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3.2.11 Potential impacts of water scarcity on the world economy

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SUMMARY: *Water is an input that is needed directly or indirectly for the production of many goods and services. Naturally, agriculture is the largest user of water, even more so in developing countries. Due to climatic conditions, economic growth and the importance of agricultural production, water shortages will especially restrain economic development in South-east Asia, Middle East and North Africa. Already today many countries use basically all available water resources. Hence, virtual water trade via trade in goods with different water intensities in production, is growing and will play an increasingly important role. Besides the available quantity of water, the quality of the water or, in other words, water pollution caused by industry and agriculture is a major problem in both developed and developing countries.*

Water affects the economy of a country in many respects. Rivers and streams are used for transportation, acid rain leads to forest damages and health problems caused by water pollution not only reduce the quality of life but also entail economic costs (just to mention a few examples). From an economic perspective, water is an input that is needed directly or indirectly for the production of most goods and services. Water is needed for irrigation in agriculture, serves as a coolant in power stations and is used for cleaning purposes in the chemical industry. The often minor monetary value of water reflects only insufficiently the importance of this most relevant natural resource also for the world economy. This paper will start with a short overview on the economic role of water, the demand for water and its supply in different world regions. This information can then be used to deduce the economic effects of increasing water scarcity on a global level – caused both by an increasing demand for water and by climate change. Furthermore, distorted water prices and trade in virtual water will be discussed.

The economic use of water in the different world regions

Analysing the use of freshwater one has to distinguish between water consumption and water withdrawal. The consumption of freshwater only comprises the water taken from reservoirs, lakes, rivers or the groundwater that evaporates and is not immediately available for further human uses. However, the water withdrawn that does not evaporate is returned into the water bodies and can be used again. Here, it is the quality of the returned water that matters. The characteristics of freshwater use – water withdrawal, water consumption and the adverse effects on water quality – depend on the economic activity or sector. Available data usually distinguish between water use in agriculture, and industry and municipal water use. Sometimes, in addition, the loss in water reservoirs is included.

Naturally, water plays the most important role in agriculture, which is at the same time the largest user of freshwater. Already for millennia water is used for the irrigation of land. The current level of water use for irrigation results from the dramatic expansion in irrigated land and the development of systematic irrigation systems for large areas in the 20th century. At present, about 15% of all cultivated lands are being irrigated (UNEP 2000) and a major part of the extracted freshwater (ca. 70%) is also consumed in the process of this irrigation. In the year 2000, agriculture was responsible for around two thirds of global freshwater use and for over 80% of global freshwater consumption (SHIKLOMANOV & RODDA 2003).

Water in industry is used for cooling, transportation and washing, as a solvent and can also directly enter the final product. The principal users of freshwater in industry are thermal and atomic power stations that need large amounts of cooling water. In addition, the chemical industry, ferrous and non-ferrous metallurgy, the wood, pulp and paper industry, the textile industry as well as mechanical engineering use considerable freshwater. The characteristics of industrial water use depend to a large extent on the water supply system in use. The two most common systems are inflow water supply systems and circulating systems. With the inflow water system the water extracted from the source is discharged, after use – treated or not – back into the same or another water body. A circulating system implies that the water is cooled, treated, and returned back to the water supply system. Thus, the necessary freshwater in circulating systems is usually an insignificant fraction of actual water intake but varies strongly between different economic branches. While in power stations only 0.5–3% of the extracted water evaporates, the evaporation rate reaches 5–20% in most industry branches and can be as high as 40%. World-wide, the industry was responsible for a little more then 10% of water consumption in the year 2000, but for around 20% of water withdrawal. 57–69% of the extracted water was used for power stations, 30–40% for industrial purposes and 0.5–

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3% for heat generation (UNEP 2000, Shiklomanov & Rodda 2003).

