the water embodied in the crop are referred to as *virtual water*. The concept of *virtual water* has been widely discussed since its first introduction by Allan (1993). Figure 1 gives a schematic definition of the concept. Recently there has been a resurgence of interest in operationalizing the concept (see Hoekstra and Hung, 2002, Oki, 2002, and Hoekstra et al., 2003). So far the literature has focused mainly on the amounts of virtual water traded under the present trade regimes. The main purpose of this study, however, is to examine the impact of trade liberalization on virtual-water trade in the future.

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2. Current Trade in Virtual Water. We began by examining the current trade pattern of virtual water embodied in agricultural products for most countries. The concept of trade-in virtual water is then applied to a set of agricultural and livestock products employing best estimates of water requirement coefficients to calculate the net trade in agricultural products (including meat production and trade). We also identified the main reasons behind the changes in the magnitude and direction of the net virtual water trade over time, and tested whether virtual water trade flows are independent of water resource endowments. Finally, based on a formal model (see Ramirez-Vallejo and Rogers, 2003), we derived demand functions to explain virtual water flows. Table 1 gives our best estimates of the current situation and is the basis of an exploration of future trade regimes. Figure 2 show graphically how the trade is distributed around the world.

Table 1 Net Trade in Virtual Water for Agricultural Products (ca. 1997)

COUNTRY	Cubic Km.	COUNTRY	Cubic Km.	COUNTRY	Cubic Km.
U.S.A	-164.724	Niger	0.158	Belarus	1.588
Argentina	-117.686	Malawi	0.170	Haiti	1.620
Brazil	-108.422	Lithuania	0.207	El Salvador	1.888
Australia	-82.100	Mauritius	0.211	United Arab E.	1.935
Canada	-50.125	Kyrgyzstan	0.223	Cuba	1.935
Malaysia	-45.567	Zambia	0.243	Sri Lanka	2.264
New Zealand	-23.943	Malta	0.247	Portugal	2.280
Ukraine	-18.158	Armenia	0.247	Korea, Dem R.	2.344
Thailand	-17.402	Croatia	0.267	Syrian Arab R.	2.537
Indonesia	-9.846	Latvia	0.279	Afghanistan	2.621
Hungary	-9.724	Togo	0.286	Kenya	2.795
India	-9.055	Gambia	0.301	Senegal	2.897
Uruguay	-5.812	Burkina Faso	0.311	Chile	3.028
Kazakhstan	-5.009	Congo, D. R.	0.314	Denmark	3.280
Viet Nam	-4.845	Mongolia	0.316	Dominican R.	3.293
Paraguay	-4.563	Czech Rep	0.320	Libya	3.307
Poland	-2.032	Liberia	0.382	Peru	3.561
Papua New G	-0.781	Sierra Leone	0.426	Singapore	3.669
Greece	-0.756	Macedonia, Fr Yug.	0.440	Jordan	3.904
Bolivia	-0.607	Zimbabwe	0.447	Yemen	4.356
Guyana	-0.543	Uzbekistan	0.450	Pakistan	4.498
Slovakia	-0.466	Somalia	0.464	Colombia	5.094
Nicaragua	-0.358	Madagascar	0.472	Tunisia	5.161
Mali	-0.329	Estonia	0.507	France	5.257
Benin	-0.273	Tajikistan	0.528	South Africa	5.357
Swaziland	-0.225	Albania	0.561	Venezuela	5.398
Iceland	-0.214	Finland	0.601	Belgium	5.544
Uganda	-0.159	Georgia	0.625	Spain	5.496
Moldova	-0.115	Mauritania	0.625	Israel	6.815
Fiji Isls.	-0.111	Trinidad and T.	0.670	Bangladesh	7.361
Turkmenistan	-0.092	Romania	0.675	Turkey	7.366
Reunion	-0.077	Cameroon	0.711	Iraq	7.942
Belize	-0.075	Ethiopia	0.734	Germany	8.378
Suriname	-0.048	Panama	0.751	Morocco	8.462
French Guiana	-0.033	Honduras	0.752	Philippines	8.545
Chad	-0.029	Oman	0.858	Italy	9.044
C.A. Republic	-0.015	Austria	0.867	Nigeria	9.128
Solomon Isl.	-0.012	Costa Rica	0.882	U. K.	10.672
Palestine	-0.002	Sudan	0.892	Netherlands	11.320
Burundi	0.000	Guinea	1.044	Algeria	12.336
Comoros	0.003	Azerbaijan	1.084	China	12.925

