Regulating Virtual Water Flows:
Introducing an integrated political Economy
for Virtual Water Trade

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ABSTRACT

Looking at the world's many challenges in the twenty-first century food supply is one of paramount importance. Given demographic change, social transformations, rapid economic development, urbanisation, and climate change, tomorrow's decision-makers will need fresh thinking to meet the expectations. One issue that is hardly looked at is the political economy of virtual water in the region. Virtual water is the hidden amount of water that is embedded in all commodities. Rising expectations amongst the aspiring new middle classes throughout developing nations and their demand for water intensive products such as meat, rice, and milk make an integrated economy for virtual water trade inevitable in order to meet the tasks of the future.

The paper focuses on the identification and elimination of welfare losses from inefficient use of the resource water, represented in actual worldwide virtual water streams. In the meanwhile, there exist successful regulatory concepts for the internalization of negative externalities like pollution for industrialized production and individuals' utility maximization constraints. However, a traditional regulatory quantity based approach - like in international carbon trade - will not work. In contrast to carbon, fresh water is a locally concentrated resource which is plentiful available in one area and absolutely untraceable in another. The main area of research is now to identify the causes for the inefficient virtual water flows and develop a concept combining reallocation incentives and a resource efficient use of fresh water resources.

With reference to already existing supranational institution-building like the European Union or ASEAN, we propose to the world's virtual water tariff and trade economy. A political economy of virtual water trade would require regulation from a suprana-

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tional virtual water institution that will formulate policies and implement them on all member states, leading an allocation of virtual water, which will transform the entire agricultural sector. This may lead to spill-over effects to other economic, if not political areas and to an increased responsibility for a responsive and sustainable use of resources worldwide.

1   Introduction

All the world's major problems in the 21st century involve unequally distributed resources. During the past decades, securing access to crude oil has been a primary reason for international conflict, political discussions and the enormous transfer of international wealth. Water is no different in this respect, except that it is a resource that can neither be reproduced nor substituted.

In terms of the planet's water availability, certain areas have more resources than others. Climate change is an additional cause of droughts and floods, which put more pressure on our supplies of agricultural and drinking water. Times are changing and scenarios predicting continuous conflicts over oil could easily change to water – the water wars. Especially overpopulation is putting severe pressure on certain world regions such as Africa, Latin America and Asia[2]. In the next 40 years, for example, more than one billion additional people will inhabit the world's largest continent – Asia[3]. The increased and rapid urbanization that will result will be one of the greatest challenges for decision-makers. While the drinking water supply infrastructures alone will cost trillions of dollars, the real challenge will be ensuring an adequate food supply through sufficient agricultural water or *virtual water*.

While every human being requires approximately 3 liter of drinking water per day, approximately 100 liter are used for domestic purposes in showers, washing machines or cookers[4]. However, the bulk of individual water consumption is through food consumption[5]. More than 3.500 liter of water are hidden in the products each of us consumes every day – 'virtual water'[6].

Malthus predicted that the world's population would grow at a faster rate than agricultural food supply[7]. This would inevitably lead to famines, diseases, plagues and wars, which – in his view – would reduce the population to a more balanced level.

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[2]   See WHO and UNICEF (2005).

[3]   See United Nations (2008).

[4]   See Howard and Bartram (2003).

[5]   See, for example, Wild Farm Alliance (2003).

[6]   See Allan (2001).

[7]   See Malthus (1798).

In contrast to Malthus' pessimistic view, classical social theorists like Marx and Weber believed that Third World cities would follow the footsteps of Manchester, Berlin and Chicago[8]. However, most southern giants went the way of Victorian-age Dublin, the poorest city in 19th century Europe. Needless to say, things have changed considerably since then, but when it comes to water, the grim examples of the past should not be neglected. The trend to move to the mega-city or *megalopolis* will create imbalances between water usage and water resources. Moreover, the food supply chain will be under more pressure than it ever has before.

Malthus is again being refuted by those who share the responsibility for the rocketing populations and cities. The availability and management of water is a *mega-question*. Fresh thinking will be needed if the mega-city dwellers and rapidly increasing populations are to be provided with drinking water, municipal water, water for industry as well as for agricultural production. Clearly, the world needs well-managed virtual water.

1.1 Area of research

This study focuses on the identification of welfare losses from inefficient resource water use, represented in worldwide virtual water streams. There are established regulatory frameworks for the internalization of negative externalities like pollution for industrial production and individuals' utility maximization constraints. The best-known example is international carbon trade, which – along with the intention to reduce carbon dioxide emissions – is leading to positive side effects like innovations in environmental protection and increased resource efficiency. But in contrast to carbon, fresh water is a locally concentrated resource which is plentiful in one area and untraceable in another. Therefore, a framework based on reduction[9] (e.g., carbon trade) cannot work for virtual water. Moreover, this local component – including the option to use much more water – must form part of a regulatory approach to virtual water. This leads me to the following holistic research question:

Does the regulation of virtual water increase the efficiency of local fresh water use?

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[8] See Davis (2006), p. 16.
[9] See Gleick (1993), p. 79.

The main area of research is now to identify the causes of inefficient virtual water flows and develop a framework that combines reallocation incentives with the resource-efficient use of fresh water resources. This framework must make provision for consumer and producer utility maximization as well as be feasible in, and applicable to, the real world.

The question of how to serve a multitude of people with limited worldwide fresh water resources that are not equally distributed to begin with is central to the study's research goals[10]. In the past, the public interest theory of regulation could generally contribute to correcting market failures that are harmful to the public[11]. Existing contributions to virtual water are predominantly led by Allen, Hoekstra and Chapagain, who identified the problem of virtual water resource inefficiency[12]. However, many contributions focus on identifying virtual water inefficiencies. Hoekstra has addressed the feasibility of maximum water usage rights through consumer taxation[13]. However, not only was this done from a political perspective, but it was also an introductory study. Hoekstra has developed a framework of *water–neutrality* − similar to carbon credit offsetting − based on the investment in water-scarce areas according to water consumption in water-abundant areas[14]. Hoekstra does not believe that this approach is sustainable and feasible in the real world as it does not allow for utility maximization by individuals. Moreover, a viable framework would need to be global in scope, as well as make provision for the improvement of local fresh water use efficiency − *virtual water trading*.

This study will address this matter and will seek to construct a regulatory regime for virtual water flows.

1.2 Methodology and structure

This study takes a conceptual, inductive approach to the identification of a feasible regulatory system in order to significantly contribute to a more sustainable and resource-efficient usage of local resource fresh water. By integrating data from water

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[10]   See Population Information Program (1998).
[11]   See Viscusi et al. (2000), p. 314f.
[12]   See Allen (2002) as well as Hoekstra and Chapagain (2008).
[13]   See Hoekstra (2008a).
[14]   See Hoekstra (2008b).

distribution, consumption and product inclusion, different theoretical regulatory measures are tested for their application to, and feasibility for, virtual water[15]. A comparative analysis reveals applicability to the realities, especially in developing countries.

We apply Whetten's approach to making conceptual contributions insofar as we address the three major elements required[16]. Firstly, the field of research is addressed by increasing virtual water efficiency in direct relationship to social stability and individual welfare. Secondly, the conceptualization is done by a relationship analysis of the factors influencing virtual water trade. Thirdly, the underlying justification for the proposed regulatory model is the result of reflective comparative factor analysis. This study will therefore contribute to the regulation of locations that depend on negative externalities.

It has to be mentioned, that in this first approach of developing a regulatory regime for virtual water flows the analysis can only focus a neoclassical perspective. Very important influence factors for the economy of virtual water trade, like economic and political conditions, agricultural and structural factors as well as climate conditions, to name just a couple, have to be addressed in ongoing research.

The paper is structured as follows. Chapter 2 introduces fresh water as a valuable and limited resource. The concept and global impact of virtual water is introduced, and evidence is presented on how inefficient global virtual water flows are endangering sustainable fresh water supply. Based on these insights, negative externalities of the inefficient use of virtual water are explained in Chapter 3 and compared to what has become known as *the tragedy of the commons*[17]. Having developed a theoretical framework for the relocation of efficient virtual water production capacities, Chapter 4 applies existing regulatory mechanisms to virtual water. In addition to synthesizing these measures, Chapter 5 compares and evaluates regulatory mechanisms and establishes a tariff and trade system for virtual water as well as a supranational authority for the regulation of virtual water. The paper ends with a summary of additional implications as well as feasibility and political recommendations.

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[15] See Miles (1979).

[16] See Whetten (1989).

[17] See Hardin (1968, p. 1244.

2   The notion of virtual water

Currently, more than 18% of the world's population (1,1 billion people) does not have access to safe drinking water[18]. This chapter indicates why this figure will increase significantly and identifies fresh water as a scarce, valuable resource, despite the fact that more than two-thirds of the earth's surface is covered with it. Based on these results, virtual water is discussed in detail and in relation to geographical disparities in virtual water consumption and production.

2.1   Water – a scarce resource

The notion that water is a prerequisite for life on earth is not new. While approximately 70% of the planet is covered with water, human beings as well as other land animals and insects can consume only 1% of our fresh water resources. Fresh water resources originate from various sources and can be categorized into three different terms: Firstly, *blue water*, which includes all fresh water resources such as ground water and water from lakes and rivers. Secondly, *green water* derives from rain, soil moisture, etc. Thirdly, *grey water* is in fact simply blue water that has been used for industrial or domestic purposes like cleaning, flushing toilets and taking baths or showers[19].
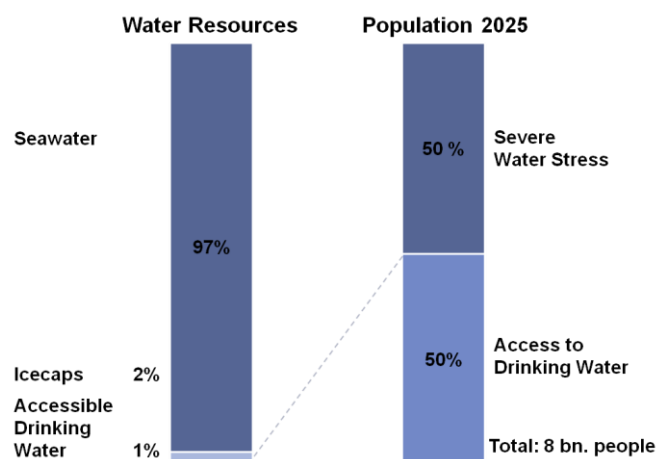

Figure 1:   **The increasing importance of access to fresh water[20]**

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[18]   See WHO and UNICEF (2005), p. 4.
[19]   See Hoekstra (2008b), p. 11.
[20]   Data from World Bank (2004) and Watergap (2003).

As indicated in Figure 1, only 1% of the world's entire water resources is fresh water that can be consumed without industrialized processing such as desalination or filtration. Another 2% is contained within the ice caps, while the remaining 97% is all sea water, which cannot be used for farming or personal purposes without prior, expensive treatment. In addition, access to this fresh water is primarily restricted to the inhabitants of developed countries. Population growth will continue and is likely to lead to about 8 billion people occupying the planet by 2025. This population growth will mean that the access to and the mount of fresh water available per person will decrease significantly[21]. The access to the remaining 1% of fresh water will be restricted to 50% of the population only. In addition, Figure 2 provides an overview of the impact of water shortages on specific world regions until 2030.

