Ecological Indicators 52 (2015) 277–283

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Virtual water and water footprints do not provide helpful insight regarding international trade or water scarcity

Dennis Wichelns

P.O. Box 2629, Bloomington, IN, United States

ARTICLE INFO

Article history:
Received 14 May 2012
Received in revised form
25 November 2014
Accepted 12 December 2014

Keywords:
Agriculture
Comparative advantage
Economics
Irrigation
Policy

ABSTRACT

Many authors have estimated the virtual water content of good and services traded internationally, and many have calculated national water footprints that account for the volumes of virtual water imported and exported. Some authors have suggested that international trade of virtual water has been harmful to selected exporting countries with limited water endowments. Some suggest also that current patterns of international trade should be rearranged to make better use of global water resources. Yet, countries do not actually trade in virtual water. They trade in goods and services for which water is one of many inputs. Wise choices regarding water resources and smart strategies regarding international trade cannot be determined by focusing on water alone. The notions of virtual water and water footprints are not helpful indicators of optimal strategies regarding water resources, particularly when considering issues such as water scarcity or international trade. I describe four perspectives regarding virtual water and water footprints, with the goal of demonstrating the inadequacies of these notions in policy discussions and in efforts to determine the optimal allocation and use of water resources. The four perspectives are: (1) international trade should not be modified or regulated to reflect the virtual water content of traded commodities or water footprints in the countries of trading partners, (2) countries do not save water by engaging in virtual water trade, (3) consumers in one country cannot alleviate water scarcity or improve water quality in other countries, and (4) water footprints are not analogous to carbon or ecological footprints.

1. Introduction

Many authors have suggested in recent years that consumers, firms, and public agencies should pay greater attention to the amounts of water used to produce goods and services, particularly those that trade in international markets. Some suggest, for example, that when rice, maize, or beef is traded internationally, the amount of water used to produce the crop or livestock product also moves across borders in “virtual” form (Oki and Kanae, 2004; Chapagain et al., 2006a; Hoekstra and Chapagain, 2007a,b; Mekonnen and Hoekstra, 2010). Several authors suggest that these “flows of virtual water” should be considered when designing national strategies regarding water and agriculture, and when evaluating guidelines pertaining to international trade (Rudenko et al., 2013; Duarte et al., 2014; Shi et al., 2014; Zhang and Anadon, 2014; Zoumides et al., 2014).

The notion of virtual water was first presented as an interesting description of how arid countries satisfy their annual food demands by importing substantial amounts of grain and other products (Allan, 1996, 2002). The notion was not intended initially to serve as an analytical framework. Indeed, there is no conceptual or empirical support for the notion that countries engage in trade to secure the water required to produce goods and services.

Several authors began calculating the “water footprints” of goods and services a few years after the notion of virtual water was introduced, with the goal of describing the direct and indirect water use by consumers and producers (Hoekstra and Chapagain, 2007a; Ercin and Hoekstra, 2014; Zoumides et al., 2014). The authors define the water footprint of an individual or community as the total volume of fresh water used to produce the goods and services consumed by the individual or community (Ercin and Hoekstra, 2014). When calculating water footprints, water use generally is measured as the net volume of water consumed or evapotranspired in production or consumption, rather than the gross volume of water applied to a farm field or run through a production process (Ercin and Hoekstra, 2014). This approach correctly prevents double-counting of water that runs off a farm field, percolates into

E-mail address: dwichelns@csufresno.edu

http://dx.doi.org/10.1016/j.ecolind.2014.12.013
1470-160X/

groundwater, or is captured and used again in an industrial operation. Yet, water footprints consider only one input and they do not address the opportunity costs or scarcity values of any inputs. Thus, water footprints are not helpful in determining wise policy choices.

My goal in this paper is to enhance understanding of the inherent limitations of the popular notions of virtual water and water footprints. These notions have gained considerable traction in both popular and scholarly literature in recent years, yet they lack the conceptual foundation and empirical validity required to be useful in policy analysis. I describe four perspectives regarding virtual water and water footprints, with the goal of demonstrating the inadequacies of these notions in policy discussions and in efforts to determine the optimal allocation and use of water resources: (1) international trade should not be modified or regulated to reflect the virtual water content of traded commodities or water footprints in the countries of trading partners, (2) countries do not save water by engaging in virtual water trade, (3) consumers in one country cannot alleviate water scarcity or improve water quality in other countries, and (4) water footprints are not analogous to carbon or ecological footprints.

