Chapter 3
Virtual Water and Trade: A Critical Economic Review

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Abstract In recent years many scholars have dealt with aspects of a "globalisation of water resources" implicating the need for a global approach to governing scarce water resources. Especially the concepts of virtual water and water footprints have garnered increasing attention due to their pledge to disclose the linkages of local water consumption and global agricultural trade. In response, trade-restricting policy instruments have been promoted by some authors in response to seemingly inefficient, unfair or unsustainable "virtual water"-trade patterns. To shed some light on the link between food trade, water and sustainability this paper discusses the informative value of the virtual water and water footprint concepts from an economic point of view, including various refinements of these indicators which have been suggested in the literature. Additionally, the performance of trade-related global water governance arrangements based on virtual water will be considered, bringing up again the debate about the environmental benefits of free trade. It must be concluded that the virtual water concept is limited in terms of its usefulness in providing policy advice or guiding economic decision-making. Specific sustainability problems (distorted pricing, bad governance, trade performance) should be solved in the respective arenas and not by virtual water-related global governance schemes or even trade barriers.

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Virtual Water and Trade: Aspects of a Discussion

In recent years the concepts of virtual water (VW) and water footprints (WF) have garnered increasing attention as a quantitative assessment of global water use. The catchword *virtual water* was coined by the geographer *Anthony Allan* in the 1990s and refers to the water used in the production process of a good. Subsequently, the concept has been widely linked to trade issues, particularly for agricultural products. The corresponding term *virtual water trade* refers to the circumstance that virtual water crosses international borders as a result of trade in water-intensive goods (Allan 1998). These trade flows and their implications have been discussed controversially, in particular since the beginning of the millennium, when the concept of WF (e.g. of a country) was additionally introduced (Hoekstra and Hung 2002).[1] Thus, virtual water can be accounted for by various measures and indicators such as virtual water contents, footprints and trade flows (Chapagain and Hoekstra 2008). Apart from mere accounting, VW concepts also have been interpreted *normatively*, that is to say that a certain footprint level or trade direction might be to a certain extent "right" or "wrong" or could be "improved" in a way. If this is the case, the concept might also be used as a scientific basis for policy advice on water-related trade or consumption patterns in order to tackle water scarcity. While many scholars from natural sciences consider the concept appropriate for normative purposes there is also serious critique against it (Perry 2014), particularly from economists (e.g. Wichelns 2004, 2011; Meran 2011; Gawel and Bernsen 2013).

As normative criteria both *resource efficiency* and *justice* have been introduced: It is remarkable that the discussion on VW and WF in this regard has changed its perspective. In the 1990s virtual water trade was originally meant to increase the global water use efficiency (Allan 1998; Hoekstra 2006), which is attained by producing water-intensive goods in the most water-abundant or water-productive regions (Hoekstra and Hung 2002). Later, WF calculations have been established to provide an accounting framework to implement resource fairness. This way, WF quotas might contribute to an allocation not according to natural water endowment, but according to the philosophy of fair shares ("virtual water for all"—Zehnder 2010).

The role of trade is somewhat ambivalent in this debate: On the one hand trade is most welcome to achieve a global water use efficiency and to contribute to global water savings by making water available for global food demand where it is the least scarce and most productive. On the other hand, VW volumes and trade flows at times are seen to have problematic moral implications for fairness and justice, which seemingly can only be addressed by restraining free trade on a global scale (Hoekstra 2011). VW trade seems to instigate fairness concerns, especially in the context of trade relations between industrial and developing countries (World Water Council 2004). In this perspective trade is no longer a supporting tool to meet global demand for food by using less water, rather it is considered now a powerful means to

[1] While usually VW and WF are just seen as different ways of looking at the same thing (Gawel and Bernsen 2013), Velazquez et al. 2009 try to elaborate some relevant differences.

access and to take possession of scare resources all over the world for particular needs in a possibly unfair way (Wackernagel and Rees 1997).

What is important here is that in *every* case free trade might not always work towards achieving these aims—be it water use efficiency or a certain idea of water justice (Hoekstra 2006). Thus, a normative interpretation of VW always implies to reorganise trade patterns according to a given normative criterion related to VW accounting. Accordingly, global water governance arrangements have been deemed necessary by some authors (Verkerk et al. 2008) to counter the detrimental impacts of trade on the sustainable and "fair" use of water resources (Hoekstra 2006, 2011).

Two crucial research questions arise from this: What can virtual water (VW) analysis tell us about the "right" direction or volume of foreign trade (Sect. "What Can Virtual Water Analysis Tell Us About the "Right" Trade Patterns?")? And is there a need for a global water governance reorganising trade patterns with respect to water availability in order to meet sustainability requirements (Sect. "Virtual-Water Oriented Trade as a Means to Obtain Water Resource Efficiency?")?

What Can Virtual Water Analysis Tell Us About the "Right" Trade Patterns?

Virtual-Water-Oriented Trade as a Means to Obtain Water Resource Efficiency?

According to the first normative criterion VW analysis might reveal "efficiency gains" through virtual water trading (global water savings—Fader et al. 2011) and uncover "efficiency" deficits in current trade patterns. In this perception, virtual water has to flow from water-abundant to water-scarce regions. Thus, *strengthening* of VW trade and a strict alignment to a "global water use efficiency" should be pursued (Allan 1998; Hoekstra and Hung 2003).