Table 10.1. **Population and water stress, 2005 and 2030**

Millions of people

Region	Degree of water stress	2005	% of total in 2005	2030	% of total in 2030	% change 2005-2030
OECD	**Severe**	**438**	35%	**525**	38%	**20%**
	Medium	415	33%	434	32%	5%
	Low	186	15%	198	14%	6%
	No	211	17%	211	15%	0%
	Total	**1 250**	100%	**1 368**	100%	**9%**
BRIC	**Severe**	**1 710**	56%	**2 319**	62%	**36%**
	Medium	216	7%	661	18%	207%
	Low	506	17%	381	10%	−25%
	No	619	20%	378	10%	−39%
	Total	**3 051**	100%	**3 740**	100%	**23%**
ROW	**Severe**	**688**	31%	**1 057**	34%	**54%**
	Medium	164	7%	272	9%	66%
	Low	143	7%	287	9%	101%
	No	1 198	55%	1 512	48%	26%
	Total	**2 193**	100%	**3 128**	100%	**43%**
World	**Severe**	**2 837**	44%	**3 901**	47%	**38%**
	Medium	794	12%	1 368	17%	72%
	Low	35	13%	866	11%	4%
	No	2 028	31%	2 101	26%	4%
	Total	**6 494**	100%	**8 236**	100%	**27%**

StatLink 🔗 *http://dx.doi.org/10.1787/257213423814*

Figure 2:   Population and water stress[22]

While for the OECD countries e.g. severe water stress will increase by 20%, for the rest of the world countries (ROW), this rate equals 54%, affecting more than 1 billion people. In the end, in 2030 almost 4 billion people will suffer from severe water stress.

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[21]   See Fallenmark (1997).

[22]   OECD (2008a), p. 223.

In the past few years, the treatment of *grey water* has gained significance in science and public life through the waves of various environmentalisms. The advocates of environmental awareness have made it clear that water can be reused or recycled for agricultural purposes, among others. However, this does not solve the problem for people in areas where fresh water is a scarce resource. In many parts of Africa, grey water reuse is only in preliminary stages.

Recent opinions that claim that desalination can solve the world's water problems do not take into account that this will be very expensive. The current prices of desalinated water in most modern plants are below 1 USD per m^3[23]. However, this figure is much higher than the average income of 40% of the world's population, which is less than 2 USD per day[24]. The agricultural use of desalinated water would be far too expensive for developing countries. Moreover, the costs of transporting desalinated water from the coast have not yet been addressed, although several high-cost solutions have been considered[25]. Furthermore, desalination will contribute to the CO_2 problem because of its massive energy requirements. In the whole of the Middle East, for example, desalination is powered by fuel.

Overall, the fact that our food consumption comprises the biggest share of our daily fresh water use complicates the situation for water-scarce countries and areas. We will now address the concept of virtual water in detail and address food consumption and water scarcity.

2.2   Virtual water product inclusion

Most of our water − virtual water − is not visible to us. This *hidden water* in everything we consume was labeled *virtual water* by Tony Allan in 1993[26]. Despite being invisible in the product, virtual water is the key to the holistic understanding of water consumption in the 21st century[27].

Virtual water requires a paradigm shift in the political and economic thinking of those in power. The challenge is hidden in the details. Certain crops consume more water

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[23]   See IDE Technologies (2009).
[24]   See World Bank (2008).
[25]   See Zhou and TOL (2004), p. 12.
[26]   See Allan (2001).
[27]   See World Water Council (2004), p. 7.

than others. While 15 000 liter of virtual water go into the production of 1 kg of wheat, 1 kg of potatoes requires only 900 liter (17 times less)[28]. Barley also requires 1 300 liter per kg, whereas rice – Asia's favorite carbohydrate source – requires 3 400 liter of water per kg[29]. An overview is presented in Figure 3.
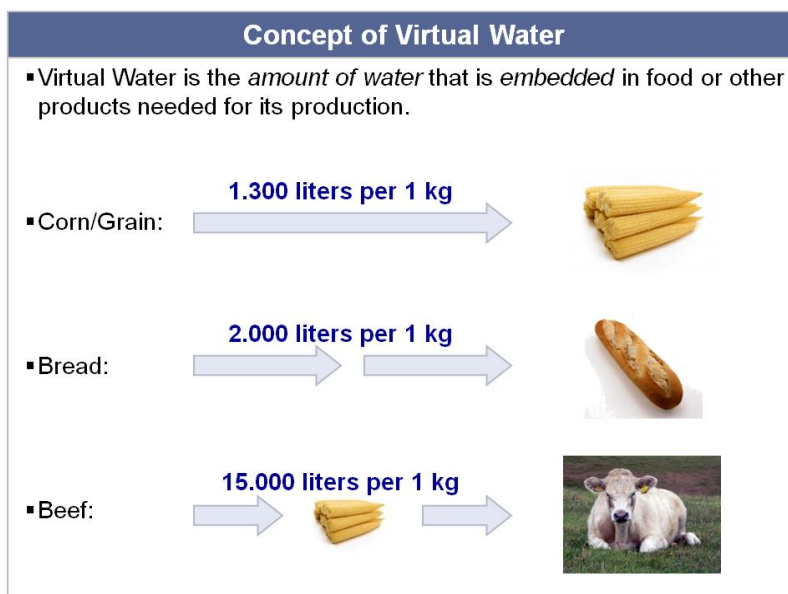

Figure 3:   The concept of virtual water[30]

When one adds up the quantities of water used for rice production worldwide, the total is 1 350 billion m³ – 21% of global crop production water use. More than 80% of the water used in crop production (e.g., wheat production) evaporates. Most products are not consumed directly from the field. Further individual or industrial processing adds more virtual water to the output of products, including bread, milk and beef. Meat production is especially water-intense as the crops used for feeding already contain virtual water.

In contrast, industrial goods' content of virtual water is low. According to Hoekstra and Chapagain, it accounts for only 10% of total global fresh water use with an overall worldwide average of 80 liter per USD in industrial products[31].

Adding up each individual's consumption of goods, the global average virtual water usage in the production process of the goods consumed is about 1 243 m³ or 1,2 mil-

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[28]   See, for example, Allan (1997) and Zuygmunt (2007).
[29]   See Waterfootprint (2003).
[30]   See, for example, Allan (1997) and Zuygmunt (2007).
[31]   See Hoekstra and Chapagain (2008).

lion liter of water per year per person[32]. This is known as the *virtual water footprint*. At 2 483 m³, the average US citizen uses more than twice the average amount, which equals exactly the entire water content of an Olympic 50-meter swimming pool.

Country	Water Footprint (m3/cap/year)
Australia	1393
Canada	2049
China	702
Egypt	1097
Germany	1545
India	980
Indonesia	1317
Italy	2332
Japan	1153
Mexico	1441
South Africa	931
Thailand	2223
United Kingdom	1245
USA	2483
Global total/avg.	**1243**

Table 1: **Water consumption patterns[33]**

As listed in Table 1, these figures differ substantially between countries. For example, the average Chinese footprint is almost a quarter that of a US citizen's.

Developed countries have done much to conserve fresh water resources. However, Table 1's figures prove that water saving is not the issue in water-abundant nations. The greatest effect can be achieved by reducing or reallocating virtual water consumption.

One could argue that water circulation is a closed system and that growing more potatoes while getting rid of a cow on an unirrigated field in the Bavarian Alps is ridiculous as well as futile in terms of world access to fresh water. However, exactly these regional effects of virtual water usage have to be addressed in the following.

2.3 Geographical disparities

The earth's natural resources are not equally distributed[34]. While most of the Americas and the northern hemisphere enjoy a humid climate with abundant fresh water

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[32] See Waterfootprint (2003).
[33] See Hoekstra and Chapagain (2008), p. 56.
[34] See Population Information Program (1998).

resources, the Middle East technically ran out of water in the 1970s.[35] The reasons are manifold: Firstly, in a semi-arid climate such as that of the Middle East, water has always been a precious resource. Secondly, dramatic increases in population and refugee streams have put further pressure on water supplies. Finally, climate change has led to desiccative lakes and rivers[36].
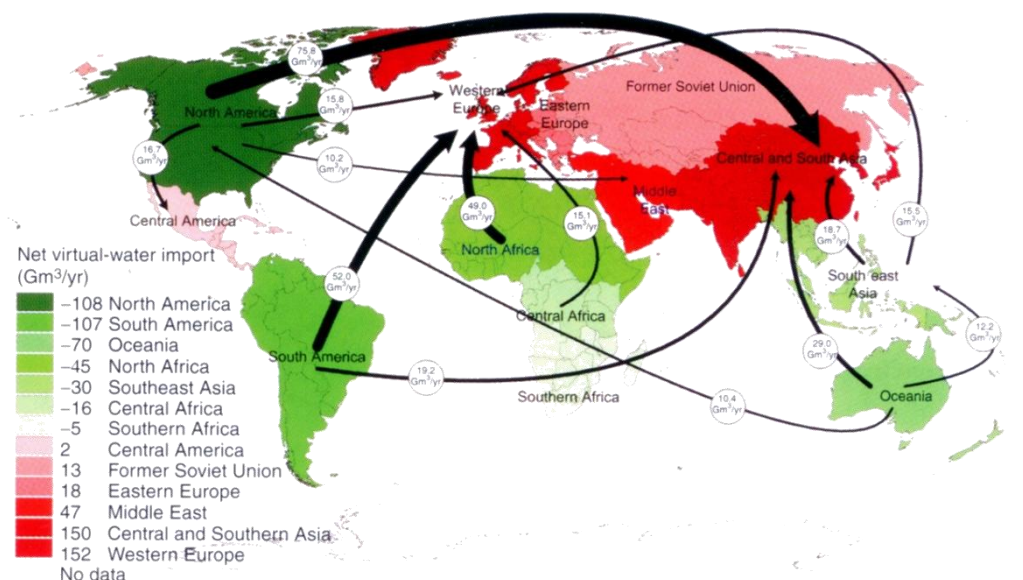

Figure 4:   Net virtual water imports in Gm³/year[37]

The individual virtual water footprint can be extrapolated to entire countries. Adding up a country's major virtual water imports and exports gives us its *virtual water trade balance*. Figure 4 provides an overview about the net virtual water imports per country between 1997 and 2001 for all virtual water flows above 10 billion m³ per year.

The countries in red are net importers of virtual water, while green marks a deficit in the trade balance. As can be seen, massive disparities exist. Europe, the Middle East, Russia, China and Japan are net importers, while the rest of the world is supplying these countries with virtual water.

Water-abundant countries can afford to export water. However, for water-scarce countries, a virtual water trade deficit will lead to an even greater scarcity in future. In

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[35]   See Allan (1997), p. 3.

[36]   See Arnell (2004), p. 40.

[37]   Chapagain and Hoekstra (2008a), p. 84f.; the figure contains only virtual water flows >10 billion m³/year.

theory, water-abundant countries should be producing the agricultural crops that require more water, while water-scarce countries should introduce water-efficient agriculture. These assumptions are based on the concept of virtual water. However, in a globalized economy based on market pressures, this may be considered wishful thinking. We will return to this point later.

But this phenomenon is also the case within countries. Especially within big countries, there are regional disparities in the distribution of access to fresh water. China is an ideal example of the regional disparities in virtual water use[38]. In the case of East Asia, overpopulation and increased desertification due to climate change have already impacted on water supply. South China is predominantly water-rich and exports water in three conveyors from the Yangtse River to the water-scarce north, as can be seen in Figure 5. 310 million people inhabit China's Huang-huai-hai area, with an water availability of 532 m³/capita/year, which is even less than the water-scarce Middle East, where 300 million people have access to 900 m³/capita/year[39].
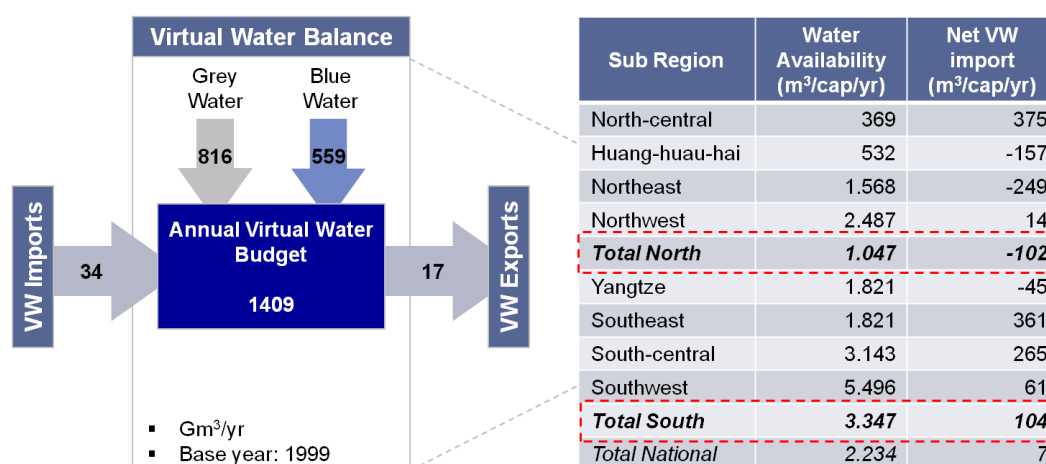

Sub Region	Water Availability (m³/cap/yr)	Net VW import (m³/cap/yr)
North-central	369	375
Huang-huau-hai	532	-157
Northeast	1.568	-249
Northwest	2.487	14
Total North	*1.047*	*-102*
Yangtze	1.821	-45
Southeast	1.821	361
South-central	3.143	265
Southwest	5.496	61
Total South	*3.347*	*104*
Total National	*2.234*	*7*

Virtual Water Balance: Grey Water 816, Blue Water 559, VW Imports 34, Annual Virtual Water Budget 1409, VW Exports 17. Gm³/yr, Base year: 1999.

