Agricultural Trade and Freshwater Resources

Jeffrey J. Reimer
Associate Professor
Department of Agricultural and Resource Economics
213 Ballard Hall, Oregon State University, Corvallis, OR, 97331
jeff.reimer@oregonstate.edu

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Oregon State University, Department of Agricultural and Resource Economics









Background

A growing literature places water in an international context. Topics include the:

- Virtual water metaphor of Allan (1998) that posits that water-scarce countries can make up for their deficit by importing products that require a lot of water in their production;
- Pure economics of virtual water trade, specifically whether it is a legitimate economic concept and how it relates to the comparative advantage concept of international trade (e.g., Reimer 2012);
- Detailed measurement of virtual water trade flows (e.g., Yang et al 2006);
- Whether renewable freshwater availability is a good predictor of trade patterns (e.g., Kumar and Singh 2005).

In contrast to the above, this study develops a quantitative simulation model of international trade in water-intensive products, making use of recent advancements in how agricultural trade can be modeled (Reimer and Li, 2010).

The model is not about the measurement of virtual water trade, but about the characterization of the global decision-making that gives rise to virtual water flows. In particular, the model shows how trade in water-intensive products is a potential mechanism for climate change adaptation and enhanced water-use efficiency.

The Model

The model predicts trade in water-intensive products between specific pairs of countries, allowing for water resources, technology, and trade barriers such as tariffs and geography to all play a role. A spatial equilibrium approach is taken, which implies that products are homogeneous and trade flows can start up and shut down easier than would generally happen in the case of differentiated-products trade models. Trade flow adjustments occur at the extensive as well as intensive margin.

The characterization of water usage is based on innovative new data from Mekonnen and Hoekstra (2010) concerning the water footprint of agricultural production in 23 countries. Taking the inverse of the water footprint for an individual commodity provides a measure of output per unit of water that is used. In the case of crops this is a measure of agricultural water productivity. This varies extensively across countries and is a force driving international virtual water flows. It is one reason why trade liberalization could lead to global water use efficiency gains.

Trade liberalization scenario

If a policy shock to final product trade occurs, how does this filter back into water usage by country? Since tariffs, tariff-rate quotas, and technical barriers to trade are pervasive in this sector, a form of trade liberalization is considered in which countries liberalize their import policies until they equal that of the country with the least restrictive import policy, which for this set of countries happens to be the United States (Reimer and Li, 2010). Although nothing is changed except each country's openness to imports, this has a beneficial effect on each country's ability to export as well. Since other countries loosen their import restrictions, it becomes easier to export to them. Changes resulting from this shock are summarized in Table 4 at the right.

Also considered is whether trade liberalization might play a role in conserving water at the global level. One useful relationship to consider is the percentage change in production against the cost of using water to produce crops, which is influenced by national technology, competitiveness, and heterogeneity in productivity across countries. The relationship is plotted in Figure 1. The correlation is -0.53, suggesting that under a liberalized import policy, production shifts to regions where the cost of using water is cheaper, all else the same. The correlation is not (and cannot) be perfectly negative due to remaining bilateral trade costs, such as freight costs and numerous other policy distortions that has not been considered. A related result is that, under trade liberalization, the percentage change in production has a 0.39 correlation with overall water availability.