Maldives	0.006	Mozambique	1.115	Saudi Arabia	14.454
Bahamas	0.008	Ghana	1.122	Iran	20.950
Qatar	0.011	Cyprus	1.153	Egypt	27.706
Lesotho	0.013	Slovenia	1.200	Korea, R.	40.449
Botswana	0.023	Angola	1.222	Russian Fed.	48.427
Laos	0.033	Bosnia and Herz.	1.227	Mexico	51.188
Cape Verde	0.041	Jamaica	1.244	Japan	116.462
Barbados	0.046	Ecuador	1.268		
Nepal	0.069	Norway	1.303		
Yugoslavia, R.	0.098	Lebanon	1.310		
Puerto Rico	0.105	Ireland	1.313		
Gabon	0.108	Kuwait	1.328		
Cambodia	0.114	Cote d'Ivoire	1.348		
Rwanda	0.116	Guatemala	1.373		
Bahrain	0.123	Sweden	1.533		
Brunei Darussalam	0.128	Tanzania	1.552		
Bulgaria	0.149	Switzerland	1.557		

Note: For virtual water trade, negative figures indicate exports, positive figures imports.

3. The Impact of full trade liberalization on virtual water flows.

Researchers at IFPRI (Rosegrant et al., 2001 and 2002) built a multi-commodity model named IMPACT, with a methodology for analyzing alternative scenarios for global food demand, supply, and trade. It covers 36 countries and regions, accounting for virtually all of the world's food production and consumption, and 16 commodities, including cereals, soybeans, roots and tubers, meats, milk, eggs, oils, oilcakes, and meals, representing a competitive agricultural market for crops and livestock.

For the purpose of simulating the impact of full liberalization on the pattern and intensity of virtual water flows, results from the IFPRI simulation model were applied. The IMPACT model simulates the effects on food production, prices and trade of removing all agricultural subsidies and trade barriers in food markets. In the full trade liberalization scenario, all price wedges (PSEs and CSEs[3]) between domestic and international cereal prices were removed, with the reductions phased in between 2005 and 2006.

IFPRI found that full liberalization would have a significant effect on cereal prices by 2020 with rice increasing the most, 14%, followed closely by maize, wheat and other course grains. Meat prices would respond with even sharper price increases with beef alone being subject to an 18% increase. The world prices under the baseline scenario (IFPRI's "best" estimate of what the 2020 prices would look like) and the scenario under full trade liberalization are shown in Table 2.

Table 2. World prices under the baseline and full trade liberalization scenarios in 2020 (US$/ton)

Commodity	BAU 2020 (1995 prices)		Full Trade Liberalization	Percentage Change from BAU (and 1995)	
Wheat	123	(133)	133	8.1	(0.0)
Rice	250	(285)	285	14.0	(0.0)
Maize	102	(103)	111	8.8	(7.8)

[3] PSE, and CSE are the producer and consumer subsidy equivalents respectively expressed as a price wedge between domestic and international prices.

Other Coarse Grains	86	(97)	93	8.1	(-4.1)
Beef	1,740	(1,808)	2,044	17.5	(13.5)
Pork	2,239	(2,304)	2,484	10.9	(7.8)
Sheep and Goat	2,832	(2,198)	3,368	18.9	(15.7)
Poultry	703	(735)	785	11.7	(6.8)

Source: IMPACT projections, June 2001.