Figure 5:   China's virtual water trade balance[40]

One would assume that the south would then be the major agricultural provider to the north. However, the contrary is true. The south exports large quantities of water to the north. Hence, the south is subsidizing the north with water, which the farmers from the north return as virtual water to the south[41]. Indeed, China perfectly illustrates the

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[38]   See Chapagain and Hoekstra (2008a), p. 74f.
[39]   See Chapagain and Hoekstra (2008a), p. 82.
[40]   According to Ma et al. (2006), p. 841.
[41]   See Chapagain and Hoekstra (2008a), p. 82.

visibility of the workings of the virtual water concept, which the government might have to take care of in the near future. One must certainly incorporate the cost of labor in the north, the fertility of the land as well as national food security. Nevertheless, other countries are unlikely to follow China's example due to the unavailability of financial resources to build and maintain such costly conveyors. The environmental impact of such mega-canals is considerable. Thus, while the Chinese example merely illustrates the workings of the concept of virtual water, it does not provide feasible solutions for other countries.

Water is an issue that has attracted much attention in recent years. Indeed, as Allan indicates, it is "a Mega-question" for future populations[42]. Yet the issue of water is often ignored, subject to mismanagement, and/or sometimes misinterpreted for ideological or religious reasons. In particular, semi-arid regions with scarce water resources and rocketing population growth create new water supply challenges. Therefore, a major challenge is the supply of water for agriculture; produce can then be exported to water-scarce areas such as urban areas. We will now address the raising of awareness of the economic stakes and possible instruments to regulate the virtual water trade.

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[42] See Allan (1997).

3 The need to care about virtual water consumption

Citizens of developed countries tend to take access to drinking water for granted. We may place access to water in the same class of public goods like public television, banking or national defense. A public good or resource is characterized by non-excludability and non-rivalry[43]. However, fresh water is perfectly excludable and rivalry as many examples can prove. Some people could die of thirst next to an irrigated field fenced with barbed wire and protected by armed guards. The same is true of virtual water. A country's virtual water trade balance could be negative while the majority of its population lacks access to clean drinking water. These issues cannot be solved by regional fresh water savings. They need to be anchored internationally by improving the efficiency of local fresh water use and, thus, virtual water trade.

However, the issue of virtual water is closely related to real fresh water resources as well as access to fresh water. We will introduce the effect of negative externalities on fresh water in order to extrapolate it to the tragedy of virtual water use. Based on this, we will derive a theoretical model in order to compensate for the negative effects of actual virtual water trade balances.

3.1 The negative externalities of direct water usage

Welfare inefficiencies generally occur if any production or consumption activity causes costs for people not directly involved in these activities. Such costs are usually referred to as negative externalities. For water, pollution generally accounts for negative externalities, i.e., when a production activity results in emissions that affect people that are not involved in the production process itself[44].

When it comes to water's negative externalities, it is not necessary to proceed immediately to virtual water. Negative externalities are already present when any process decreases downstream water quality. Especially in developing countries, direct water pollution is a significant problem that directly affects health levels. Water pollution, which was considerable during the Industrial Revolution, is still a major cause of health issues in developing countries, as depicted in Figure 6[45]. Along with limited

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[43] See Frank (1999) and Samuelson (1954), p. 387f. and Introduction, concept and theory, Chapter 2.
[44] See Pandey (2005), p. 347.
[45] See El-Naser and Abbadi (2006), p. 2.

access to secure fresh water, this is a major cause for increasing death rates[46]. For example, at the Yellow River, mining takes place in the mountains, where the springs originate. Due to low standards and environmental issues, heavy metals are not adequately treated in the process and flow into the water. This water is then used for industrial purposes in production and cooling.
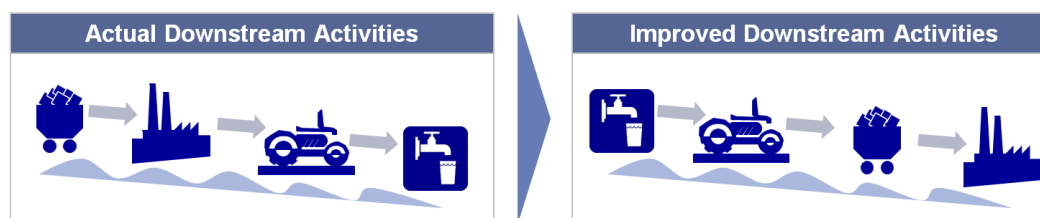

Figure 6: **Direct downstream water activities**

Harmful substances are again added to the water streams. Further downstream, the same water is used for farming. Substances from fertilizers and crop protection chemicals remain in the water, which flows back into the river. The people living in villages on the river banks get their drinking water from the river. In Europe during the Industrial Revolution, water contamination by lead and faeces led to a more resource-efficient use of water. But for developing countries, high poverty levels limit individuals' options. Here, public intervention is required: "Many poor countries lack the necessary financial ability to either develop infrastructure for irrigated agriculture or purchase food from the international market."[47]

In the case of water pollution, virtual water regulatory mechanisms will have little impact. It can create strong incentives for a resource-efficient use of fresh water. Virtual water regulation must take this into consideration and provide mechanisms to shift water-intense activities further down the *water value chain*.

3.2 The tragedy of virtual water

Negative externalities of location-dependent inefficient fresh water use arise when more fresh water is used than what is available in that area in terms of acceptable, sustainable usage levels. One reason for negative externalities is individuals' tenden-

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[46] See Appendix 1 for details.
[47] Word Water Council (2004), p. 10.

cies to rational maximization schemes which generally underestimate negative exter-nalities, especially in the long term.

In what has become known as *the tragedy of the commons*, Hardin described a public pasture. Every farmer will try to keep as much cattle as possible on this commons. According to Hardin, every farmer's adding of another animal to the pasture has a positive and a negative component[48]:

1. Positive: Every farmer receives all the proceeds from this additional animal, equivalent to +1.

2. Negative: Every additional animal will contribute to overgrazing and reduce overall utility by –1. However, every farmer is just affected by a fraction of –1.

In this example, all farmers will continue to send cattle to the common to graze until it is depleted due to overgrazing. According to Hardin:

"Each man is locked into a system that compels him to increase his herd without limit – in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all."[49]
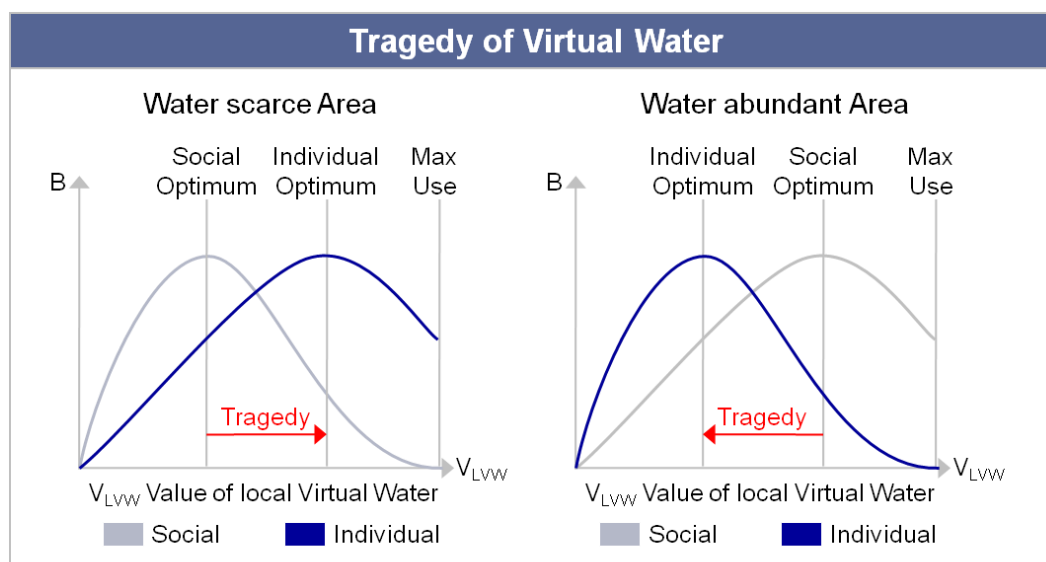

Figure 7:   The tragedy of the commons in water-abundant and water-scarce areas

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[48]   See Hardin (1968), p. 1244.
[49]   Hardin (1968).

Hardin's description fits the virtual water phenomenon. However, another perspective is added. Besides overexploitation of fresh water in a water-scarce area, fresh water is used less where it is abundantly available, as depicted in Figure 7. The horizontal axis indicates the value of local virtual water (V_{LVW}) contained in products produced, in relation to the fresh water consumption. The vertical axis indicates the individuals' and/or overall social benefit (B).

For this interdependency, the following case serves as an example: In a water-scarce area, fresh water use (e.g., animal breeding and other water-intense production processes like denim fabric production) is optimized by the optimum individual water consumption but exceeds the social optimum fresh water usage. Fresh water is used by the factory owner and turned into virtual water contained in the resulting products in a quantity that is much higher than the overall social optimum for the population living in that area. Some people may even be excluded from access to fresh water. This is the tragedy that results from an individual producer's access to local virtual water resources, which is much higher than the social optimum. On the other hand, in a water-abundant area, an individual does not internalize the negative externalities of water-scarce areas due to a lower production output of goods high in virtual water, which could in turn be transported or exported to water-scarce areas. The tragedy lies in the lower individual optimum production capacities than required by the social optimum.

In short, for the water-scarce area described in the left-hand graph in Figure 6, Hardin's pasture model works perfectly. Local water resources are first exploited, then exported from the area because each individual rationally maximizes his or her individual utility. However, the social optimum lies below that level, as the water should be used as drinking water and for the production of goods that require less blue water. For a water-abundant area, the opposite is true. Here the individual optimization constraint leads to an underusage of fresh water as a resource. Herein lies the tragedy[50] of virtual water.

Instead of goods high in virtual water being produced, goods low in virtual water are also produced and exported to water-scarce areas, which trade them for goods high in

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[50]   See Akerlof (1997).

virtual water[51]. Therefore the overall social optimum would involve focusing on the production of goods high in virtual water, which will increase the quantity.

At this stage, the interchangeability of fresh water and virtual water at the production site becomes clear again. As soon as the product is exported out of the area, this interrelationship changes towards the virtual water product inclusion scheme, as discussed above.

Now the question is: Is there a framework that allows for the internalization of these negative externalities into the individual utility constraint, i.e., that can overcome the tragedy of virtual water? A theoretical regulatory scenario is discussed in order to curb the continued exploitation of water-scarce areas; this will help answer the question.