Due to the large share of water withdrawn by industry that does not evaporate, it is the quality of the returned water that plays the most important role. The development of industrial water withdrawal is one of the main causes of water pollution in the world. While the use of water for cooling purposes only has minor effects on the water quality, polluted water from e.g. the paper production causes environmental and health problems or requires expensive counter measures. Each year industry accumulates 300–500 million tons of heavy metals, solvents, toxic sludge and other waste products. Industry sectors based on organic resources are responsible for most of the organic water pollution. The food processing industry is responsible for 40–54% of organic water pollution alone, followed by the paper industry (10–23%), the textile industry (7–15%), the metal industry (7–10%) and the chemical industry (7–8%) (UNESCO 2003). While the waste products are at least partially disposed adequately in industrial countries, in developing countries more than two thirds of industrial waste products are disposed without treatment.

It is expected that water withdrawal and evaporation will rise futher, especially in agriculture. According to current estimates and compared to 2000, both will increase by ca. 30% until 2030. *Fig. 3.2.11-1* shows the development of global water withdrawal in different sectors and regions.

Asia, especially South-east Asia, where irrigation systems are most prevalent, is the region withdrawing by far most of the freshwater. In this region water demand is also projected to experience the second largest growth. North America and Europe are the second largest withdrawers of water. Data for the loss through evaporation are only available in aggregated form. As a tendency, the richer a region, and the further north its geographical location, the smaller the loss by evaporation. While in Europe and the USA 35–40% of withdrawn water evaporates, it is around 50% in South America, about 60% in Asia, Oceania and over 70% in Africa (Shiklomanov & Rodda 2003).

The pattern of water use varies strongly between regions as well. As a tendency, in poorer countries a major share of the water is used for agriculture while in developed countries industry is a comparable or the largest user of water. *Table 3.2.11-1* shows the relative shares of water withdrawal in the different world regions and income groups of countries.

Water scarcity

To assess whether water impedes economic development, it is necessary to determine where it is scarce and not sufficient to meet the demand that is increasing with population and economic growth and potentially climate change. To measure water scarcity, Shiklomanov & Rodda 2003 compare water use with renewable water resources of surface waters[1]. On a global level, water withdrawal is not very high, in total amounting to only 8.4% of global water resources in 1995 (s. Chart in blurb). By 2025 this figure is expected to increase to 12.2%. However, water resources are distributed very unevenly around the globe, so that water supply varies considerably between different world regions. While even in 2025 only 1–2% of the water resources will be used in South America and Oceania, water withdrawal comprises 15–17% of water resources in Europe and is projected to rise to over 20%. In South- and Central Europe the use rate is even 24–30%. The largest variation can be observed in Africa and Asia. In North Africa water resources are already almost entirely withdrawn (water withdrawal is 95% of water resources). In 2025 large water inflows from other regions have to meet the demand of 130% of available water resources. In the remaining African regions water use even in 2025 does not reach 10%