However, from an economic perspective, the idea of reorganising trade patterns according to the availability of one single production factor appears to be weird in a sense. First, having a look at the empirical evidence water availability is without any clear impact on trade volumes and trade flows (Kumar and Singh 2005).[2] Rather there is a more significant impact by the availability of (arable) land: Often trade flows can be observed from "water-scare but land-abundant" countries to "water-abundant, but land-scarce" countries. For instance, the Netherlands as a water-abundant but land-scarce country turns out to be a net importer of VW whereas Kazakhstan (water-scarce but land-abundant) is a net exporter (Kumar and Singh 2005). Theoretically, these findings are hardly surprising: Water is just one single trade determining production factor besides land, labour, capital and

[2] An early statistical and modelling analysis on the water-food trade relations has been conducted by Yang et al. (2003).

knowledge. It can be shown in a simple Heckscher-Ohlin-model (HO-model) representing the standard economic textbook theory for foreign trade between countries with different resource endowments that 1. relative endowment of water is not decisive for optimal trade direction with respect to mutual welfare and that 2. relative endowment *should not* be relevant either, again for reasons of welfare (Meran 2011). According to the HO-theorem in a 2-goods-2-factors (say water W and land L)-2-countries-model a country turns out to be an exporter of the very good that is using the "relative abundant" factor more intensively. But this does not necessarily imply that the water-abundant countries are net exporters of virtual water: The HO-theorem is based on *relative abundance* with respect to the *factor proportion* (i.e. $W_1/L_1 > W_2/L_2$) between countries, not on absolute factor scarcity. Therefore, a relatively water-rich country ($W_1 > W_2$) may be at the same time a net importer of VW (Ansink 2010). There is no distinct relation between water availability and preferable trade position (Meran 2011). This is why any attempt to bring trade patterns into line with mere VW numbers run the risk of decreasing overall welfare. Furthermore, foreign trade may result in global water savings but does not necessarily have to: Theoretically, a mere (but welfare-increasing) redistribution of the same total amount of water used might be a possible solution as well.

Virtual-Water Oriented Trade as a Means to Achieve Resource Fairness?

Recently, normative concepts of *justice* have also been associated with virtual water trading. This way, virtual water trade now may appear as a problem to be tackled by VW analysis revealing fairness deficits in both consumption and trade patterns and suggesting a *restriction* of VW trade with respect to fairness norms leading to a certain "anti-trade bias" (van den Bergh and Verbrüggen 1999). The manifold arguments brought forward in this regard (see Table 3.1) can be mainly divided into three dimensions (Gawel and Bernsen 2013): 1. imperfections in the current regime of world trade; 2. the wide regional and interpersonal disparities in income and (water) consumption; and 3. potential adverse local impacts as a consequence of using water resources to produce tradable goods.

The most apparent flaw of this approach is the arbitrariness of the distribution norms to come into question and the consequential ambiguity of their implications: Again, no clear conclusion can be drawn from the calculations of virtual water indicators. Rather, nearly everything seems to be problematic: a trade flow from the North to the South (dependencies of the poor) as well as a trade flows from the South to the North (exploitation of scarce resources, pollution export). Moreover, a dilemma becomes evident considering a water-rich country such as the USA with respect to what it should do with its abundant water resources. An above-average consumption of water would appear to be just as "unfair" as a hoarding strategy concerning the own (sufficient) endowment (Hoekstra 2011; Verkerk et al. 2008).

Table 3.1 Normative criticisms to virtual water trade and their related policy dimensions

Indicators of virtual water		Corresponding set of concerns	Dimension of the problem		
			Trade regime	Consumption patterns	Adverse local impacts
Virtual water specific consumption	*Virtual water content of a commodity*	Implies a high water consumption of the respective product, which is why the water intensive meat consumption in industrialised countries is questioned (Lotze-Campen and Welp 2007)		X	X
	Water footprint of a product	Is meant to show consumers their negative impact on (external) water resources (Hoekstra et al. 2009)		X	X
	Water footprint of a person	An indicator of the "wasteful" behaviour of people in the industrialised world (Hoekstra et al. 2009). May lie below or above the average "fair share" a person is entitled to (Hoekstra 2006)		X	
	Water footprint of a company	Indicator for the awareness and risk of a company of its water use throughout all of its operations (The CEO Water Mandate 2009)		X	X
	Water footprint of a country	The extent to which a nation is depleting its own water resources, as well as water resources in other parts of the world (Hoekstra and Chapagain 2007). May differ from a nation's "reasonable share" (Verkerk et al. 2008)		X	
	Global virtual water budget	May not coincide with the "maximum human water footprint" (Verkerk et al. 2008)		X	X

(continued)

Table 3.1 (continued)