3.3   Virtual water redistribution goals

While at present the agricultural and industrial production process does not internalize virtual water consumption in the production process[52], the production function does include the cost of local fresh water sourcing. Therefore, an economic frontier depends on the availability of fresh water in a specific region. Keeping cattle in a desert would not be economically viable. However, production does not take worldwide resource efficiency into account. As shown in the previous chapter, overall welfare would be much higher if goods that require large quantities of fresh water are grown in water-abundant areas. These goods can be exported to water-scarce areas in exchange for products requiring low quantities of fresh water[53]. Because of the real-world dualism of water scarcity and water abundance, the simple allocation of virtual water trade – as suggested by Hoekstra [54] will not help overcome individual utility maximization constraints. However, according to Stigler, integration is a precondition for a working regulatory scheme[55]. Therefore, an idealistic virtual water flow regulatory model – as depicted in Figure 8 – was developed.

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[51]   See Word Water Council (2004), p. 12 as well as Hoekstra and Chapagain (2003).
[52]   See Wild Farm Alliance (2003), p. 4.
[53]   See Chapagain and Hoekstra (2008a), p. 43.
[54]   See Hoekstra (2003), p. 13.
[55]   See Stigler (1971), p. 3f.

This model is based on Ricardo's notion of comparative advantages[56]. The export of goods containing large quantities of virtual water has to be supported in the case of water-abundant areas and restricted in the case of water-scarce areas.
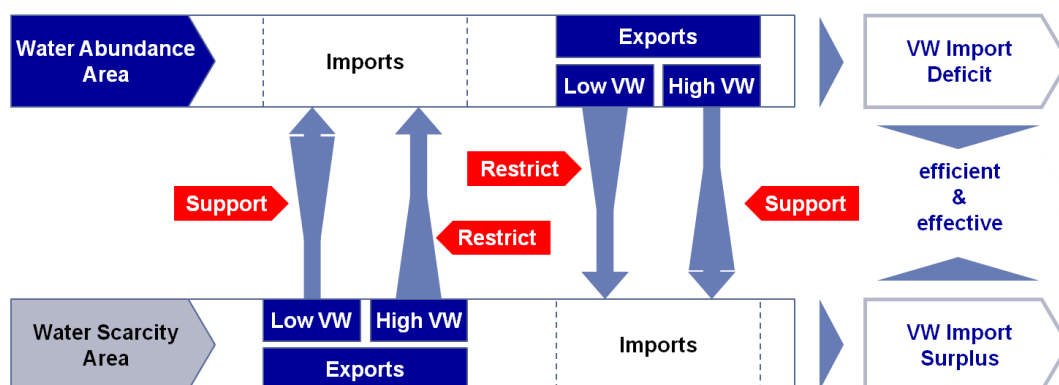

Figure 8:   Idealistic model of virtual water flow regulation

Similarly, the export of goods containing low quantities of virtual water must be supported in the case of water-scarce areas. In order to keep the international supply of goods containing low quantities of virtual water at a constant level, their export from water-abundant areas must be restricted. The model's ultimate target is to reverse the actual virtual water trade balance between water-scarce and water-abundant areas, leading to a negative virtual water trade balance for water-abundant areas and a positive virtual water trade balance for water-scarce areas. Due to the fact that domestic demand for the goods under *trade restrictions* will not increase, prices will fall and production capacity will decrease. For the goods under *trade support*, the opposite will happen as international demand for these goods will increase. In the end, production capacities will be shifted from products with high quantities of virtual water to goods with low quantities of virtual water in water-scarce areas, and vise versa in water-abundant areas.

What would this mean in practice? Fresh meat requires 15 m³ of water per kg. Ethiopia has a competitive advantage in skin and hide production. This industry is using enormous quantities of blue water resources. Furthermore, the demand for livestock (the input factor in Ethiopia's skin and hide production) is supplied for by breeding cattle locally[57]. Putting these cattle in a water-abundant area (e.g., the middle of the

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[56]   See Ricardo (1821), p. 41f.
[57]   See Ofcansky and LaVerle (1991).

Bavarian Alps) would lead to a more resource-efficient use of local fresh water without diminishing Ethiopia's competitive advantage and income. The massive price disparity between Bavarian and Ethiopian cattle prevent a market based sourcing of cattle from Bavaria. By subsidizing livestock exports from Bavaria to Ethiopia, cattle become affordable. Furthermore, subsidizing crops low in virtual water (e.g., grain or cotton) from Ethiopia for export incentives will support the move away from water-intense industries (e.g., the tanning of leather) in water-scarce areas. Moreover, the remaining water will serve the local population as drinking water and contribute to products low in virtual water.

The theoretical model developed contains options for the integration of location-dependent resource-efficient virtual water consumption into the production function in order to increase overall welfare. The challenge is now to transfer this theoretical concept into practice and establish its fit with reality. This will be discussed in the next chapter.

4   The applicability of regulatory concepts

A wide range of regulatory concepts is helping us reduce the negative externalities of private or industrial consumption (which are harmful to the environment). The focus is on proven environmental models, including legislation and interdiction, consumer and/or producer taxation, and permission rights. If these concepts can successfully be transferred to virtual water, their applicability to virtual water resource use efficiency can be tested. Compared to the reduction of pollution levels[58], for example, the complexity of global virtual water regulation is due to three major factors, which have to be addressed by the regulatory mechanisms:

- Location (water-scarce area or water-abundant area)

- Fresh water consumption patterns (industrial or private)

- Income levels (poor nation or rich nation)

The resulting regulatory mechanism(s) must fulfil these major requirements in order to shift production from goods high in virtual water to water-abundant areas and from goods low in virtual water to water-scarce areas, in relation to the location and the amount of fresh water resources used in production. However, this will only work if the mechanisms consider the income disparities between countries (i.e., developing and developed countries).

Furthermore, it must be considered that fresh water and virtual water can be viewed as interchangeable at the production site. However, if the resulting product is consumed in a region outside the region of production, a transfer of virtual water occurs that must be reflected in the regulatory framework.

In the following, mechanisms for the prevention of negative externalities are introduced and extrapolated to virtual water. This approach highlights the advantages and disadvantages of the applicability and effectiveness of increasing virtual water location-dependent fresh water usage.

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[58]   See Byrne and Glover (2000).

4.1 Rules and laws

Many environmental issues are addressed by means of legislation. There are a great many environmental laws and transnational agreements. One famous example is the case of the interdiction of halogenated hydrocarbons by the Montreal Protocol on substances that deplete the ozone layer signed by 195 countries on 1 January 1989[59].

In the case of law, virtual water would need an internationally agreed framework and an implementation in national law. In the case of rules, virtual water would primarily need rules restricting the production of goods high in virtual water in water-scarce areas. This focuses the reduction of a deadweight welfare overall loss. In addition, rules are likely to increase people's sensitivity to the issue of virtual water and thus lead to a change in consumption patterns. In water-scarce regions, prices for locally grown goods high in virtual water will increase, as their production – and, thus, availability – will be restricted.

At the end of the day, laws and rules will only be effective measures if they are able to change the individual production and consumption behavior in developed and especially developing countries As the latter are home the majority of the world's population). Figure 9 presents an individual maximization scheme for virtual water consumption.

Figure 9: **Individual maximization scheme for virtual water consumption**

As long as the individual's profit from using a higher-than-allowed quantity of virtual water is not lower than the individual sanction, rules and law will not lead to any change in consumption patterns.

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[59] See OECD (2006), p. 6.

In deriving the individual profit maximization scheme, the expected profit (E) depends on water consumption as more water in the production function generates more output. Thus, expected profit and fresh water consumption are positively related. However, the individual will stop producing restricted goods if the expected cost – in the form of sanctions or punishment – is higher than the expected profit. Therefore, the expected costs depend on the probability of being caught as well as the nature of the sanctions.

As long as the expected individual profit is higher than the expected costs of sanctions, laws and rules will not improve virtual water efficiency. Furthermore, ensuring enforcement is tougher in developing countries than developed countries. The introduction of sanctions will also impact citizens of developing countries more. After the introduction of virtual water laws, a farmer in Africa – who faces higher risks than farmers in developed countries – will need to decide to stop farming or to continue farming with even higher odds and higher risks than before.

Moreover, laws and rules are always beset by adverse selection, moral hazards and/or hold-up problems[60]. In the end, poor people might be adversely affected by the changes and dislocations brought about by virtual water sanctions and laws.

4.2 Consumption-related taxation

Consumer taxation or tariffs are used to internalize the external effects (and their costs) of changing consumption patterns. By increasing market prices through governmental intervention, the intention is that the good be bought and used less, and that the gained taxes be used to compensate for negative externalities.

Examples are taxes on fuel, which can set incentives to reduce carbon emissions by regulating driving patterns, for example[61].

The introduction of a consumer tax on virtual water containment will increase the prices of goods high in virtual water. Such a tax will depend on the quantity of virtual water contained in the good, i.e., the amount of fresh water used for its production. This could lead to a situation where – for example – meat (15 000 liter virtual water per kg) will carry a tax burden that is 7,5 times higher than that of bread (2 000 liter of

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[60] See Picot, Reichwald and Wigand (2008), p. 58f.
[61] See Dornbusch and Poterba (1991), p. 72.

virtual water per kg). As illustrated in Figure 10, the consumer has to pay a higher price – *P'* instead of *P* by the amount of *t* – for a good high in virtual water. The tax (*t*) is prescribed by a central authority. This will reduce demand for goods high in virtual water from *Q* to *Q'*. In contrast, prices for goods low in virtual water will be subject to lesser price increases. Supplier price levels will remain the same.
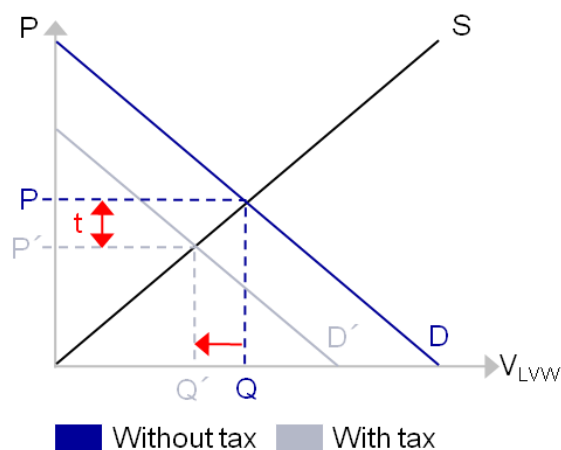

Figure 10:   Consumer tax on virtual water[62]

The advantages of this approach include clear consumer knowledge regarding virtual water containment as this is reflected in price levels. As a result, the consumer will internalize virtual water containment in his or her consumption behavior. The biggest drawback is the fact that the effects of regional disparities in water scarcity and water abundance are not considered. Furthermore, this would lead to distortions in local water prices as fresh water, for example, would be taxed equally in areas where fresh water is abundant and areas where it is scarce. Grey markets, which are the biggest sector in developing countries[63], are also not included.

In short, while shifting the virtual water tax burden to consumers internalizes virtual water containment, it does not consider that redistribution effects would prejudice water-scarce areas. The acceptance of a virtual water tax is therefore likely to be low, especially in water-scarce areas.

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[62]   Based on Varian (1999), p. 282.
[63]   Currently, in the Third World, only the wealthy farmers produce crops for sale, while the rest is trade-based. See Fafchamps (1992), p. 90.

4.3 Production-related taxation

Production tariffs incentivize markets to reduce a specific production function or produce fewer of a specific good. These taxes are sometimes referred to as *Pigouvian taxes*[64]. In contrast to consumer taxation, these taxes are paid by the producer according to his or her output quantity. Examples include carbon emission tariffs and harmful substance waste disposal[65].