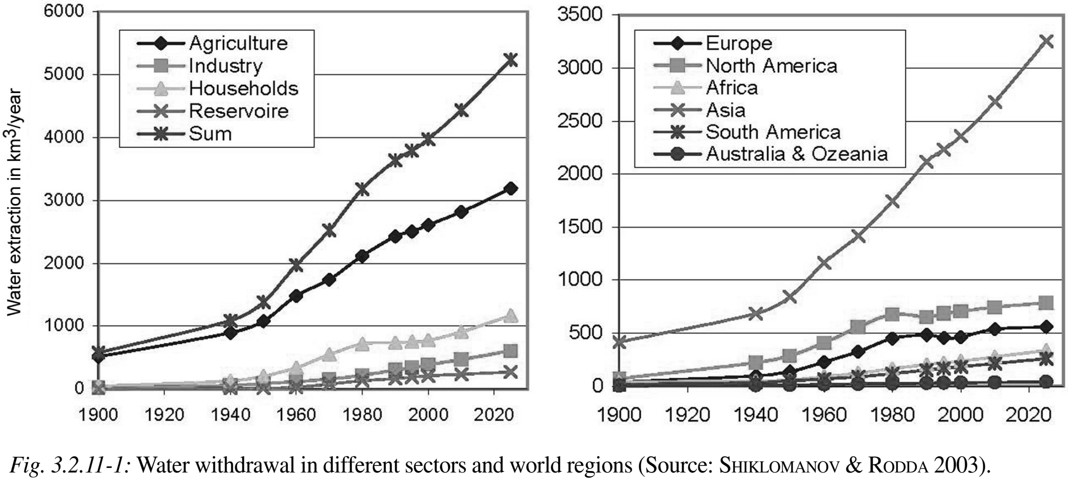

Fig. 3.2.11-1: Water withdrawal in different sectors and world regions (Source: Shiklomanov & Rodda 2003).

and in Central Africa only a negligible share of water resources is used. In West-, Middle- and South Asia 40–80% of water resources where used in 1995. In 2025 the share is expected to rise to 60–80%. However, water rich South-east Asia has only a single-digit use rate. In some countries, nevertheless, water resources are entirely used.

Future water availability mainly depends on two factors: the economic and social development of a country or region and the regional climatic conditions (see next section). Against this background, SHIKLOMANOV & RODDA (2003) examine the historic and future development of a different measure that captures water availability. This measure is the amount of water resources per head of water consumption. They come to the conclusion that water availability only slowly decreases in industrial countries while it is decreasing rapidly in developing countries. One result is also that in developing countries the decrease is slightly higher in arid climate zones compared to humid climate zones.

The impacts of climate change

All estimates for future water use and water scarcity that we have presented so far were based on the assumption that the climatic conditions remain in the next few years almost unchanged. This may be a very rough approximation in the short and medium term since climatic conditions react only slowly and with a time lag to increased greenhouse gases concentrations in the atmosphere. In the longer term climate change will affect precipitation and thus available water resources as well as water demand. Predictions in this respect are extremely difficult though. Currently there is only a limited and incomplete understanding of the impacts of a global increase in mean temperature on precipitation and in turn of the effect of changing precipitation on water resources. For this reason, projections of different models differ considerably and sometimes even contradict each other. As a tendency the model results show that arid regions will become even more arid and humid regions even more humid. In addition, extreme events are likely to occur more frequently. Especially for arid regions, the overall effects of climate change can be dramatic. According to the calculations of American scientists an increase of global mean temperature by 2 °C leading to a 10-percent reduction of precipitation for example decreases water resources in arid regions by the factor 1.5–2 (SHIKLOMANOV & RODDA 2003).

Higher temperature also increases the demand for water. Nevertheless, it is also possible that water availability increases in certain regions. A study by DEKE et al. (2001) for example analysing the impacts of climate change on agricultural production, shows considerable differences across scenarios. While agricultural production is expected to decrease in a pessimistic scenario in all world regions except North America, Europe and Oceania by 1% (North Africa and Middle East) up to 8.4% (India), in an optimistic scenario the signs switch and India for example gains 11.6% in agricultural output. Again, the study shows that the strength and variability of the effects is most strong in South-east Asia and Africa.

The monetary value of water

Usually, the importance of a resource or any other input is determined by its price. In the case of water though, its monetary value is almost negligible. Traditionally, water is viewed as a free, unlimited resource that can be used at no charge. Thus, water users had at best to pay a small amount, that could only cover a minor part of withdrawal, distributions, cleaning, and disposal costs. In large part this is still the case. Water prices are in addition often regulated and thus distorted and do not reflect market values. Existing water prices differ across sectors and countries. The average price for one cubic metre of water (including charges and taxes) varies for a private household in industrial countries between 0.30 and 3.20 US $ (OECD 1999, UNESCO 2003). The water prices for industry are mostly even smaller (0.3 to 1.8 US $/m³). In many countries the charge for water for agricultural purposes is less then 1 Cent per cubic metre and at maximum reaches 1.5 US $/m³. For developing countries there are no figures available for agriculture and industry. Often, water has only be paid when taken from the public (potable) water provision system. Extraction from groundwater or streams and lakes is free of charge. The minor monetary value of water is shown e.g. by the gross value added[2] of the sector »water and services of water distribution« in Germany. This sector is only responsible for 0.3% of the gross domestic product[3] (GDP) of Germany. Even if