Indicators of virtual water		Corresponding set of concerns	Dimension of the problem		
			Trade regime	Consumption patterns	Adverse local impacts
Virtual water trade flows	*Magnitude of virtual water trade*	Shows the rising interdependencies between countries, which are oftentimes thought to be at the detriment of the poorest countries (Neubert, 2008).	X		X
	Water savings through virtual water trade	Shows the global water savings of Virtual Water trade that may or may not occur (de Fraiture et al. 2004; Chapagain et al. 2005)			X
	Virtual water trade balance	Water scarce countries may have a trade surplus while water rich countries may have a trade deficit (Chapagain and Hoekstra 2008). Large trade surpluses in industrial countries result in dependencies of importing countries (Warner 2003), while trade deficits point to wasteful consumption patterns (Sonnenberg et al. 2009). Adverse local impacts may result from virtual water net imports, as well as net exports	X	X	X
	Virtual water import dependency	Import dependency is often seen as problematic from the viewpoint of poor arid countries (World Water Council 2004). Water-abundant industrial countries are enabled to pressure importers politically (Roth and Warner 2008). Water import dependency and water scarcity are usually not correlated (Hoekstra and Hung 2002)	X		
	Top exporters and top importers	Virtual Water exports are dominated by industrialised countries (Zehnder 2003)	X		
	Interregional trade flows	Dry regions may be net exporters or on the other hand be too dependent on Virtual Water imports from another region (World Water Council 2004)	X	X	
	External water footprint of a country	A country can be blamed for certain environmental problems in the exporting nation (Hoff 2009). Industrial countries are generally seen to have a too high external water footprint		X	X

Source Gawel and Bernsen (2013)

The only other option would be to export VW, which (as illustrated above) would also entail "unacceptable" states of dependence for developing countries, according to trade critics. Whatever this country might do it could be condemned for the sake of justice. This reveals the contradictory nature of these normative concepts.

Do Water Footprints Reveal Relevant Information on Sustainability?

WFs are intended to be a transfer of previous footprint concepts such as the carbon footprint to the realm of water resources, assessing amongst other things the virtual water content of people, nations, firms or products (Hoekstra et al. 2009). WF are considered to be in line with previous developed carbon footprint concepts (Gerbens-Leenes et al. 2007). However, greenhouse gases are a real *global* problem, since their emission contributes to global warming in a *homogeneous* way, regardless of where and when exactly the emission takes place. Thus, the carbon footprint always reveals strictly comparable quantitative information about an activity's impact on climate change. However, final decisions about abatement strategies have to take into account not only the magnitude of the carbon footprint but additional (economic) indicators like abatement costs and the values that people place on different climate-relevant activities. In contrast, water is a *heterogeneous* resource with diverse local impacts. While a significant carbon footprint always indicates a high impact on climate change (even though still no direct policy conclusion can be derived), a considerable WF does not even provide information about whether environmental harm has actually occurred (CEO Water Mandate 2009). In a similar vein, the concept of "water neutrality" (Hoekstra 2008) is more difficult to substantiate than the corresponding "carbon neutrality" since water depletion and water pollution are site-specific problems in particular.

Therefore, no valid information concerning the sustainability of water use can be provided by WF. And no economically relevant information is given either on where best to reduce water input.

Suggested Remedies: Is There a Case for a VW-Based Global Governance?

Many scholars have stated that the majority of water crises around the world do not actually relate to absolute water scarcity, but to poor water management and the lack of appropriate water prices resulting in water management crises (e.g. Rogers and Hall 2003; OECD 2003). On which scale should these management problems be addressed? The traditional view in hydrology and water resource management is that the mobility of water is confined within river basins, and thus "the management of water on one continent has no direct bearing on the management of water on another continent" (Young et al. 1994, p. 18). The Agenda 21 explicitly stipulates that water resources should be managed at the river basin level, as does the European Union's Water Framework Directive.

However, this traditional view has been contested by some (e.g. Hoekstra 2011), who point to global linkages ("teleconnections") induced by natural and anthropogenic forces, which might lead to a "globalisation of water resources" and imply the need for a global governance approach. Apart from physical "teleconnections" throughout the biosphere such as large-scale irrigation impacts on intercontinental climate patterns, moisture feedback effects and water-related climate change due to global GHG emissions, a second kind of interconnection "originating from economic globalisation and agricultural trade" is seen to be at work (Hoff 2009, p. 141). Thus, "globalisation" and international trade could change the location of production and water use and "[transform] water into a global issue" (World Water Assessment Programme 2009, p. 35). The need for global water governance is therefore put forward because many driving forces behind water-related problems and conflicts are beyond the scope of national, local, or water catchment–oriented governance (Pahl-Wostl et al. 2008; Schnurr 2008; Moss and Newig 2010; Hoekstra 2011). Following this perception, water might appear as a "major global public good" (Pahl-Wostl et al. 2008).

A coordinated global water policy framework, however, does not exist today (Dellapenna and Gupta 2009), and global water governance still remains an academic concept (Ünver 2008). However, ideas for regulating foreign trade with respect to water resources are rampant in this debate: Petrella (2001) even suggests the introduction of a world water contract that would declare water a global good and the common patrimony of humanity, which should not be subject to trade transactions or purchased by foreign investors. Ethical aspects are also emphasised by McKay (2003) who proposes a VW Trading Council within the WTO, which would be concerned with the redistribution of VW on ethical grounds. Hoekstra (2006, 2011) and Verkerk et al. (2008) suggest a whole range of global institutional arrangements to promote "fairness" and "resource efficiency" in water use around the world. These include an international water-pricing protocol, international business agreements, a pollution tax on internationally traded goods that cause water pollution in their waste stage, the labeling of water-intensive products, and a scheme of WF quotas. WF quotas have the objective of assigning a "reasonable" or "fair" share of the world's water resources to every country and person, in the face of widely diverging per-capita consumption rates between industrial and developing countries (Hoekstra 2011). For a country to remain within its "reasonable bounds", a tax on water-intensive (import) goods is recommended (Hoff 2009).