Applying production tariffs to virtual water will increase the costs of producing goods high in virtual water. These tariffs are also prescribed by a central authority. The impact of such tariffs will be low on goods low in virtual water and high on goods high in virtual water. This would lead to a situation where a certain amount (t) is paid by the producer for every liter of fresh water used in production that is turned into virtual water during production. The higher the water consumption (for example, per kg of goods produced), the higher the amount payable. The producer tariff taxation model is set out in Figure 11.
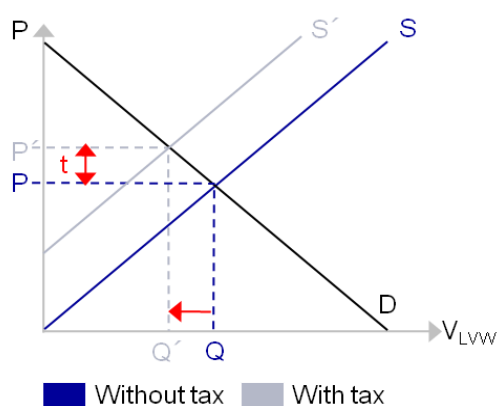
Figure 11:   **Producer tax on virtual water**[66]

The major advantage of a producer tariff is a clear focus on mass producers, which are much easier to incentivize to produce lesser goods high in virtual water. In addition, the producer tariff model will incentivize innovative production processes that require less fresh water and thus less virtual water. However, due to moral hazard problems in production due to profit maximization, the risk of fraud would be higher. The major

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[64]   See Frank (1999), p. 577.
[65]   See Newbery (2005), p. 10.
[66]   Model based on Frank (1999), p. 56.

disadvantages of the model are that producer tariffs would increase production costs[67] without limiting the virtual water waste through setting specific targets as well as the non-existence of redistribution incentives of water consuming production capacities.

And producer tariffs would not work in developing countries as the grey market will not be included.

4.4 Tradable permits for virtual water

The notion of tradable permit rights is a further development of producer tariffs based on the the Pigouvian tax model[68]. The carbon emissions trading scheme (e.g., in the European Union) is a good example of a tradable permit system[69]. A central authority issues a certain amount of emission rights, which also serves as a maximum cap. These rights or permits, which are allocated to the producers under a specific distribution scheme, can be reduced over time. These permits are tradable, which allows companies producing more emissions to buy permits from a company that produces less emissions and that is willing to sell permits at a specific price – the market price for pollution allowances[70]. Introducing a tradable virtual water permit system will also require a central authority to issue these rights, depending on fresh water availability in a specific region. The negative externalities of inefficient fresh water use would be represented in the amount of permission rights, which permit a specific amount of fresh water use in a specific region.

we will introduce a simplification. Switching costs to goods lower in fresh water are higher in water-abundant areas than in water-scarce areas. This might be due to high investments (e.g., in the buildings and machines required for breeding cattle). A more realistic approach will be presented in Chapter 5.

As depicted in Figure 12, allowing trade between companies and between regions leads to the desired relocalization effect of fresh water usage, positively related to fresh waster abundance, as explained in the following. The abscissa indicates the reduction of fresh water used for production (q). The ordinate describes the price (μ) related to the reduction. The individual marginal costs (*MC*) for the reduction of fresh

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[67]   See Varian (1999), p. 566.

[68]   See Quiggin (1988), p. 1072.

[69]   See, for example, European Commission (2004).

[70]   See Gunasekera and Cornwell (1998), p. 11f.

water use (and thus virtual water product containment) are depicted in the model with a linear function for each producer (*A* and *B*).
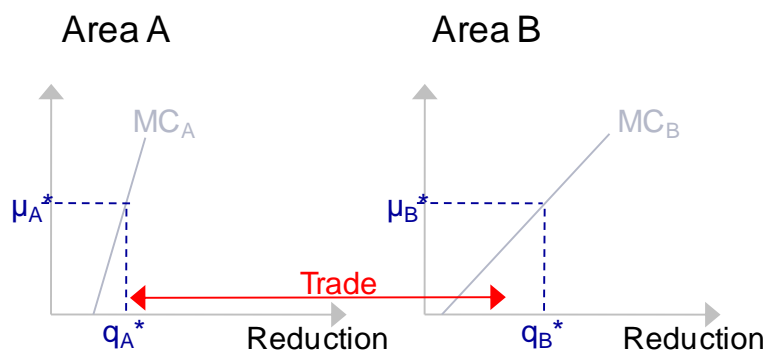

Figure 12: **Tradable permission rights for virtual water[71]**

Introducing trade establishes a given market price for the fresh water usage rights of μ^*. Hereby, each area (*A* and *B*) will reduce its fresh water consumption as long as marginal costs (*MC*) are lower than the costs for the required amount of tradable permits. As soon as $MC = \mu^*$, it becomes cheaper for the area to buy the rights instead of reducing its fresh water consumption. This will lead to a reduction level of q_A^* and q_B^* respectively in the equilibrium. q_B^* in the water-scarce area is much higher than q_A^* in the water-abundant area due to the lower marginal cost of reduction. A major advantage of the trade model is its higher welfare – compared to the taxation model – due to a self-allocation mechanism that efficiently generates a given level of reduction at the lowest overall costs[72]. This will be proved by applying theory to virtual water, which will also serve as an example for this theoretical model. Therefore, the existing system of carbon-tradable permit rights, which is location-independent, will be extended to a location-dependent dimension, as required in the case of virtual water regulation.

The overall welfare gains of the virtual water tradable permit system are illustrated in the example in Figure 13.

Let us imagine two farms: Farm A is located in a water-abundant area and farm S in a water-scarce area (where the relative value of fresh water is much higher than in a water-abundant area). Each of the farms has an initial fresh water consumption of 1

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[71] Model based on Frank (1999), p. 612.
[72] See Tietenberg (1985), p. 18f. and Schärer (1999), p. 143.

000 m³. This is not a problem in the water-abundant area, but in the water-scarce area, some people might have been excluded from access to drinking water. The interchangeability of fresh water and virtual water product containment during the production process must again be considered.
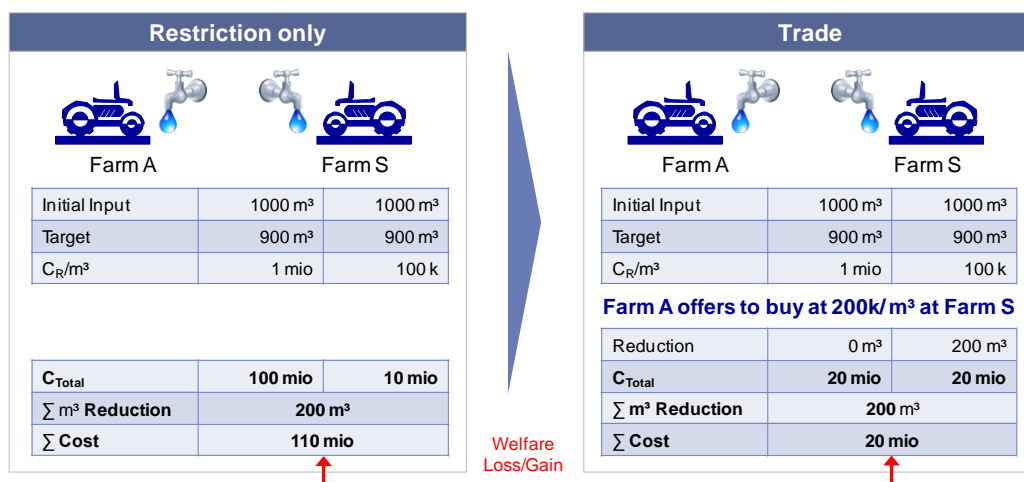

Figure 13:   The welfare gains from virtual water trade compared to restrictions

Regulation is now introduced by a central authority, which lowers the overall virtual water product containment to 1 800 m³ (which, at the production site, equals the same amount of fresh water). It is again assumed for this example that switching costs to goods requiring less fresh water for production are higher in water-abundant areas. This may be the case due to high investments (e.g., in buildings and machines required for breeding cattle). As pointed out, this limitation will be removed later.

In case of *reduction* only*, each farm must reduce its virtual water product containment by 100 m³, hence 100 m³ of fresh water for production. Costs for farm A are much higher, at 1 million per m³, compared to 100 k per m³ for farm S. In the case of reduction, to fulfil the reduction requirements, farm A will have costs of 100 million and farm S of 10 million. The overall reduction of fresh water consumption will be 200 m³ for a total cost of 110 million.

In case of *trade*, the regulator issued both farms with tradable virtual water permits. Nevertheless, the overall amount of virtual water product containment by both farms may not exceed 1 800 m³. Farm A is aware of its high reduction costs and will search the market for virtual water rights below the price of 1 million per m³. As farm S offers to sell virtual water rights at a price of 200 k per m³, farm A will buy these virtual water rights for 100 m³ at a price of 20 million, which is much less than the 100 mil-

lion farm A would cost the reduction at its own production site. Farm S must reduce water consumption to 900 m³ plus the 100 m³ originally from farm A. Therefore, farm S will have a reduction cost of 20 million. However, the entire cost is paid by farm A, which imposes a financial burden of zero on farm S in the water-scarce area. The overall reduction of fresh water use is 200 m³, at an overall cost of 20 million, paid by farm A to farm S.

In the case of *trade* (when compared to the case of *restriction*), the overall welfare gain is more resource-efficient water use. Fresh water consumption was reduced only in the water-scarce area and former additional unnecessary cost of 90 million did not occur due to trade.

To conclude, tradable virtual water permits allow for internalization and self-regulated market efficiency levels simultaneously. Unfortunately, the *trade* option is accompanied by concerns of controllability, the private sector and moral hazards in production[73]. Especially in developing countries, it is not easy to integrate a large number of producers into a worldwide trade model[74]. The next chapter deals with an introductory potential real-life application of the models presented.

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[73] See Tietenberg (1985).

[74] In developing countries, the level of 'aggregation' farmers must address the effect on small farmers. See Fafchamps (1992) for farming structures in the Third World.

5 Introducing a supranational institution for virtual water trade

The analysis showed the theoretical benefits of the tradable permit system for virtual water reallocation. However, the tradable permit system should only be regarded as part of a framework of instruments. Moreover, the system can incorporate each of the other presented regulatory options, depending on the tradable permit system's configuration[75]. For example, if all the permits were handed out for free, this would involve regulatory rules whereas, if the permit prices were fixed, this would be more like a tax. These coherences are presented in Figure 14.
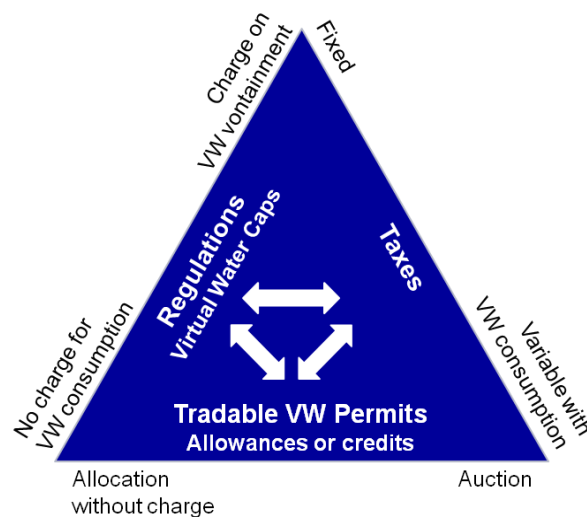
Figure 14: **Tradable virtual water permits in relation to other regulatory instruments[76]**

In this sense, it is even more important to evaluate regulatory mechanisms for their application to reality. Based on such a comparative analysis, a resulting trade and tariff model managed by a supranational institution for virtual water trade will be introduced.

5.1 Trade-off of regulatory options

A major goal of the new regulatory framework is to increase local resource-efficient virtual water consumption. Some of the considered regulatory mechanisms fulfil these goals better than others. However, applicability to developing countries without ex-

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[75] See Schreiner (1999).

[76] Based on OECD (1999) and Schreiner (1999), who applied the model to carbon rights.

posing them to further risk is a major requirement for the future virtual water regulatory framework.