Table 3.2.11-1: Water Withdrawal in 2000 (FAO 2003).

Share in %	*Agri-culture*	*Industry*	*House-holds*
World	70	21	10
Low Income	87	6	7
Middle Income	70	20	10
Low & middle Income	78	13	8
East-Asia & Pacific	68	26	7
Central Asia & Eastern Europe	59	31	10
Latin America & Caribbean	71	10	19
Middle East & North Africa	88	5	7
South Asia	89	5	6
Sub-Saharan Africa	83	5	11
High Income	41	44	15
European Union	34	51	15
united States	41	46	13

Table 3.2.11-2: Indicators for the economic role of water.

	BIP-share of VA in %		***Water use in m^3 per 1,000 USD***		
	Agriculture	***Industry***	***GDP***	***VA Agriculture***	***VA Industry***
World	4	27	122	2,317	93
Low Income	19	24	1,044	3,182	279
Middle Income	10	35	314	2,268	189
Low & middle Income	11	32	471	3,182	203
East-Asia & Pacific	11	44	380	2,238	221
Central Asia & Eastern Europe	9	30	420	2,760	450
Latin America & Caribbean	6	36	130	1,615	52
Middle East & North Africa	15	34	619	3,544	102
South Asia	24	40	1,399	5,223	187
Sub-Saharan Africa	9	16	130	1,169	45
High Income	2	26	36	884	58
European Union	2	26	28	491	54
United States	2	25	49	1,338	98

adding water disposal, the share only increases marginally and remains well below one percent.

The distortion of water prices leads to an inefficient use of the resource water. In other words, in industry and agriculture the same output of goods and services could be produced with less water and in addition water is not used where it leads to the highest returns. Two goals in the context of the Rio-process are thus to establish prices for water services that reflect the costs of their provision and to improve the efficiency of water use especially in agriculture.

Indicators for the economic role of water

To assess the economic importance of the resource water despite the distorted prices, other indicators have to be used. As agriculture is the largest user of water, especially those countries are affected economically by water scarcity in which the agricultural sector is of major importance and where at the same time the climatic conditions require a high degree of irrigation. One general indicator for the economic importance of water is the water intensity of different sectors or the entire economy. The amount of water that is directly or indirectly used in the production of a good or service is also denoted as virtual water. *Table 3.2.11-2* shows the use of water in cubic metre per thousand US$ value added (VA) in agriculture, in the industry sector and per unit gross domestic product, as well as the share of value added of agriculture and industry relative to the GDP

The data clearly show that agriculture is an important economic sector especially in South-east Asia and Africa and furthermore that mainly in South Asia but also in the Middle East and North Africa the largest amount of water is needed in agriculture per dollar value added. These two regions thus need the highest amount of water to produce one dollar GDP. South Asia clearly stands out and is at the same time the region in which the highest increase of water demand in agriculture is projected. The smallest economic impact can be expected in temperate Europe with small share of agriculture in GDP and small water use in agriculture.

Water and world trade

Water is also related to international trade. While water is hardly traded directly, it is traded indirectly through trade in more or less water intensive goods. For regions, where water is scarce and expensive, it is responsible for the import of water intensive goods and for exports of goods with low water content. In this sense there is trade in the water used in the process of the product. This is called virtual water. In the past 40 years international trade in virtual water has continuously increased. Today, approximately 1,000 km^3 of virtual water are traded internationally each year. This is ca. 15% of world-wide water use, including the use of rainwater in agriculture. A major share of virtual water trade takes place through trade in agricultural products. On global levels, figures are available for the production of crops and livestock including

Table 3.2.11-3: Trade in virtual water (gross imports – gross exports).