However, from an economic point of view, it appears to be rather questionable whether trade restrictions really make sense in order to promote sustainability (Gawel and Bernsen 2011a; LeVernoy and Messerlin 2011): The contentious issue whether trade is always welfare-increasing or might particularly aggravate environmental problems (and should therefore be regulated) has been discussed already since the 1990s. From the ecological economics point of view, trade might have a tendency toward overexploitation of resources and also imply the risk of discriminating developing countries (Daly 1993; Daly and Cobb 1994). In contrast, neoclassical economists emphasise the economic benefits of trade in general and the ineptitude of trade regulation to specifically address regional environmental problems (Bhagwati 1993; Schulz 1996; Siebert 1996). Even in the face of market failure it is local environmental policy that is needed rather than trade restricting rules. Although local governance and water pricing are far from being perfect, to say nothing of the trading rules that determine international trade, one should be cautious in deciding whether a particular global governance approach can really address the existing problems. Firstly, the conception of water as a global public good (theoretically characterized as non-rivalrous and non-excludable) is questionable, since the scope of its benefits and externalities is still mostly local or regional (Mehta 2002). Market-based global drivers or impacts should not be confused with global commons! Therefore, even though many water use-related impacts are widespread around the globe, they are, in a strict economic sense, not truly global in nature as is the case for climate protection (Mehta 2003; Vörösmarty et al. 2004; Gawel and Bernsen 2011c).[3] This does not affect global water governance approaches in general but reminds us that teleconnections "originating from economic globalization and agricultural trade" (Hoff 2009, p. 141) should not be mixed up with global externalities (that may indeed occur in the global hydrological cycle). Secondly, global trade-flow regulations or the imposition of average water consumption levels will lead to nothing but distortions and losses in wealth. Trade restricting policies would be highly arbitrary and even paternalistic since they represent ideas of global equity and fairness without taking into consideration the needs and preferences of individuals or even "poor countries". Furthermore, they deny developing countries the capability to decide on production and trade patterns in their own best interests. Hence, policies and instruments aiming at reorganising global trade patterns according to merely quantitative VW calculations run the risk of being inefficient (neglecting costs and preferences), ineffective (not solving local environmental problems) and at the same time even patronising (restricting local production and trade decisions).

May Recent Refinements Overcome the Flaws?

May VW analysis deliver more relevant information if it is refined (for an overview see Lillywhite et al. 2010) and takes more aspects of scarcity into account?

[3] Population growth and changing consumption patterns will differ among regions, and this will affect the associated impact of water scarcity, which is why "water is far from having the properties of a global public good" (Mehta 2003, p. 556). By comparison, the global climate system *can* be characterized as a global public good, because no person on earth can be excluded from its benefits or from the negative consequences of climate change.

The most prominent recent development in this field might be the distinction between *green* and *blue water*. According to Falkenmark (2003), blue water refers to the water found in rivers, lakes and groundwater aquifers, while green water denotes the water stored the unsaturated zone of soils stemming directly from rainfall and thus being used for biomass production of rainfed agro-ecological systems. Only one third of global precipitation becomes runoff in rivers and recharges aquifers, whereas two thirds infiltrate into the soil and form green water resources (Hoff et al. 2010). The supposed relevance of the water's colour stems from the assumption, that in terms of supply green water is a "free good", which bears low or zero opportunity costs (Schubert 2011), while blue water causes high opportunity costs due to its many alternative uses, and deserves specific attention in VW and WF accounting (Yang et al. 2006).

However, the colour approach first and foremost reveals that unspecific calculations of VW disregarding heterogeneity of resource use, commonly used so far, have obviously been deficient. But what do we gain by taking additionally into account the water's colour? The over-simplifying assumption that green water always has lower opportunity costs than blue water neglects that soil moisture can indeed have substantial opportunity costs, while ground- or surface water can have low opportunity costs under certain conditions (Wichelns 2010a). Assuming that green water bears no opportunity costs reveals a great deal of anthropocentrism, because cultivated land might alternatively serve as a habitat for other species and contribute to biodiversity—even though biodiversity in itself serves humankind (Biewald 2011), which is why the existence of negative or missing opportunity costs for green water is doubtful. To assess appropriately water abstraction for human needs we need to take into account the respective full opportunity costs which is a continuous variable. A simple dichotomous distinction between "blue" and "green" cannot serve as a sound base for an economic assessment of resource use—even more if we consider that opportunity costs of blue water are unclear and context-sensitive and that green water is needed for ecosystem services competing with agricultural use and thus is not at all an economically "free good" (that is free of opportunity costs). Using green water for a non-commercial habitat (instead of cultivation of crops) might be of the same total economic value as using blue water for shipping (instead of irrigation). Thus, the introduction of colours does not solve the main flaw of the concept—to address heterogeneity of water resource use in a sound way that allows for discriminating products or trade flows to be "good" or "bad".