2. International trade should not be modified to reflect virtual water or water footprints

Several authors of the literature on virtual water suggest or imply that water-short countries should import water-intensive products from countries with larger water endowments, and that water-abundant counties should focus on producing and exporting water-intensive goods (Yang and Zehnder, 2002; Hoekstra and Hung, 2005; Velázquez, 2007; Chapagain and Hoekstra, 2008; Winter et al., 2014). Some propose changes in the geography or methods of production, to produce the goods and services consumed worldwide with the smallest possible water footprints (Ercin et al., 2012). In a sense, the authors are suggesting that local and regional water scarcity issues should be addressed by rearranging global production and trade patterns. Some of the authors promoting this perspective suggest that the notion of virtual water is analogous to the economic concept of comparative advantage, which is a core principle of international trade theory (Allan, 2003; Lant, 2003). That perspective is not correct.

Comparative advantage requires consideration of the opportunity costs of production for each trading partner. The opportunity costs will depend on resource endowments and the technology of production in each setting. The virtual water perspective considers only a country's water endowment. There is no consideration of technology and no comparison of the opportunity costs of production within or across trading partners. At its best, virtual water might be described as an application of absolute advantage, which is not a sufficient criterion for determining optimal trading strategies (Wichelns, 2004, 2011a,b). Absolute advantage neglects consideration of opportunity costs, which must be considered to identify the strategy that maximizes the sum of net benefits from international trade.

Several water-short countries, such as Israel, Jordan, and Australia produce and trade water-intensive products. Those activities generate substantial revenues for the producers, while enhancing the portfolio of goods and services available in both the exporting and importing countries. The optimal allocation and use of limited water resources can best be determined by considering local and regional opportunity costs, and addressing locally relevant equity and justice concerns.

The conceptual inadequacy of the virtual water perspective is reinforced by empirical analysis of international trade. Kumar and Singh (2005) analyze data describing water availability and international trade for 146 countries. They find that observed trading patterns are not consistent with those predicted by the virtual water perspective. Some water-abundant countries import food, while some water-scarce countries export food. The authors conclude that relative land endowments, access to arable land, and water storage in the soil profile would be more helpful than water endowments in explaining the observed variation in international trade patterns.

de Fraiture et al. (2004) also find limited empirical support for the virtual water perspective. They caution against inferring that international trade will be helpful in mitigating water scarcity, in part, because political and economic considerations can have greater influence than water scarcity in determining national trading strategies. Lopez-Gunn and Llamas (2008) also observe that international trade in food is driven largely by factors other than water.

Wichelns (2010a,b) examines the estimates of virtual water imports and exports prepared for 77 countries by Chapagain and Hoekstra (2004). He concludes that the amount of arable land per person in a country is a better descriptor of international trade patterns than is the amount of renewable water resources available, per person or per hectare. A country's arable land endowment is not a sufficient predictor of trade patterns, but it is a better descriptor of trade in crop and livestock products than a country's water endowment.

Ramirez-Vallejo and Rogers (2004) examine empirical information in the context of the Heckscher–Ohlin model of international trade. That model has fewer restrictions than the model of comparative advantage, yet still the authors find little empirical support for predicting trade patterns on the basis of national water endowments. Rather, they find that variables such as average income, population, irrigated area, and the amount of value added in agriculture are helpful in explaining the observed variation in traded agricultural commodities.

Guan and Hubacek (2007) examine the current movement of agricultural products between northern and southern China, with the goal of determining whether or not the data reflect implementation of a virtual water trading strategy. Their null hypothesis is that water-scarce northern China will import water-intensive goods and export goods requiring less water in production, while water-abundant southern China will operate in reverse. The data do not support the "virtual water hypothesis." Water-scarce northern China exports many water-intensive goods and services, while water-abundant southern China imports water-intensive goods. The authors suggest that several factors influencing agricultural input use and productivity – water price, labor availability, and soil and land quality – might be responsible for the results they have observed. These factors are among those that help determine opportunity costs and comparative advantages.

In several of the examples cited here, the authors suggest that arable land, irrigated area, or water stored in the soil profile is a more helpful indicator of international trading strategies than is the estimate of a country's water endowment. Water resources are certainly considered when preparing estimates of arable land, irrigated area, and soil moisture. Yet by including other factors, such as land and irrigation investments, the alternative indicators have greater predictive usefulness than estimates of water endowments.

3. Countries do not save water by engaging in virtual water trade

Several authors have suggested that countries save or lose water when they engage in international trade. The authors obtain their estimates of water savings and losses by examining the water requirements (evapotranspiration) in the importing and exporting countries (Yang et al., 2006; Hoekstra and Chapagain, 2007b; Yang