Because of the larger livestock price changes, the full trade liberalization scenario has a greater effect on regional livestock production, demand and trade than it does on cereals. This is because existing levels of protection are generally higher for livestock products than for cereals. However, the increase in livestock demand generates an equally important increase in demand for animal feed. Table 3 compares the current levels of VWT with the 2020 BAU scenario for various regions of the world.

Table 3

Virtual Water Embodied in meats, wheat and rice trade, 1997 and 2020 Under the BAU Scenario ($Km^{3)}$

	Meats		**Wheat**		**Rice**	
	1997	**2020**	**1997**	**2020**	**1997**	**2020**
Developed World	-75.1	-185.8	-81.0	-137.7	-1	1.9
United States	-74.7	-182.8	-33.9	-53.5	-6.6	-7.4
EU15	-58.8	-71.4	-16.8	-23.7	1.1	1.0
Former Soviet U.	79.4	75.7	3.5	-7.8	1.5	1.7
Developing World	75.1	185.8	81.0	137.7	1	-1.9
Latin America	-9.3	-73.1	10.1	2.5	4.0	2.3
Sub-Saharan A.	4.5	8.7	8.5	18.1	11.3	17.2
West Asia/North A	27.3	53.0	33.6	49.1	9.2	15.4
South Asia	-6.0	13.5	6.8	25.5	-8.7	2.3
Southeast and East Asia	6.5	176.2	21.3	41.5	-16.5	-40.4

1. In Virtual Water Trade, negative figures indicate amount of water being exported, and positive numbers the amount of water being imported.
2. IFPRI adopted the following definitions of regions and countries: EU15: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom. West Asia/North Africa (WANA): Egypt, Turkey, Algeria, Cyprus, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Saudi Arabia, Tunisia, United Arab Emirates, and Yemen. South Asia: Bangladesh, India, Pakistan, Afghanistan, Maldives, Nepal, and Sri Lanka. South East Asia: Indonesia, Malaysia, Myanmar, Philippines, Thailand, Viet-Nam, Brunei, Cambodia, and Laos. East Asia: China (including Taiwan and Hong Kong), Republic of Korea, People's Republic of Korea, Macao, and Mongolia.

The estimated impacts of trade liberalization on trade in virtual water using the results of the IFPRI's IMPACT model are shown in Tables 4 and 5. The baselines reported in these tables are for the expected 2020 virtual water trade for the specific crop without full liberalization.

Table 4.
Amount of Virtual Water in Net Trade of Meat 2020
Km^3

COUNTRY/REGION	Virtual Water Baseline Scenario	Virtual Water Full Liberalization Scenario	Net Effect Km^3	
United States	-183	-267	84	Increase in Water Exports
EU15	-72	-54	18	Decrease in Water Exports
Japan	96	105	9	Increase in Water Imports
Former SU	75	99	24	Increase in Water Imports
Latin America	-72	-159	87	Increase in Water Exports
Sub-Saharan Africa	9	45	36	Increase in Water Imports
West Asia/North Af.	54	39	15	Decrease in Water Imports
South Asia	15	69	54	Increase in Water Imports
Southeast Asia	15	39	24	Increase in Water Imports
East Asia	162	198	36	Increase in Water Imports

In Virtual Water Trade, negative figures indicate amount of water being exported, and positive numbers water being imported.

Table 5.
Amount of Virtual Water in Net Trade of Cereals 2020

COUNTRY/REGION	Virtual Water Baseline Scenario	Virtual Water Full Liberalization Scenario.	Net Effect Km^3	
United States	-214.2	-216	1.8	Increase in Water Exports
EU15	-52.2	-41.4	10.8	Decrease in Water Exports
Japan	54	68.4	14.4	Increase in Water Imports
Former SU	-54	-55.8	1.8	Increase in Water Exports
Latin America	5.4	3.6	1.8	Decrease in Water Imports
Sub-Saharan Africa	48.6	52.2	3.6	Increase in Water Imports
West Asia/North Africa	131.4	138.6	7.2	Increase in Water Imports
South Asia	37.8	37.8	0	Neutral
Southeast Asia	16.2	18	1.8	Increase in Water Imports
East Asia	120.6	117	3.6	Decrease in Water Imports

In Net Virtual Water Trade, negative figures indicate amount of water being exported, and positive numbers water being imported.