Moreover, already the distinction of water into a blue and green category runs into serious difficulties, because these two are not necessarily distinct (Wichelns 2011). In the hydrological cycle, water which transpires from plants and evaporates from surface water or soils comes back as rainfall and interacts with rivers, lakes and groundwater reservoirs, while certain plants and land uses can have significant impacts on blue water resources (Ridoutt and Pfister 2010).

On the aggregated level of trade flows, the colour of water is irrelevant from the perspective of both trading partners and consumers in the importing countries, because decisions about efficient water use are still made on the local level and have to take into account opportunity costs depending on the socio-economic context without any distinct relation to "colours".

Beyond "colouring" water there have recently been introduced several other concepts in order to improve the explanatory power of VW analysis. To make VW and WF assessments more informative as to the actual local impact of water use, some authors have attempted to weight explicitly water footprints with indicators of scarcity, sustainability or even shadow prices.

The concept of an "unsustainable WF" (Schubert 2011) only considers blue water, which has been "unsustainably" extracted in the place of production, or which has been polluted to "some inacceptable degree". WF calculations according to this concept (just like scarcity-weighted WF—see below) usually lead to different figures than traditional WF analysis, which reveals a great deal of arbitrariness and contributes to the fragmentation of the WF concept (Lenzen et al. 2013). Just as arbitrary is the qualification "to a certain degree", which gives no idea about the external costs of agricultural production. On the other hand, the definition of "unsustainable" might not be universally accepted, and therefore cannot be simply prescribed to any country. In conclusion, the concept would demand a huge amount of data collection while being only a controversial and unnecessary loop way in assessing (locally already well-known) problems of water scarcity and pollution.

Another upcoming strand of literature aims at weighting the VW flows using explicit information on economic scarcity. This is relevant since it allows for more accurate addressing of heterogeneity of resource uses in terms of values (instead of colours or dichotomous variables like "non-sustainability").

Ridoutt and Pfister (2010) introduced a scarcity-weighted water footprint, which again includes blue and grey water only. Here, the water use at every production step is weighted with a scarcity indicator from the producing region. Additionally, the characterisation of blue virtual water consumption in a specific river basin with the methods of lifecycle impact assessment (LCIA) has been proposed by Pfister et al. (2009). Others (Aldaya and Llamas 2009; Aldaya et al. 2010; Garrido et al. 2010) take an economic approach by including water productivity into virtual water analysis. Garrido et al. (2010) introduce a new indicator of apparent water productivity, the price of a good divided by its virtual water content, as well as the terms of trade of virtual water, the value of virtual water imports divided by the value of virtual water exports. Thus, virtual water flows here are valued by the prices of the goods for whose production the water was used. Biewald et al. (2011) attempt to evaluate blue water savings induced by trade by a weighting with shadow prices. The authors assess the green and blue water use with and without international trade, and come to the conclusion that globally less water is used as a result of trade, although the use of blue water slightly increases, while regionally especially arid countries save large amounts of blue water. The blue water savings are then weighted with shadow prices, which leads to an index depicting the value of water savings (difference in blue water consumption [trade and no trade] times water shadow price).

May these enhancements of VW and WF analysis really overcome the fundamental flaws described above? The newly introduced "economic" approach of assigning value-oriented informations (e.g. Garrido et al. 2010) has already been commented on by Wichelns (2010c) who observes that the inclusion of economic productivities, product prices and exchange terms is "of questionable value" (p. 692) because methods to assess agricultural water productivities already exist. The perspective that such an approach will add credibility and stature to the application of virtual water to policy questions is therefore misplaced (p. 694) and is in any case too "water-centric" ignoring all other factors of production.

The approach of Biewald et al. (2011), for instance, is to weight the (blue) water savings resulting from trade with shadow prices to assess the savings' monetary value. Hence, instead of quantitative flows we obtain value flows. Does this really remedy the mentioned shortcomings? First of all, it is not obvious how fictional shadow prices, even if these could correctly be calculated, can give information about the welfare gains from free trade, because they do not consider changes in other activities and factor uses. Weighted VW calculations still do not contain the information which actually is of interest, that is, the efficiency of local decisions on water use. Thus, the problems of traditional VW analysis remain. Just like it doesn't matter to a country whether it imports blue or green VW resources (Wichelns 2010b), it should not matter whether A imports greater euro-amounts in VW than B, as long as this water has been employed sustainably in the place of production, and water has been remunerated according to its scarcity. Finally, shadow prices still give no information as to what would be a "good" trade flow, or where water savings of which colour are especially desirable (Gawel and Bernsen 2011b).

The various efforts to enhance the water footprint's informative value all strive in completely different directions, which adds to the impression of a widespread confusion. Unfortunately, while none of the new concepts is really convincing, the great awareness which is supposed to be created among consumers will be degraded because VW and WF analysis will be ever more fragmented, since every methodology will lead to different VW contents, values and implications.

Conclusions

With respect to VW, foreign trade is subject to either expectations (water savings, water use efficiency) or concerns (fairness, participation)—in either case it is often suggested that trade should be (re-) organised according to (physical) water availability. However, VW accounting unfortunately does not at all provide reliable information neither for economic decisions on water-related trading nor a global governance regulating trade or consumption patterns.