Figure 1. Scatter plot of production change under import liberalization

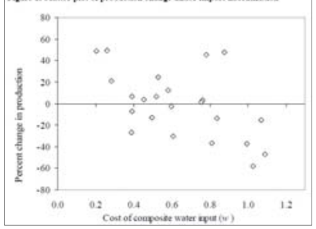

Table 4. Scenario 2: Liberalized import policy for final products

Source country i	Openness original estimate	Openness imposed value	Production $w_i L_i = \sum_j X_{ij}$ % change	Crop price P_i % change	Cost of water use w_i % change	Crop exports $\sum_{j \neq i} X_{ij}$ % change	Crop imports $\sum_{j \neq i} X_{ji}$ % change
Argentina	2.705	5.875	49.3	38.3	39.0	158	9,178
Australia	2.274	5.875	-7.3	-20.1	-2.5	1,914	539
Brazil	2.633	5.875	20.9	14.1	17.5	540	745
Bulgaria	-4.046	5.875	3.2	-30.8	12.0	1,584	102,012
China	1.732	5.875	-27.0	-32.7	-20.3	13,637	737
Ethiopia	1.873	5.875	6.5	-8.3	8.5	1,536	3,829
France	3.228	5.875	3.7	-15.0	7.4	172	119
Greece	-0.986	5.875	-15.3	-77.8	18.2	2,416	155
Hungary	-1.179	5.875	47.7	-34.5	62.1	461	5,409
Italy	0.028	5.875	-13.5	-53.4	2.4	1,836	230
Japan	-0.861	5.875	-37.2	-45.4	-28.3	980	2,717
Mexico	-0.704	5.875	-30.5	-51.1	-18.6	5,485	184
Morocco	0.593	5.875	12.5	-16.6	17.1	630	2,534
Peru	-3.554	5.875	-57.9	-71.3	-44.5	101,723	367
Romania	-2.286	5.875	45.1	-34.1	59.1	614	27,408
Russia	-0.749	5.875	24.6	-25.9	33.1	3,509	4,896
South Africa	1.698	5.875	-12.8	-25.2	-7.0	3,466	232
Spain	1.107	5.875	1.6	-42.5	14.8	619	146
Turkey	0.853	5.875	-2.8	-40.8	9.1	10,040	322
Ukraine	-2.522	5.875	6.4	-15.0	10.3	3,059	67,591
United States	5.875	5.875	49.0	46.8	36.9	241	626
Uruguay	-3.418	5.875	-36.7	-68.2	-18.5	11,609	402
Zimbabwe	-4.294	5.875	-47.3	-72.1	-30.2	43,526	1,397

Irrigation water scenario

One of the largest impacts of global climate change is expected to be on regional freshwater resources. Climate models predict that many drought-prone and marginal areas in the subtropics and mid-latitudes will become drier. Water stored in glaciers and snow cover is predicted to decline, reducing irrigation water availability at critical times in many regions.

In this scenario, green water, which refers to soil water originating from rain, is distinguished from blue water, which is surface water or groundwater evaporated as a result of the production of the product. The scenario considers an extreme shock in which all irrigation water becomes unavailable. Although this is an extreme case that is not predicted by any climate model, it provides a starting point to show how reduced ability to irrigate can be alleviated to some extent by virtual water trade in final products. Results are reported in Table 2. Production is reallocated according to the cost of water use, geographic location, trade policies, technology, and other aspects of competitiveness. Some new trade flows start up, while others shut down, based on a rich mix of parameters. The simulation sheds light on many of the adjustments that might be seen under climate change – impacts that are too big for one country to handle by itself in isolation.

Table 2. Counterfactual 1: All irrigation water is taken away

Source country i	L_i original value	L_i new value	Production $w_i L_i = \sum_j X_{ij}$ % change	Crop price P_i % change	Cost of water use w_i % change	Crop exports $\sum_{j \neq i} X_{ij}$ % change	Crop imports $\sum_{j \neq i} X_{ji}$ % change
Argentina	1.00	0.92	8.0	17.6	13.5	16.2	12.8
Australia	1.00	0.77	-1.9	27.0	20.7	-18.8	11.0
Brazil	1.00	0.97	7.3	10.6	8.0	63.0	-28.7
Bulgaria	1.00	0.91	2.9	13.5	10.3	42.3	-23.5
China	1.00	0.85	0.4	18.5	14.0	-7.5	-7.4
Ethiopia	1.00	0.85	0.6	19.0	14.5	10.0	-8.0
France	1.00	0.82	0.6	22.8	17.5	3.7	1.6
Greece	1.00	0.77	-5.4	20.0	17.1	-0.3	7.0
Hungary	1.00	0.92	7.3	17.1	13.1	21.5	-3.8
Italy	1.00	0.88	3.2	20.1	14.8	14.9	-4.9
Japan	1.00	0.90	2.4	7.1	5.4	66.8	-46.1
Mexico	1.00	0.66	-10.9	31.6	26.3	-27.9	20.0
Morocco	1.00	0.69	-7.5	34.5	26.5	-33.2	60.5
Peru	1.00	0.82	-1.9	19.3	15.1	16.0	7.6
Romania	1.00	0.87	3.1	18.5	14.1	12.1	4.8
Russia	1.00	0.82	-0.7	21.7	16.7	-2.2	24.0
South Africa	1.00	0.70	-8.2	30.3	24.6	-21.7	27.9
Spain	1.00	0.55	-25.9	29.2	28.0	-39.0	26.8
Turkey	1.00	0.81	-1.6	21.2	16.5	-0.4	4.4
Ukraine	1.00	0.89	1.2	14.0	10.7	39.1	-25.6
United States	1.00	0.77	-2.3	26.7	20.4	-7.2	42.7
Uruguay	1.00	0.92	3.9	14.1	10.2	38.4	-13.1
Zimbabwe	1.00	0.60	-20.2	47.1	37.4	-55.4	120.1

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For further information: jeff.reimer@oregonstate.edu phone 541-737-1415

OSU Oregon State University