The acceptance and applicability of a virtual water regulatory framework and its instruments depend on sociopolitical and economic dimensions and considerations[77]. The following criteria must be fulfilled:

- **Reallocation potential**

   Serving the goal of redistributing the production of goods that require high quantities of water for production to water-abundant areas and shifting goods requiring low quantities of virtual water for production to water-scarce areas fulfils the needs of efficient local water use.

- **Supporting developed countries**

   The system has to be accepted and supported by developed countries' production and farming architectures. Furthermore, it is evident that it is compatible with individual local production functions.

- **Supporting developing countries**

   Due to local disadvantages, the need to support developing countries should outweigh supporting developed countries from a welfare perspective. As the current situation is one in which a majority of developed nations is endangering sustainable water supply due to trade, supporting developing countries might have to outweigh supporting developed countries. Furthermore, it is evident that it is compatible with individual local production functions.

- **Transparency**

   The system mechanism must be a clear and easy to understand, which also reduces the potential of fraud by minimizing unnecessary complexity[78].

- **Controllability**

   The controllability by a central authority, government or even competitors must be high. Along with transparency, this might also decrease the potential of fraud[79].

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[77]   See Laffont and Triole (1993), p. 592.
[78]   See Laffont and Triole (1993), p. 482.
[79]   See Newbery (2005), p. 20.

- **Implementation**

  The system must be able to support the actual market conditions as well as the desired change in production structure. Later on, many political barriers will have to be knocked down to introduce such a system. However, the focus is on the system's coming into being rather than on the process of political negotiation about the system.

Applying these evaluation criteria to the aforementioned regulatory mechanisms allows for feasibility assessment. The results of the previous chapter's applicability analysis have been summarized in Table 2. Each regulatory measure has been evaluated on a scale of 1 to 5. *Harvey balls* are used to indicate the degree of the model's feasibility for each factor[80].

	Rules and Laws	Consumer Tax	Producer Tax	Trade
Reallocation potential	○	◔	◑	◑
Supporting industrialized nations	◔	◔	◕	◔
Supporting dev. countries	○	◔	◑	◑
Intend to defraud	◕	◕	◑	◔
Control	○	◕	◔	◕
Implementation	●	◕	◔	◑
TOTAL	◔	◑	◑	◕

Table 2: **The valuation of regulation measures for virtual water**[81]

For the goal of relocating fresh water intense production to water-abundant areas, *trade* was identified as having the highest potential. While *producer tax* scored well in terms of supporting developed countries, its control measures are ineffective for developing countries. In contrast, *trade* scores high for developing countries as monetary transfers accompanying incentives would flow primarily from developed countries to developing countries. While fraud risk was inherent to *rules and laws* as well as *consumer tax*, fraud risk was low for *tradable permits*. Control mechanisms are

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80 See Eremenko (2005), p. 10 for economic market evaluation, or Passerini (2007), p. 186, and Hüner et al. (2009) for the use of this approach to evaluate IT projects.

81 Based on the evaluation of regulatory models, as presented in Chapter 4.

best suited to *consumer tax* (e.g., a value added tax) or *trade*, again due to positive incentives, especially for water-scarce areas. Implementing a *law* is simpler than enforcing a *consumer tax* or *trade* system. However, imposing a *producer tax* on every farmer in every developing country would be no easy task.

Aggregating these results, *rules and laws* do not fulfil the defined requirements at all. Even *trade* is not perfectly suited to virtual water regulation. At the end of the day, the disadvantages of *trade* could be overcome by combining this measure with the measure of *tariffs* and its positive elements. This tariff and trade model will be described in detail in the following.

5.2 Establishing a tariff and trade model

A major constraint in the implementation of one common model for both developing and developed countries is compatibility[82]. In combination with the sociopolitical and economic dimensions and considerations as well as individual utility maximization, trade on its own should not be overestimated as a solitary mechanism. Furthermore, a central authority is required; this authority would evaluate – from a perspective that is as independent as possible – the extent and nature of the water reserves of every area, region and country[83]. This is where the dual presence of water-scarce areas and water-abundant areas within one country becomes an issue. Providing national permits only will not internalize the negative effects of the overusage of water in the water-scarce area, even if that country as a whole is within its usage target. The only solution here would be a kind of consumer tax, in the form of a national import and export tax or subsidy[84]. As a result, the combination of the benefits of a trade model between water-scarce and water-abundant areas with the benefits of import/export tariffs is suggested. These mechanisms will be implemented in a two-stage approach according to the theoretical model presented in Chapter 3.3, as follows:

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[82] See Rangel (1986), p. 12.

[83] This central authority would fulfil a similar role as the Commodity Futures Trading Commission, which has full oversight authority for all carbon market trading. See CFTC (2009).

[84] See Laffont and Tirole (1993), p. 10.

Phase 1:   Virtual water tariffs

- For the import of goods containing a high quantity of virtual water originating from a water-scarce country, a *tax* is imposed when entering a water-abundant country.

- For the import of goods containing a low quantity of virtual water originating from a water-abundant country, a *tax* is imposed when entering a water-scarce country.

- For the import of goods containing a high quantity of virtual water originating from a water-abundant country, a *subsidy* is paid when entering a water-scarce country.

- For the import of goods containing a high quantity of virtual water originating from a water-scarce country, a *subsidy* is paid when entering a water-abundant country.

Phase 2:   National tradable permits

- Water-abundant areas are entitled to a higher amount of tradable virtual water permits. The production of goods with a low need for fresh water requires the equivalent amount of tradable virtual water permits. In contrast, for the production of virtual water intense goods, no tradable permits are required.

- Water-scarce areas are entitled to a lower amount of tradable virtual water permits. The production of goods with a high need for fresh water requires the equivalent amount of tradable virtual water permits. In contrast, for the production of goods with a low need for virtual water, no tradable permits are required.

- Trade between water-scarce and water-abundant countries is allowed.

However, will the trade model alone not suffice? Initially, the self-regulating mechanisms of trade are not quite clear, and it cannot be predicted whether the market will respond in the desired way[85]. For example, it may be the case that the farmers in water-abundant areas buy all the certificates at any price in order to protect their production of goods that require low quantities of virtual water. A regulatory authority with

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[85] See Stern (1997) and Stern and Holder (1999) p. 49.

two instruments is capable of countering negative effects by setting incentives for virtual water relocation by means of tariffs. The same thinking applies in the case of initially keeping the national market closed. Over time, trade with other countries can be allowed, and the tax can be abolished. Until then (as in the case of carbon trade's multistage model), a dual model is required[86]. The welfare effects of the regional availability of fresh water will be discussed in detail.

5.2.1 Transnational level: Tariffs

The tariff model is required as a result of the disparities in the availability of fresh water between nations[87]. A countermeasure against the exploitation of living conditions in especially developing countries can be found in the implementation of virtual water tariffs. This allows some relocation on an international level by a central authority, which will be introduced later.
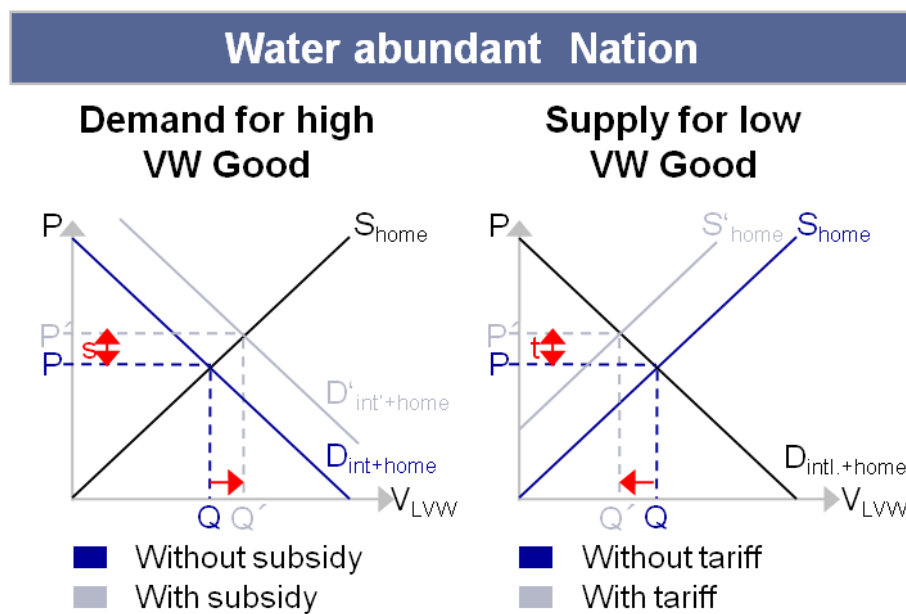

Figure 15:   **The effects of supply and demand on water-abundant nations**

The tariff scheme will help shift fresh water intense production from water-scarce nations (Figure 16) to water-abundant nations (Figure 15).

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[86]   For carbon emission, there is a hybrid trade system that contains a fixed amount of long-term permits, although the regulatory authority can also supply short-term permits. See McKibbin and Wilcoxen (2002), p. 115 - 119.
[87]   See Blanchard (1999), p. 343f.

The domestic and international demand for goods high in virtual water in a water-abundant nation is depicted on the left in Figure 15 as $D_{int + home}$. Placing a subsidy (s) on the export of goods high in virtual water shifts the initial demand curve upwards to $D'_{int + home}$, driven by an increase in international demand from Q towards Q'. The national supply curve (S_{home}) remains unchanged.

In contrast, the domestic and international demand for goods low in virtual water in a water-abundant nation is depicted on the left as $D_{int + home}$. Placing a tax (t) on the export of goods low in virtual water leaves the demand curve unchanged, given the fact that the nation's market share is comparatively low. However, the supply curve (S_{home}) shifts upwards to S' due to the reduced production at a given international market price (P) as producers have to internalize the tax (t) in order to compete in the market, leading to a reduced production from Q towards Q'.

As a result, the water-abundant nation will produce more goods high in virtual water and less goods low in virtual water for the international markets, using more of the locally abundant resource fresh water.
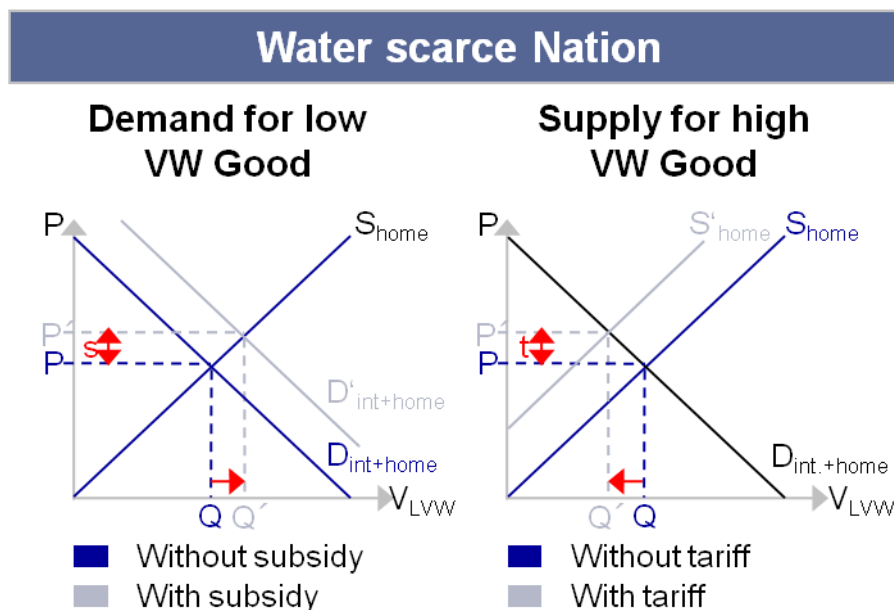

Figure 16: **The effects of supply and demand in water-scarce nations**

The same is true for a water-scarce nation, with contrary effects, as depicted in Figure 16. The domestic and international demand for goods low in virtual water in a water-scarce nation is depicted on the left as $D_{int + home}$. Placing a subsidy (s) on the export of goods low in virtual water shifts the initial demand curve upwards to $D'_{int + home}$, driv-

en by an increase of international demand from Q towards $Q´$. The national supply curve (S_{home}) remains unchanged.