First, VW accounting lacks relevant economic scarcity information concerning heterogeneous water resources and thus to provide suitable policy advice. The mere counting of water quantities does not offer specific information on values, particularly whether trading VW really illustrates or even causes an unsustainable exploitation of water resources. Since no information on local costs and benefits of water extraction and water use is given, and the influence of other production factors as well as preferences for import and export goods is neglected, it is not possible to the determine the "right" direction of VW trade flows this simple way. There is no stable relation between a country's welfare and its net position of trading VW. Taking up trade can lead to a negative net position of a water-scarce country while increasing welfare at the same time. This is due to the fact that trade patterns (volumes and directions) are economically based on both preferences and full comparative production costs not only on relative water endowment. For the same reason, the welfare enhancing effect of trading water-intensive goods does not necessarily depend on concurrent global water savings. Moreover, VW net positions are no sound indicators for fairness of water resources distribution.

The various efforts to enhance the water footprint's informative value all strive in completely different directions. Ultimately, however, these refinements mainly confirm the impression that the concept in its current form is not useful in giving reasonable policy advice. It may be noted that the concepts have succeeded in creating a kind of qualitative awareness to the great amounts of water which are at times "hidden" in our food, but until now has not offered specific information for any further policy-relevant conclusions.

Second, to evaluate trade flows numerous normative criteria are used, be it "water resource efficiency" or fairness of global water access. Hence, the normative framework as well as the conclusions drawn appear to be highly contradictory. It remains unsettled whether the aspired goal consists of a realignment of trade flows according to either principles of equity and justice or concepts of scarcity or "global water use efficiency". Applying these (contradictory) normative criteria almost every conceivable trade pattern could be animadverted on.

When addressing globally sustainability problems of regional water use, a "problem of fit" must be stated, that is, problems related to water depletion and pollution are addressed at the wrong scale. To achieve sustainability in resource use we have to take into account local and regional economic scarcity as well as relevant externalities induced by water use. This should not be mixed up in (restricting) trade policies. The prerequisites for a sustainable regional water management (cost-covering water prices, good governance etc.) and the challenge of fairness in global trade regimes have to be addressed in their respective arenas. For that reason, environmental and trade policies should not be based on mere VW calculations and their predominantly misleading policy implications.

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References

Aldaya MM, Llamas MR (2009) Water footprint analysis (hydrologic and economic) of the Guadiana River Basin. Accompanying report to the U.N. world water development report no. 3. United Nations Educational, Scientific and Cultural Organization, Paris
Aldaya MM, Garrido A, Llamas MR, Varelo-Ortega C, Novo P, Casado RR (2010) Water footprint and virtual water trade in Spain. In: Garrido A, Llamas MR (eds) Water policy in Spain. CRC Press, Leiden, pp 49–59
Allan JA (1998) Virtual water: a strategic resource, global solutions to regional deficits. Groundwater 36(4):545–547
Ansink E (2010) Refuting two claims about virtual water trade. Ecol Econ 69(10):2027–2032
Bhagwati J (1993) The case for free trade. Sci Am 269:18–23
Biewald A (2011) Give virtual water a chance! An attempt to rehabilitate the concept. GAIA 20(3):168–170
Biewald A, Lotze-Campen H, Rolinski S, Hoff H (2011) The impact of trade on local green and blue water availability. Discussion paper. Potsdam Institute for Climate Impact Research, Potsdam, 15 Apr 2011
CEO Water Mandate (2009) From footprint to public policy—the business future for addressing water issues. Pacific Institute DP, Pacific Institute of Public Policy, Port Vila, Vanuatu. http://ceowatermandate.org/files/research/From_Footprint_to_Public_Policy.pdf. Accessed 18 Jan 2014
Chapagain AK, Hoekstra AY (2008) The global component of freshwater demand and supply: an assessment of virtual water flows between nations as a result of trade in agricultural and industrial products. Water Int 33(1):19–32
Chapagain AK, Hoekstra AY, Savenije HHG (2005) Saving water through global trade. Value of water research report series 17. Institute of Water Education, Delft, Netherlands. http://www.waterfootprint.org/Reports/Report17.pdf. Accessed 18 Jan 2014
Daly HE (1993) The perils of free trade. Sci Am 269:24–29
Daly HE, Cobb J (1994) For the common good—redirecting the economy toward community, the environment and a sustainable future. Beacon Press, Boston
Dellapenna JW, Gupta J (eds) (2009) The evolution of the law and politics of water. Springer, Berlin
Fader M, Gerten D, Thammer M, Heinke J, Lotze-Campen H, Lucht W, Cramer W (2011) Internal and external green-blue agricultural water footprints of nations, and related water and land savings through trade. Hydrol Earth Syst Sci Discuss 8(1):483–527
Falkenmark M (2003) Freshwater as shared between society and ecosystems: from divided approaches to integrated challenges. Philos Trans R Soc Lond B 358(1440):2037–2049
de Fraiture C, Cai X, Amarasinghe U, Rosegrant M, Molden D (2004) Does international cereal trade save water? The impact of virtual water trade on global water use. In: Comprehensive assessment research report 4, Colombo, Sri Lanka. http://www.iwmi.cgiar.org/Assessment/files/pdf/publications/ResearchReports/CARR4.pdf. Accessed 30 Jun 2011
Garrido A, Llamas MR, Varela-Ortega C, Novo P, Rodríguez-Casado R, Aldaya MM (2010) Water footprint and virtual water trade in Spain—policy implications. Springer, New York
Gawel E, Bernsen K (2011a) Do we really need a water footprint? global trade, water scarcity and the limited role of virtual water. GAiA 21(3):162–167
Gawel E, Bernsen K (2011b) The colour of water: what does it tell us about scarcity? GAiA 21(4):224–228
Gawel E, Bernsen K (2011c) Globalisation of water: the case for global water governance? Nature + Culture 6(3):205–217
Gawel E, Bernsen K (2013) What is wrong with virtual water trading? On the limitations of the virtual water concept. Environ Plann C (Government and Policy) 30(6):168–181