Based on this simulation, a scenario of full liberalization of agriculture in 2020 compared to a baseline scenario (BAU 2020) would have a greater net effect on virtual water flows from the readjustments of meat trade than from that of cereals' trade. When the net effect of the meat and cereals markets are added together, the two major contributors to the increase in virtual water trade would be the United States, which would increase its annual virtual water exports by about 86 km^3, and Latin America with a similar 89 km^3 increase (Figure 3). The major changes in virtual water imports would occur in Asia in general (South Asia, Southeast Asia, East Asia) with

an increase of 112 Km^3, Sub-Saharan Africa with an increase of almost 40 km^3 and the former Soviet Union with an increase in water imports of 22 km^3, mostly due to an increase in meat imports. West Asia and North Africa together, on the other hand, would decrease the level of virtual water imports by about 7 km^3, but will remain as an important net importer of virtual water of about 176 km^3.

4. Results and Findings.

This paper has examined trade of virtual water used producing agricultural products for export for most countries of the world. The concept of trade-in virtual water was applied to a set of agricultural and livestock products applying estimated water requirement coefficients. The current (data for 1997) world trade of virtual water that is embodied in the agricultural products considered in this study was equivalent to 684 cubic kilometers of water, but it could go to an even higher level depending on the assumptions of water requirements. Other estimates (Hoekstra and Hung 2002, Oki 2002, and Hoekstra et al. 2003), report 835 km^3, 683 km^3, and 1,148 km^3 respectively. The products that contribute the most in virtual water flows are cereals, meat, and oilseeds and edible oils. The contribution of the rest is very small. The largest virtual water exporter countries under current trade conditions are the United States, Argentina, Brazil, Australia, Canada, and Malaysia, while the largest importers are the following countries: Japan, Mexico, the Russian Federation, Korea, Egypt, and Iran.

Using the change over time in net virtual water embodied in agricultural products since 1967, we identified the main reasons behind changes in the magnitude and direction of the net virtual water trade over time. Complex interactions among technology, policy, investments, environment, and human behaviour influence them. Any factor or condition that alters the demand or supply sides of the agricultural commodities markets has an impact on the net virtual water trade.

We have shown that the simple trade theorems do not apply for water as a factor of agricultural production, implying that net virtual water trade flow is independent of water resource endowments. Instead, other variables were found to have greater explanatory power of the variance of virtual water imports. These are: (i) the average income (GDP); (ii) population; (iii) agriculture as value added (% of GDP); (iv) irrigation (actual and potential); and, (v) exports of goods and services (% of GDP). The sign found for each of these variables in the estimated equations were as expected, with the absolute value of elasticities ranging from 0.3 to 0.7.

The findings of this study lie not in just characterising the flow pattern of virtual water trade but predicting the elasticities of income and agricultural support that enable sound analysis of the virtual water market, and developing a methodology for assessing the effects of changed trade regimes on virtual water trade flows. For year 2000-2001, estimates of the income and agricultural support elasticities of demand for imports have the expected sign, and are statistically significant. A very strong relationship between income and virtual water imports was found with an income elasticity of 0.52. An equally strong relationship was found between the level of support/protection to agriculture and virtual water trade with an elasticity of – 0.9.

6. Conclusions.

When the net effects of the meat and cereals markets are added together for the BAU scenario and combined with full trade liberalization in Figure 3 we see that the two major exporters of virtual water would be the United States and Latin America in similar amounts and both would increase their exports with trade liberalization. The major change in virtual water imports would appear in Asia, Sub-Saharan Africa, and the former Soviet Union mainly due to an increase in

meat imports. West Asia and North Africa together, on the other hand, would decrease the level of virtual water imports, but will remain as an important net importer of virtual water. The impact of trade liberalization of agriculture on virtual-water trade based on a simulation of global agricultural trade made by IFPRI would have a greater net effect on virtual water flows from the relocation of meat trade than from the adjustment in cereals' trade.