The domestic and international demand for goods low in virtual water in the water-scarce nation is depicted on the right as $D_{int + home}$. Placing a tax (t) on the export of goods high in virtual water leaves the demand curve unchanged, given that the nation's market share is comparatively low. However, the supply curve (S_{home}) shifts upwards to $S´$ due to the reduced production at a given international market price (P) as producers have to internalize the tax (t) in order to compete in the market, leading to a reduced production from Q towards $Q´$.

This will lead to a water-scarce nation with a higher production quantity of goods low in virtual water and less goods high in virtual water for the international markets, using less of the locally scarce resource fresh water for production. As a result, the population has access to drinking water and water for other uses. A more efficient local use of the resource fresh water is achieved.

5.2.2 Regional level: Tradable permits

As we have seen, a national tradable permit system is required due to the unequal availability of fresh water within any country. The example of northern and southern China presented in Chapter 2.3 reflects possible regional differences. Assigning national tradable permits only will not bring about change. Therefore, Phase 2 requires the implementation of area-specific fresh water consumption permits at a subnational level.

It is important that the specific area is allocated specific rights based on its water-scarcity. Therefore, every kind of production requires a certain amount of tradable permits, and the total number of companies within that area should not exceed the maximum allowances[88].

A thorough inquiry into every nation's fresh water resources is indispensable. This includes the evaluation on a per area basis, which has to be defined by a central regulatory authority. Water-scarce areas and water-abundant areas are clearly defined and communicated as well as granted a corresponding amount of tradable permit rights. A key concept of this approach is the condition that permits are only required for re-

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[88]   As per the two-stage carbon trade model; see Skea (1999).

source-inefficient production, which means producing goods high in virtual water in a water-scarce area or goods low in virtual water in a water-abundant area. Production exceeding the amount of permits held is not allowed. After the initial granting of specific fresh water use permits to production sites, production sites can trade in permits. However, it is not permitted for any producers to have more permits than the maximum number specified by the regulatory authority. Such a region-specific price mechanism renders resource-inefficient production expensive.

The trade permits negatively affect the production of goods low in virtual water in water-abundant areas as well as goods high in virtual water in water-scarce areas, as described in Chapter 4.4. This leads to increasing costs for inefficient production and shifts production capacities to local fresh water resource-efficient goods. As can be seen from this convergence, the marginal costs of reducing fresh water consumption are no longer the determining factor for production decisions. The individual budget constraint is characterized by the required amount of permits in order to produce local fresh water inefficient goods. So the assumptions initially required for trade in Chapter 4.4 can be suspended.

5.3   A central authority: Virtual water clearing body

Up to now, the presented measures referred to some sort of body that should either be responsible for setting the tariffs or for issuing the tradable virtual water permits. This supranational virtual water regulation authority will be instrumental in the entire virtual water regulation system and its viability. Its primary responsibilities will be the operation of the tradable permit system as well as the tariff system for virtual water[89]. Its major tasks and responsibilities will include:

- **Virtual water content product definition**
  Agricultural goods in particular have to be evaluated and documented for their virtual water content as a basis for the virtual water tariff model.

- **National blue water availability**
  Water-scarce and water-abundant countries must be identified and evaluated according to their virtual water trade balances.

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[89]   See Laffont and Triole (1993), p. 610f. on the problem of the choice of watchdog.

- **Regional blue water availability**

  Water-scarce and water-abundant regions within countries have to be identified according to their virtual water trade balances.

- **Tariff empowerment**

  Assessing product-specific tariffs and subsidies.

- **Tradable virtual water permit administration**

  Issuing tradable permits and acting as a clearing body.

This regulatory authority will clear the export taxes and subsidies as well as the allocation of the national tradable permits. The relationships as well as the money and permit streams are presented in Figure 17. Furthermore, a national virtual water body in every country is proposed in order to establish disparities between blue water abundance and scarcity within that country, among other roles. The administration of tradable permits in specific countries can be outsourced.
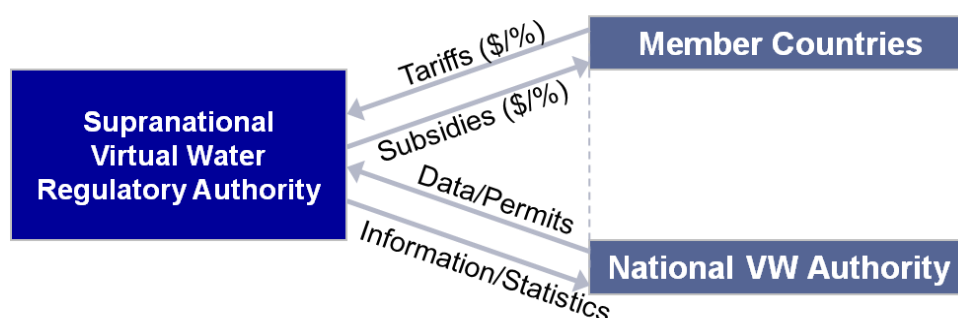

Figure 17:   A central authority for tradable virtual water permits

Another central function of the supranational virtual water regulatory authority is the collection and evaluation of water data in order to disseminate relevant data directly to producers[90]. This body will also decide on tariff update cycles and the amount and allocation of tradable permits.

This body will require international support of, independence from and acceptance by international organizations. While establishing it will not be an easy task, the increasing pressure of the worldwide lack of access to fresh water will appear on government agendas sooner rather than later – if it has not already done so.

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[90]   See Stern and Holder (1999).

6 Shortcomings and recommendations

The actual use of fresh water without taking into account the local relative value leads to massive negative impacts on overall welfare. Improving resource efficiency in international virtual water flows contributes significantly to sustainability and conditions of access to drinking water, especially for people in the developing world.

The notion of, and framework for, virtual water regulation through combining tariffs and trade via a supranational virtual water regulatory authority seeks to provide a starting point for future debate.

The model's advantages outweigh its disadvantages. The virtual water tariff and trade regulatory model contributes towards a *resource-efficient* relocation of fresh water. In contrast to the case of carbon trade, where the location of pollution does not matter[91], the local conditions of water availability are crucial, and are supported by the model. It was shown that a *central body* such as a supranational virtual water regulatory authority would be capable of managing not only at an international level but also on a *micro, (subnational) perspective* in order to fulfil the different needs of water-scarce and water-abundant areas.

This policy model is designed as an *incentive-based approach*. The trade of permits creates *dynamic efficien*cy in the market.[92] These incentive schemes include intrinsic mechanisms that regulate competition. Cheating, i.e., using more fresh water than the permits possessed allow, leads to a depreciation of the permits. Thus, the producers will monitor themselves. The tariff and trade system *stimulates process and product innovation*[93]. New and cheaper products and processes will decrease fresh water requirements and lead to additional benefits in terms of reduction. The trading of permits *generates a new market sector*. Marketplaces are required for the processing of trade in permits. This will create employment, for the marketplaces and in the producing companies (in terms of permit management).

However, the *measurement of virtual water content* is critical. Only assumptions can be made until fresh water consumption is measured at the source as well as in the pro-

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[91]   See Klaassen (1999), p. 92f.
[92]   See Schreiner (1999), p. 138.
[93]   See Tietenberg (1985), p. 38.

duction process. Unfortunately, there is a high willingness among producers to manipulate measuring points or provide adjusted figures according to the permits in their possession.

In a final stage of the model, worldwide permit trading could *allow wealthy countries to live beyond the planet's capacity*.[94] Rich countries can afford to pay for permits and acquire them, especially from poor developing countries. In turn, the industrialization of developing countries could be delayed as they are unable to swiftly develop their production capabilities.

Tariffs and tradable permits *create market distortions*. The payments for permits will cause a rise in consumer prices[95]. The control of fresh water consumption by a regulatory authority adds another uncertainty factor and risk factor to a company's already uncertain market environment. An additional risk premium will be added to the price calculation and increase the market price disproportionately.

Furthermore, international relations theory can help create sustainable water solutions. In the case of virtual water, the functionalist paradigm, which seeks to create transnational institutions, can pave the way for food and water security in the 21st century. Access to fresh water is an archetypal example of the national security that every nation so fervent seeks to attain or should seek to attain. Environmental issues are certainly on policy-makers' agendas. Serving as an example, the first ASEAN ministerial meeting (AMM) on the environment took place as early as 1981. However, given future environmental challenges, including a declining water cycle due to climate change and greater demand due to population growth and growing prosperity, state centrism cannot provide answers or solutions and must be seen as an outdated product of the 19th and 20th centuries. Functionalism is a preferred paradigm because it allows for the integration of political economies under the supervision of transnational institutions[96]. When applied to virtual water, we can identify the urgent need for governments to cooperate in agriculture in order to achieve food security in the future. This should include collaboration in food trade in order for regions to form strong

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[94]   See Byrne and Glover (2000), p. 1.

[95]   See Schreiner (1999), p. 139f.

[96]   See Wunderlich (2007), p. 10f.

trade blocs in the global food market. To what extent such cooperation can be achieved is a question we must force onto the agenda of our decision-makers.

In March 2008, 32 states in the UN Human Rights Council agreed to establish a right to water and sanitation, which sought to make drinking water a universal human right[97]. Such agreements prove the (stated) willingness by governments to cooperate over water. The natural next step would be to include virtual water in this international agreement.
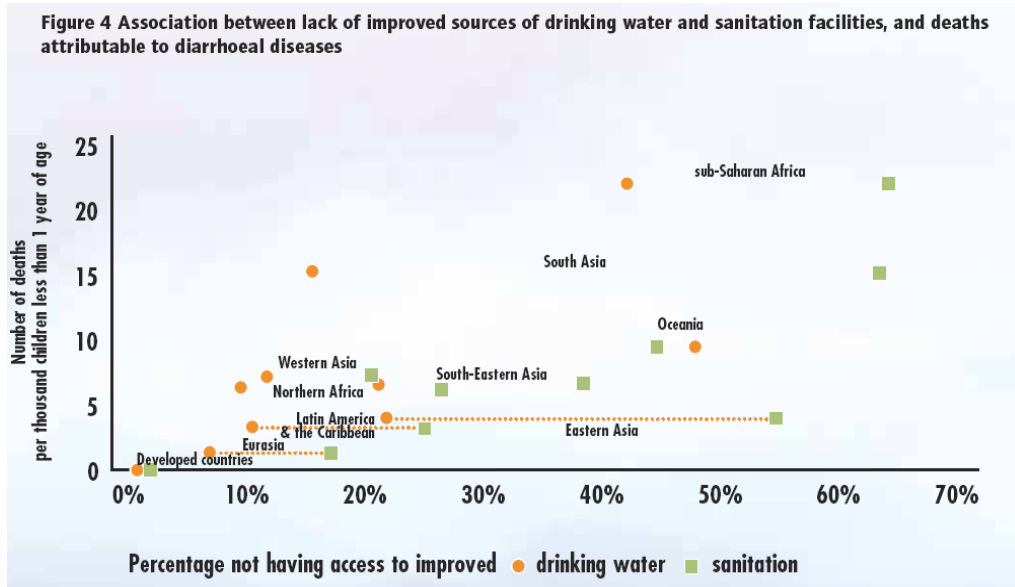
Virtual water is also a unique opportunity for developing countries with booming populations to combine economic prosperity and environmental sustainability. As Malthus predicted in 1798, population growth is highly limited. Let's hope we can foil Malthus once again by increasing virtual water usage efficiency.

In conclusion, the author hopes to have presented ideas to cut the Gordian knot of virtual water management. The framework might be open to corruption. But the case of carbon trade has developed swiftly from inception to internationally accepted system. Virtual water trade tariffs and trade regulation might well hold the key to securing and protecting our future. If this study were to spark a debate on and work towards a regulated political economy of virtual water, it would fulfil its intention.