Gerbens-Leenes W, Hoekstra A, Holland R, Koch G, Moss J, Ndebele P, Orr S, Ronteltap M, de Ruyter van Stevenink E (2007) Water neutrality: a concept paper. http://www.indiaresource.org/campaigns/coke/2008/Waterneutrality.pdf. Accessed 18 Jan 2014

Hoekstra AY (2006) The global dimension of water governance: nine reasons for global arrangements in order to cope with local water problems. Value of water research report series 20. Institute for Water Education, Delft, Netherlands. http://doc.utwente.nl/58371/1/Report_20.pdf. Accessed 18 Jan 2014

Hoekstra AY (2008) Water neutral: reducing and offsetting the impacts of water footprints. Value of water research report series 28. Institute for Water Education, Delft, Netherlands. http://www.waterfootprint.org/Reports/Report28-WaterNeutral.pdf. Accessed 18 Jan 2014

Hoekstra AY (2011) The global dimension of water governance: why the river-basin approach is no longer sufficient and why cooperative action at global level is needed. Water 2011(3): 21–46

Hoekstra AY, Chapagain AK (2007) Water footprints of nations: water use by people as a function of their consumption pattern. Water Resour Manag 21(1):35–48

Hoekstra AY, Chapagain AK, Aldaya MM, Mekonnen MM (2009) Water footprint manual, state of the art 2009. Water footprint report. Water Footprint Network, Enschede, Netherlands. http://www.waterfootprint.org/?page=files/Publications. Accessed 18 Jan 2014

Hoekstra AY, Hung PQ (2002) Virtual water trade: a quantification of virtual water flows between nations in relation to international crop trade. Value of water research report series 11. Institute for Water Education, Delft, Netherlands. http://www.waterfootprint.org/Reports/Report11.pdf. Accessed 18 Jan 2014

Hoekstra AY, Hung PQ (2003) Virtual water trade: a quantification of virtual water flows between nations in relation to international crop trade. Value of water research report series 11. Institute for Water Education, Delft. http://www.waterfootprint.org/Reports/Report11.pdf. Accessed 18 Jan 2014

Hoff H (2009) Global water resources and their management. Curr Opin Environ Sustain 1(2): 141–147

Hoff H, Falkenmark M, Gerten D, Gordon L, Karlberg L, Rockström J (2010) Greening the global water system. J Hydrol 384(3–4):177–186

Kumar MD, Singh OP (2005) Virtual water in global food and policy making: is there a need for rethinking? Water Resour Manag 19(6):759–789

Lenzen M, Moran D, Bhaduri A, Kanemoto K, Bekchanov M, Geschke A, Foran B (2013) International trade of scarce water. Ecol Econ 94:78–85

LeVernoy A, Messerlin P (2011) Water and the WTO: don't kill the messenger. Paper prepared for the workshop "accounting for water scarcity and pollution in the rules of international trade" Amsterdam, 25–26 Nov 2011

Lillywhite RD, Allan AJ, Chapagain A, Garnett T (2010) Water footprinting—a review in support of the defra project WU0120. Department of Environment Food and Rural Affairs, London

Lotze-Campen H, Welp M (2007) More food with less water: the role of efficiency gains, lifestyles and trade. In: Lozán JL, Graßl H, Hupfer P, Menzel L, Schönwiese D (eds) Global change: enough water for all? Hamburg, p 306–309

McKay J (2003) A proposal for an international virtual water trading council: building institutional frameworks at international level to reduce poverty. In: Ünver O, Gupta RK, Ayşegül K (eds) Water development and poverty reduction. Kluwer Academic Publishers, Norwell, pp 111–128

Mehta L (2003) Problems of publicness and access rights: perspectives from the water domain. In: Kaul I (ed) Providing global public goods, managing globalization. Oxford, New York, p 556–575

Meran G (2011) The unimportance of "virtual water" for environmental policy. http://www.infraday.tu-berlin.de/fileadmin/fg280/veranstaltungen/infraday/conference_2011/papers_presentations/presentation—meran.pdf. Accessed 18 Jan 2014