An important conclusion from this study is that apart from the US and Latin America, it is not *a priori* obvious what will happen under trade liberalization. Explaining why flows change is a complex tale of increasing demands for agricultural products in general, and for animal products in particular, rising incomes particularly in Asia, and, of course, rapidly increasing populations.

Future studies of trade and water resources are important because the future policy debate will demand informed answers to questions about the effect on water development of international trade/integration agreements. An evaluation of the links between trade and water development may also help countries design a strategic approach to food security and redefine their water policy. On the other hand, the Uruguay Round Agreement on Agriculture (URAA) contains a specific provision (Article 20) that a new negotiation on agriculture takes into account, inter-alia, non-trade concerns. These concerns have been encircled in a concept known as "multi-functionality". Water then may come to play an important role in the composition of *multi-functionality* of agricultural trade, not only as a major input in food production, but also as a factor to achieve food security and to potentially generate negative or positive impacts on the environment.

When discussing virtual water other issues naturally arise. Why not consider *virtual nutrients* and *virtual energy* both of which are also important inputs into agricultural production and, hence, trade? What about the ecological effects of consuming large quantities of water and soil nutrients for products, which are then exported? Was this the fate suffered by the North African region as the main supplier of grain, and hence virtual water, to Imperial Rome 2000 years ago? In many countries, such as India, China, the US, and Russia) and there are large climatic differences between parts of the countries. How can the concept of virtual water trade be used in developing water policies? Would the current Chinese South-North river diversions and the proposed Indian linking of all river basins be seriously challenged by an examination of the domestic trade of virtual water? These issues remain largely unexplored and cry out for further research.

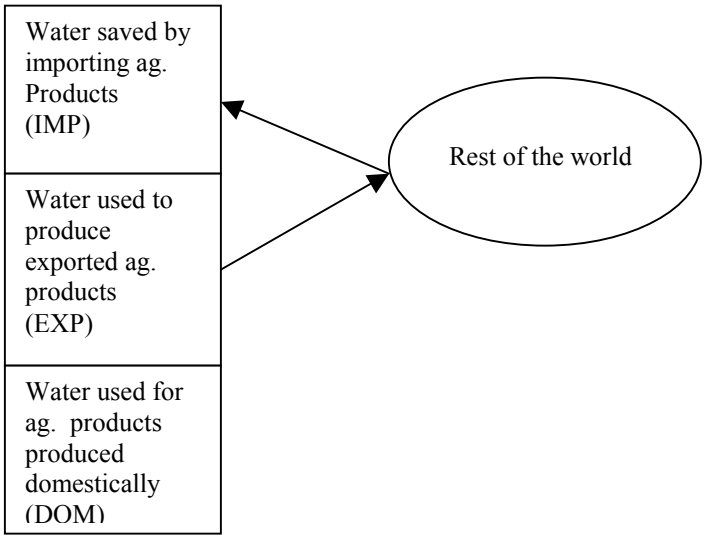

Figure 1. Definitions of Virtual Water Trade and the Agricultural Water Footprint for a specific country. In the figure the Footprint is equal to DOM - EXP + IMP