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[97]   See United Nations (2008).

Appendix

Appendix 1: Correlation between access to drinking water and death rates

Figure 4 Association between lack of improved sources of drinking water and sanitation facilities, and deaths attributable to diarrhoeal diseases

Source: WHO and UNICEF (2005), p. 12

References

Akerlof, G. A. (1997):" Social Distance and Social Decisions", in: Econometrica, Vol. 65, No. 5 (Sep., 1997), pp. 1005-1027

Allan, A.J. (2001): "The Middle East water question: hydropolitics and the global economy", Tauris Publishers, London, 2002

Allan, A. J. (1997): "Virtual Water`: a long term solution for water short Middle Eastern economies?", paper presented at the 1997 British Association Festival of Science, Roger Stevens Lecture Theatre, University of Leeds, Water and Development Session - TUE.51, 14.45, 9 September 1997

Arnell, N. W. (2004):"Climate change and global water resources: SRES emissions and socio-economic scenarios", in Global Environmental Change, Volume 14, Issue 1, Climate Change, April 2004, Pages 31-52

Blanchard, O. (1999):"Macroeconomics", 2nd edition, Prentice-Hall, 1999

Bowden, C., (2003): "Killing the Hidden Waters", University of Texas Press, 2003

Byrne, J./ Glover, L. (2000): Climate Shopping: Putting the Atmosphere Up for Sale, in: TELA: Environment, Economy and Society Series, 2000

CFTC (2009):"About the CFTC", available online at:
http://www.cftc.gov/aboutthecftc/index.htm, [cited on 17th July 2009]

Chapagain, A. K./Hoekstra, A. Y./Savenija, H. H. G. (2005): "Saving Water through Global Trade",Value of Water Research Report Series No, 17, September 2005

Davis, M. (2006): "Planet of Slums", Verso, 2006

Dornbusch, R./Poterba, J. M. (1999):" Global warming: economic policy responses", MIT Press, 1991

El-Naser H./Abbadi, M. (2006):" Virtual Water in the MENA Region", Paper, Presented at the International Expert Seminar, Amman, Jordan, 2006

Eremenko, P. (2005):"When 'Fairness' is Efficient: The Role of the Judiciary in Maximizing Aggregate Social Welfare", (August 30, 2005). Available at SSRN:
http://ssrn.com/abstract=900463 [cited on 17th July 2009]

European Commission (2004): "EU emissions trading. An open scheme promoting global innovation to combat climate change", Brussels, 2004

European Commission (2004): EU emissions trading. An open scheme promoting global innovation to combat climate change, Brussels, 2004

Fafchamps, M. (1992):" Cash Crop Production, Food Price Volatility, and Rural Market Integration in the Third World", in: American Journal of Agricultural Economics, Vol. 74, No. 1 (Feb., 1992), pp. 90-99

Falkenmark, M., (1997): "Meeting water requirements of an expanding world population, in: The Royal Society

Frank, Robert H. (1999): "Microeconomics and Behaviour", Boston et al.: Irwin McGraw-Hill

Gleick, P. H., (1993): "Water and Conflict: Fresh Water Resources and International Security", in: International Security Vol. 18 No. 1,

Gunsekera, D./Cornwell A. (1998): "Essential Elements of Tradable Permit Schemes", in Bureau of Transport Economics (1998): Trading Green-house Emissions: Some Australian Perspectives, Canberra: The Bureau of Transport Economics, 1998

Hardin, G. (1968): "The Tragedy of the commons", in Jounal of Science Vol. 162. No. 3859, pp. 1243 – 1248

Hoekstra, A.Y. (2008): "Water scarcity and international trade: The need to extend the scope of water resources management", in: Bastian, C., Gunkel, A., Leistert, H., Menniken, T., Rhodius, R. and Schlipphak, B. (2008): Wasser – Konfliktstoff des 21. Jahrhunderts, Heidelberg: Universitätsverlag Winter, pp. 121-141.

Hoekstra, A.Y. (2008b):"Water neutral: reducing and offsetting the impacts of water footprints", Value of Water Research Report Series No. 28, published by UNESCO-IHE Institute for Water Education, University of Twente and Delft University of Technology, 2008

Hoekstra, A. Y., (2003) "Virtual Water trade: Proceedings of the International Expert Meeting on Virtual Water Trade", IHE Delft, The Netherlands, 12-13 December 2002

Hoekstra, A. Y./Chapagain, A. K. (2008): "Globalization of Water – Sharing the Planet's Freshwater Resources", Blackwell, 2008

Hoekstra, A.Y./Hung, P. Q. (2002): "Virtual Water Trade A Quantification of Virtual Water flows between nations in relation to international crop trade", Value of Water Research Report Series No. 11, 2002

Hüner, K./Ofner, M./Otto, B. (2009):" Towards a maturity model for corporate data quality management", in Proceedings of the 2009 ACM symposium on Applied Computing, Pages 231-238

IDE Technologies (2009): "IDE wins 'Desalination Plant of the Year 2006' award", available online at: http://www.ide-tech.com/News_item.asp?iid=6065&pid=1599&ppid=1489&z=1&p=1 [cited on 17th of July 2009]

Miles, M.B. (1979): "Qualitative Data as an Attractive Nuisance: The Problem of Analysis", Administrative Science Quarterly, 24 (4): pp. 590-601

Howard, G./Bartram, J. (2003): "Domestic Water Quantity, Service, Level and Health", World Health Organization, Geneva, 2003

Klaassen, Ger et al. (2005): Testing the theory of emissions trading: Experimental evidence on alternative mechanisms for global carbon trading, Ecological Economics, 53(1): pp. 47 – 58

Klaassen, Ger (1999): Emissions trading in the European Union: practice and prospects, in Sorrell, Steve and Skea, Jim (1999): Pollution for Sale: Emissions Trading and Joint Implementation, Cheltenham: Edward Elgar

Laffont, J.-J./Tirole J. (1993): A Theory of Incentives in Procurement and Regulation, Massachusetts: MIT Press, 1993

Ma, J./Hoekstra, A./Wang, H./Chapagain, A. K./Wang, D. (2006):" Virtual versus real water transfers within China", Philos. Trans. R. Soc. London, Ser. B, 361, pp. 835–843

Malthus, T. (1798):" An Essay on the Principle of Population", printed for j. johnson, in st. paul's church-yard, London, 1798.

McKibbin, W./Wilcoxen, P. (2002): The Role of Economics in Climate Change Policy, Journal of Economic Perspectives, 16 (2): pp. 107 – 129

McKibbin, Warwick J. (1998): International permit trading: creating a sustainable system, in ABARE (1998): Proceedings of the International Conference on Greenhouse Gas Emissions Trading, Canberra: ABARE

Newbery, D. M. (2005):” Why Tax Energy? Towards a More Rational Policy”, in: The Energy Journal, Vol. 26, No. 3, p1-39

OECD (2008): “OECD Environmental Outlook to 2030”, OECD Report, Paris, 2008

OECD (2006):” Handbook for the Montreal Protocol on Substances that Deplete the Ozone Layer”, 7th Edition, UNEP/Earthprint, 2006

Ofcansky, T.P./LaVerle, B. (1991): “Ethiopia: A Country Study. Washington: GPO for the Library of Congress”, available online at: URL: http://countrystudies.us/ethiopia/95.htm

Pandey, R. (2005):”Pollution Taxes for Industrial Water Pollution Control”, in Sahu N. C./Choudhury A. K. (2005):” Dimensions of Environmental and Ecological Economics”, Orient Blackswan, 2005

Passerini, K. (2007):”Evaluating Learning Management Systems”, in Esnault, L. (2007):“Web-Based Education and Pedagogical Technologies: Solutions for Learning Applications”, Idea Group, 2007 pp. 159 - 182

Picot, A./Reichwald, R./Wigand, R. T. (2008): “Information, Organization and Management”, Springer, Berlin/Heidelberg, 2008

Population Information Program (1998): “Water Availability and Use”, in Population Reports Volume XXVI, Number 1, available online at: http://www.infoforhealth.org/pr/m14/m14chap2.shtml [cited on 17th of July 2009]

Quiggin, J. (1988): “Private and Common Property Rights in the Economics of the Environment”, Journal of Economic Issues, 22(4)

Rangel, C. (1986):” Third world ideology and Western reality: manufacturing political myth”, Transaction Publishers, 1986

Ricardo, D. (1821):” On the Principles of Political Economy and Taxation” John Murray, London, 3rd edition, 1821

Samuelson, P.A. (1954): "The Pure Theory of Public Expenditure", *Review of Economics and Statistics* 36 (4): pp. 387–389

Schärer, B. (1999): "Tradable emission permits in German clean air policy: considerations on the efficency of environmental policy instruments", in Sorrell, Steve and Skea, Jim (1999): Pollution for Sale: Emissions Trading and Joint Implementation, Cheltenham: Edward Elgar

Schreiner, P. (1999): "Obstacles to the Implementation of Tradable Permits: The Case of Norway", in OECD (1999): Implementing Domestic Tradable Permits for Environmental Protection, Paris: OECD Publications

Skea, J. (1999): "Flexibility, emissions trading and the Kyoto protocol", in Sorrell, S./Skea, J. (1999): Pollution for Sale: Emissions Trading and Joint Implementation, Cheltenham: Edward Elgar

Stern, J. (1997):"What makes an independent regulator independent?",in: Business Strategy Review, 1997, Summer, 67–75.

Stern, J./ Holder, S. (1999):"Regulatory governance: criteria for assessing the performance of regulatory systems: An application to infrastructure industries in the developing countries of Asia", in Utilities Policy, Volume 8, Issue 1, March 1999, Pages 33-50

Stigler, G. J. (1971):"The Theory of Economic Regulation", in: The Bell Journal of Economics and Management Science, Vol. 2, No. 1 (Spring, 1971), pp. 3-21

Tietenberg, T. (1985): "Emissions Trading: an exercise in reforming pollution policy", Washington: Resources of the Future

United Nations (2008):" Promotion and Protection of all Human Rights, civil, political, economic, social and cultural Rights, including the Right to Development", General Assembly, GE.08-11903 (E) 200308, 2008

Varian, H. R. (1999):"Intermediate Microeconomics. A Modern Approach", 5th edn, W. W. Norton & Company, 1999

Viscusi, W./Vernon, J./Harrington, J (2000):" Economics of Regulation and Antitrust", MIT Press, Cambridge, 2000

Watergap (2003): "Global modelling of water resources, water use and water quality", tool by the Institute of Physical Geography, University of Frankfurt, available online at: http://www.geo.uni-frankfurt.de/ipg/ag/dl/forschung/WaterGAP/index.html [cited on 17th of July 2009]

Whetten, D.A. (1989): What Constitutes a Theoretical Contribution?, The Academy of Management Review, 14 (4): pp. 490-495

WHO/UNICEF (2005): "WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation - Water for life : making it happen". WHO Library, Geneva, 2005

Wild Farm Alliance (2003): "Water: Life Blood of the Landscape", Wild Farm Alliance Briefing Papers, 2003

World Bank (2008): "WDI, GDF & ADI Online Databases", available online at: http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentM DK:20398986~menuPK:64133163~pagePK:64133150~piPK:64133175~theSiteP K:239419,00.html, [cited on 17th of July 2009]

Word Water Council (2004): "E-Conference Synthesis: Virtual Water Trade - Conscious Choices", edited by the World Water Council, 2004

Wunderlich, J.-U. (2007):"Regionalism, globalisation and international order: Europe and Southeast Asia", Ashgate Publishing, 2007

Zhou, Y./Tol, R. S. J. (2004):"Evaluating the costs of desalination and water transport", in Water Resour. Res. 41 (3) (2005), p. W03003

Zygmunt, J. (2007): "Hidden Waters", report on behalf of waterwise, London, 2007