Moss T, Newig J (2010) Multi-level water governance and problems of scale: setting the stage for a broader debate. Environ Manag 46(1):1–6
Neubert S (2008) Strategic virtual water trade—a critical analysis of the debate. In: Scheumann W (ed) Water politics and development cooperation: local power plays and global governance. Springer, Berlin, pp 123–145
Organisation for Economic Co-operation and Development (OECD) (2003) Improving water management: recent OECD experience. OECD, Paris
Pahl-Wostl C, Gupta J, Petry D (2008) Governance and the global water system: a theoretical exploration. Glob Gov 14(4):419–435
Perry C (2014) Water footprints: path to enlightenment, or false trail? Agric Water Manag 134:119–125
Petrella R (2001) Wasser für alle. Ein globales Manifest, Rotpunktverlag, Zürich
Pfister S, Koehler A, Hellweg S (2009) Assessing the environmental impacts of freshwater consumption in LCA. Environ Sci Technol 43(11):4098–4104
Ridoutt BG, Pfister S (2010) A revised approach to water footprinting to make transparent the impacts of consumption and production on global freshwater scarcity. Glob Environ Change 20(1):113–120
Rogers P, Hall A (2003) Effective water governance. TEC Background Paper 7. Global Water Partnership, Stockholm. http://www.tnmckc.org/upload/document/bdp/2/2.7/GWP/TEC-7.pdf . Accessed 18 Jan 2014
Roth D, Warner J (2008) Virtual water: virtuous impacts? The unsteady state of virtual water. Agric Hum Values 25(2):257–270
Schnurr M (2008) Global water governance: managing complexity on a global scale. In: Scheumann W (ed) Water politics and development cooperation: local power plays and global governance. Springer, Berlin, pp 107–120
Schubert H (2011) The concepts of virtual water and water footprints. acatech Materialien no. 4. Acatech, Munich
Schulz C-E (1996) Trade policy and ecology. Environ Resource Econ 8(1):15–38
Siebert H (1996) Trade policy and environmental protection. Kiel Working Papers 730. https://www.econstor.eu/dspace/bitstream/10419/878/1/194370208.pdf. Accessed 18 Jan 2014
Sonnenberg A, Chapagain A, Geiger M, August D (2009) Der Wasser-Fußabdruck Deutschlands. Woher Stammt das Wasser, das in unseren Lebensmitteln steckt?, WWF Germany, Berlin
Ünver O (2008) Global governance of water: a practitioner's perspective. Glob Gov 14(4): 419–435
Van den Bergh J, Verbrüggen H (1999) Spatial sustainability, trade and indicators: an evaluation of the 'ecological footprint'. Ecol Econ 29(1):61–72
Velázquez E, Madrid C, Beltrán MJ (2011) Rethinking concepts of virtual water and water footprint in relation to the production-consumption binomial and the water-energy nexus. Water Resour Manag 25(2):743–761
Verkerk MP, Hoekstra AY, Gerbens-Leenes PW (2008) Global water governance: conceptual design of global institutional arrangements. Value of water research report series 26. Institute for Water Education, Delft, Netherlands. http://www.waterfootprint.org/Reports/Report26-Verkerk-etal-2008GlobalWaterGovernance.pdf. Accessed 18 Jan 2014
Vörösmarty C, Lettenmaier D, Leveque C, Meybeck M, Pahl-Wostl C, Alcamo J, Cosgrove W, Grassl H, Hoff H, Kabat P, Lansigan F, Lawford R, Naiman R (2004) Humans transforming the global water system. Eos, Trans Am Geophys Union 85(48):509–520
Wackernagel M, Rees W (1997) Unser Ökologischer Fußabdruck: Wie der Mensch Einfluss auf die Umwelt Nimmt. Birkhäuser Verlag, Basel
Warner J (2003) Virtual water – virtual benefits? Scarcity, distribution, security and conflict reconsidered. In: Hoekstra AY (ed) Virtual Water Trade–Proceedings of the International Expert Meeting on Virtual Water Trade. IHE Delft Value of Water Research Report Series No. 12
Wichelns D (2004) The policy relevance of virtual water can be enhanced by considering comparative advantages. Agric Water Manag 66(1):49–63

Wichelns D (2010a) Virtual water: a helpful perspective, but not a sufficient policy criterion. Water Resour Manag 24(10):2203–2219

Wichelns D (2010b) Virtual water and water footprint offer limited insight regarding important policy questions. Int J Water Resour Dev 26(4):639–651

Wichelns D (2010c) Virtual water and water footprints: policy relevant or simply descriptive? Int J Water Resour Dev 26(4):689–695

Wichelns D (2011) Virtual water and water footprints. Compelling notions, but notably flawed. GAIA 20(3):171–175

World Water Assessment Programme (2009) Water in a changing world. Third UN world water development report. UNESCO, Paris

World Water Council (2004) Virtual water trade—conscious choices. E-conference synthesis. World Water Council, Marseille. http://www.waterfootprint.org/Reports/virtual_water_final_synthesis.pdf. Accessed 18 Jan 2014

Yang H, Reichert P, Abbaspour K, Zehnder AJB (2003) A water resources threshold and its implications for food security. Environ Sci Technol 37(14):3048–3054

Yang H, Wang L, Zehnder AJB, Abbaspour KC (2006) Virtual water trade: an assessment of water use efficiency in the international food trade. Hydrol Earth Syst Sci 10:443–454

Young GJ, Dooge JCI, Rodda JC (1994) Global water resource issues. Cambridge University Press, Cambridge

Zehnder AJB (2003) Water issues: the need for action at different levels. Aquat Sci 65(1):1–20

Zehnder AJB (2010) Water food nexus. Presentation at the first water research horizon conference, Berlin, 13 July 2003