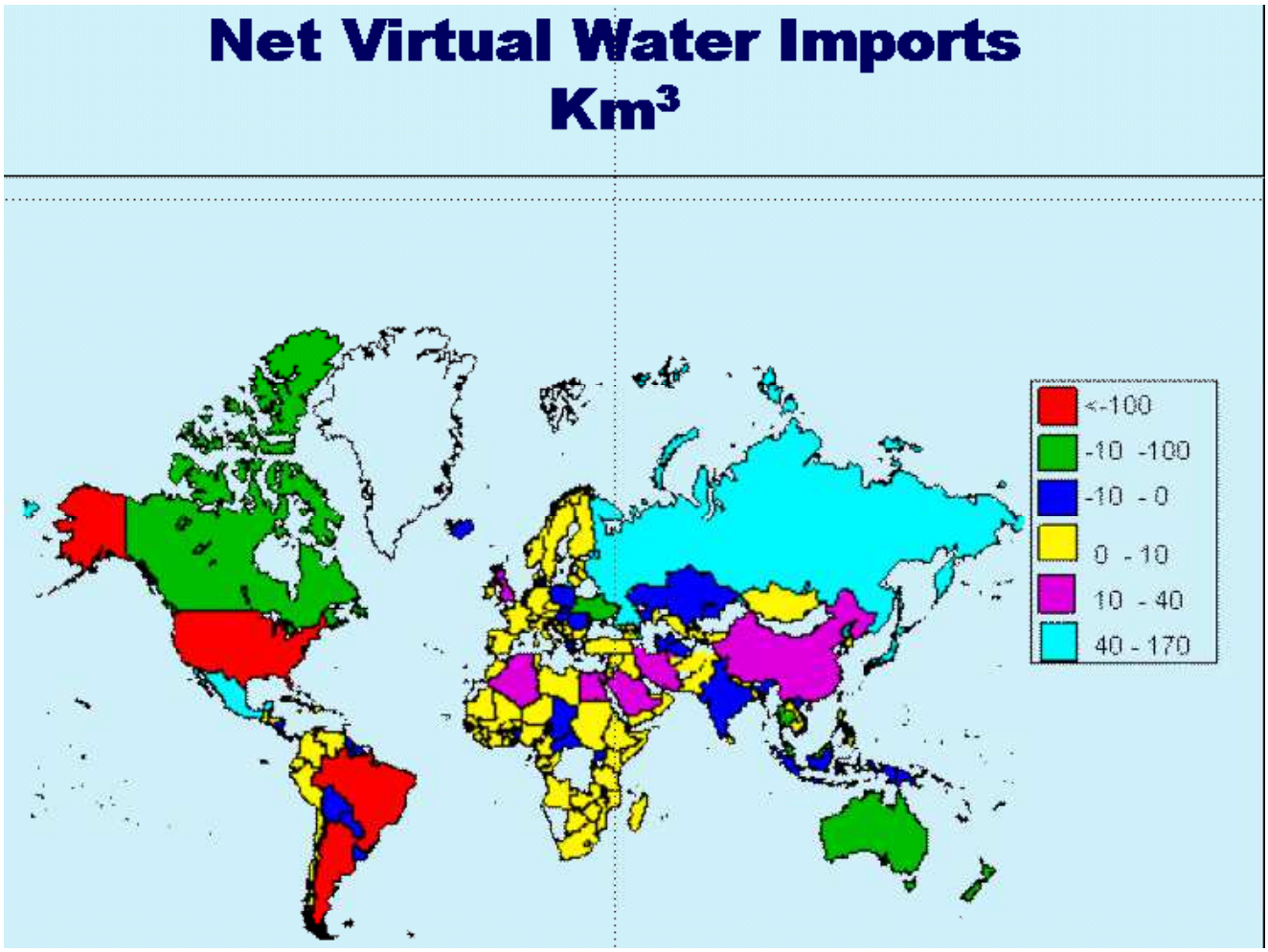

FIGURE 2

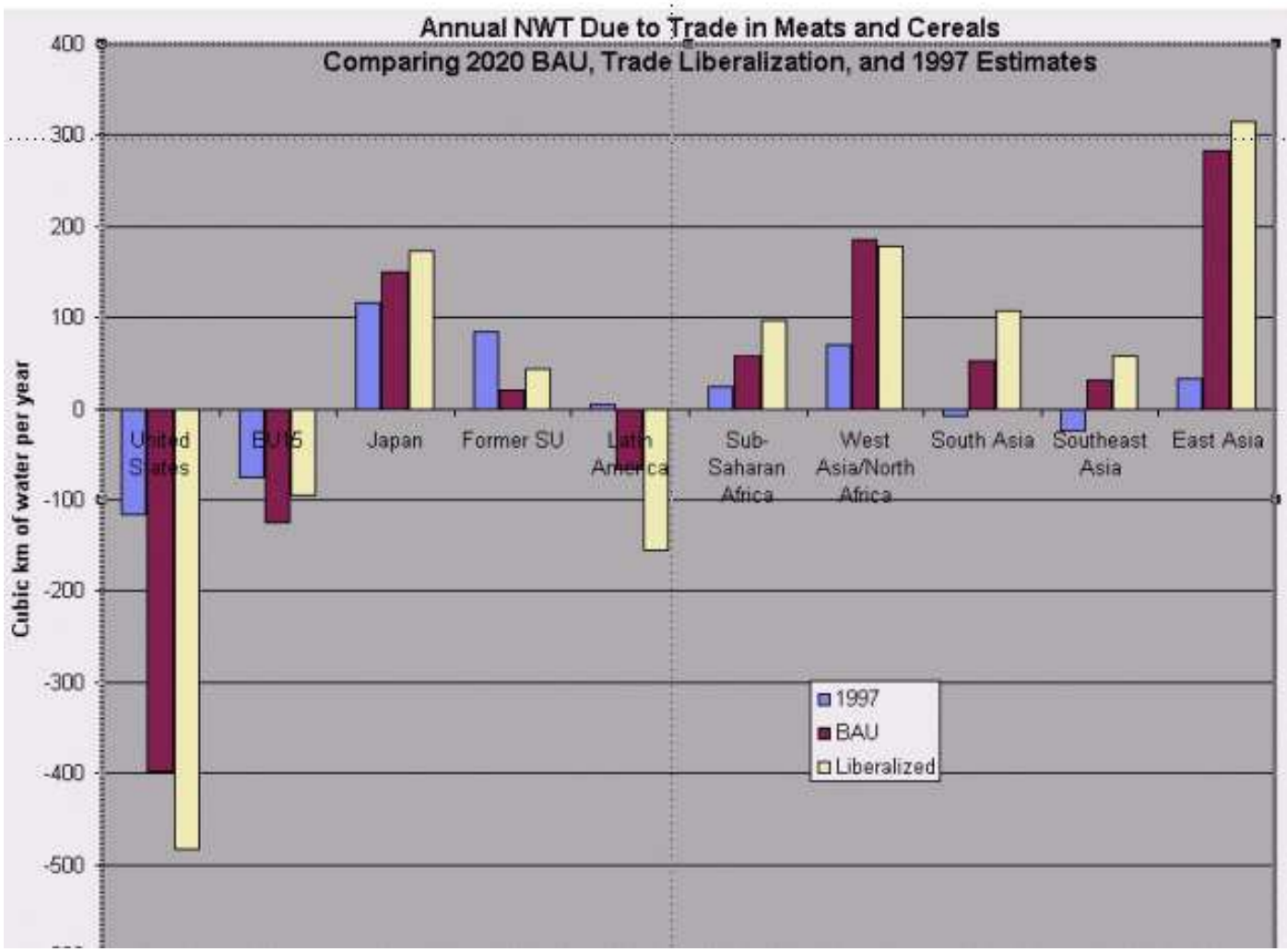
Annual NWT Due to Trade in Meats and Cereals
Comparing 2020 BAU, Trade Liberalization, and 1997 Estimates
Cubic km of water per year
400
300
200
100
0
-100
-200
-300
-400
-500
United States
EU15
Japan
Former SU
Latin America
Sub-Saharan Africa
West Asia/North Africa
South Asia
Southeast Asia
East Asia
1997
BAU
Liberalized

FIGURE 3

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