Period 1995–1999 in km^3/year	***Crops***	***Livestock products***	***Sum***
Central- & South Asia	167	47	214
Western Europe	76	6	82
North Africa	44	5	50
Middle East	30	13	43
Central & South Africa	6	2	9
Former Soviet Union & E-Europe	-10	9	-1
South-east Asia	-27	14	-23
Central- & South America	-52	15	-37
Oceania -28	-41	-69	
North America	-206	-42	-248

Table 3.2.11-4: The economic importance of water in different world regions.

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
East Asia & Pacific	XX	XX		X	X		XX
Central Asia & Eastern Europe		XX	X	X		X	
Latin America & Caribbean	X	X			X		X
Middle East & North Africa	X	XX	XX	X	XX	X	X
South Asia	X	XXX	X	XX	XX	X	XX
Sub-Saharan Africa		X		X	XX	X	X
North America							
Europe						X	
Pacific OECD							

(1) Annual economic growth until 2025 XX > 6%; X> 4%
(2) Water use in km^3 per Million. USD GDP XXX > 1000; XX > 300; X >100
(3) Share of water withdrawal rel. to water resources in 2025 XX > 80% X> 60%
(4) GDP-share of value added of agriculture XX>20%, X>9%
(5) Share of agricultural water use XX > 80%; X > 65%
(6) Importer of virtual water
(7) Effects of climate change on water use and water resources: XX very large; X large

associated products (CHAPAGIAN & HOEKSTRA 2003). Between 1995 and 1999, on average almost 20% of total water withdrawal in these sectors was exported in the form of virtual water. The five largest net exporters of virtual water are the USA, Australia, Canada, Argentina and Thailand. The five largest net importers are Japan, Sri Lanka, Italia, South Korea and the Netherlands. Regionally central and South Asia and following with some distance Europe as well as the Middle East and North Africa are the largest net water importers, while North America and to a smaller degree also South America and Oceania are the main net exporters.

In general, trade in virtual water is seen as a chance to circumvent regional water scarcity. As can be seen in *Table 3.2.11-3*, this is for agricultural products already partly the case. Except for Westerns Europe the largest net importers are also the regions with the most severe water scarcity. At the same time one can observe that in the course of globalisation water intensive industrial production is relocated to developing countries adding to water scarcity in these regions. South-east Asia for example is an exporter of virtual water, which is one reason why water scarcity will increase.

Conclusions

Since water is increasingly not available in sufficient quantity and quality, it is evident that this most important natural resource has a major impact on the growth of the global economy. In the future, water scarcity will be a problem in many developing countries. Especially the dynamic Asian regions with high economic growth, where water-intensive agriculture is responsible for a large share of total production, can be negatively affected in their economic development. For this reason, trade in virtual water will become increasingly important. At the same time, water prices will need to reflect the scarcity of this resource and the costs for their provision, in order to provide incentives for an efficient use. In this context it is also necessary to avoid water contamination, that constitutes a problem both in developing and industrial countries. *Table 3.2.11-4* summarises again the different indicators that can be used to derive the economic importance of water. The more X a region displays, the larger the economic importance of water♦

[1] To be precise SHIKLOMANOV & RODDA (2003) compare the total water withdrawal and the values of local water resources summed up with half the inflow from outside.

[2] Value added refers to economic value generated in different economic sectors. It is determined by the difference between the value of produced goods and services and the value of the intermediate inputs (e.g. material inputs) used in the economic sectors.

[3] The gross domestic product (GDP) is the value of economic production of an entire economy in one period. It corresponds to the sum of value added of all sectors.