THE IMPACT OF TRADE LIBERALISATION ON WATER USE: A COMPUTABLE GENERAL EQUILIBRIUM ANALYSIS

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Abstract

We used that GTAP-W model – GTAP5 with water resources added – to estimate the impact of hypothetical Doha-like liberalization of agricultural trade on water use. Three conclusions emerge. First, the change in regional water use is less than 10%, even if agricultural tariffs are reduced by 75%. Second, patterns are non-linear. Water use may go up for partial liberalization, and down for more complete liberalization. This is because different crops respond differently to tariff reductions, but also because trade and competition matter too. Third, trade liberalization tends to reduce water use in water scarce regions, and increase water use in water abundant regions, even though there no water markets in most countries.

Keywords: Computable General Equilibrium, Trade Liberalization, Water Policy, Water Scarcity

JEL Classification: D58, F13, Q17, Q25

1 Introduction

Trade liberalisation policies can be effective in stimulating economic growth and reducing the poverty gap by expanding market access opportunities. In particular, agricultural trade liberalization is beneficial as developing countries' comparative advantages are in agriculture. Therefore, the protectionist agricultural policies of OECD countries are often criticized. The Doha Development Agenda, launched in 2001, is meant to improve the situation, but is subject to seemingly interminable delays. However, trade liberalization is unambiguously welfare-improving only if property rights are well-defined (Chichilnisky, 1994). This is rarely the case for environmental resources, particularly in developing countries. In this paper, we focus on the impacts of agricultural trade liberalization on water use – where markets and property rights exist in only a few countries.

There is an extensive literature on the costs and benefits of trade liberalization in general and agricultural trade in particular using different approaches, data and trade liberalization scenarios. The most recent publications are related to the Doha Round. Depending on the scenario chosen, most studies find a positive economic effect of agricultural trade liberalization for developing countries (for some recent studies see e.g. Anderson *et al*., 2006, or Francois *et al*., 2005); Bureau *et al*. (2006) are less favourable.

Changes in tariffs or subsidies for agricultural goods involve regional as well as global adjustments in the production of the goods in question but have effects on other markets, such as factor input markets, as well. Water is one production factor in agriculture. In 2000 about 70% of all water was used for agriculture.[1] Although water is already scarce in many countries, attempts to economize on the consumption are little successful. For some developing countries the average irrigation efficiency is far below what is technically possible. The current level and structure of water charges mostly do not encourage farmers to use water more efficiently. In many regions, water use is even subsidized. This is partly because of desired food self-sufficiency (Ahmad, 2000). However, food demand could be met by importing more water-intensive food from water abundant countries, and producing and exporting commodities that are less water-intensive. The water embedded in commodities is also known as virtual water (Allan, 1992, 1993). So far, few studies provide estimates of global virtual water trade (see e.g. Chapagain and Hoekstra, 2004). Trade liberalization in agriculture would affect virtual water trade and might enhance or alleviate problems related to water use and water availability. To our knowledge, this has not been investigated in a multi-region, multi-sector general equilibrium model. The analysis of the present study is based on scenarios related to the Doha Agenda.

Most of the current analyses on agricultural trade liberalization ignore the impact on water use and problems related to water availability. Some authors have looked at the potential impact on sustainable development in developing countries including water as an environmental service. George and Kirkpatrick (2004) state in their qualitative analysis that further trade liberalisation would lead to improved overall availability of water through increased efficiency in all developing countries.[2] Their study does not distinguish between developing countries nor is a quantitative assessment provided. Other studies related to water issues investigate the implications of the GATS negotiations on service trade liberalisation on water management and the ability of governments to regulate water services (see e.g. Watson, 2004 or Kirkpatrick and Parker, 2005)

Our analysis is based on countries' total renewable water resources and differences in water productivity. Growing wheat in North Africa requires more water than growing it in Germany. Also, different crop types have different crop water requirements; and regions grow different crop varieties. For example, the production of a ton of rice is more water intensive

[1] Number is taken from AQUASTAT.
[2] They mention that regulatory and subsidy frameworks are critical.

than the production of a ton of wheat. In this paper, we do not look at a reallocation of water, but we do look at a reallocation of water-intensive products. National and international markets of agricultural products would be affected. A complete understanding of a water pricing policy is therefore impossible without understanding the international markets for food and other agricultural products, such as textiles. We use the computable general equilibrium (CGE) model GTAP-W which allows for a rich set of economic feedbacks and for a complete assessment of the welfare implications.

The remainder of the paper is organized as follows: the next section 2 briefly reviews the literature on economic models of water use. Section 3 presents the model used and the data on water resources and water use. The basic model and the corresponding data can be purchased from the Global Trade and Analysis Project (http://www.gtap.agecon.purdue.edu/). The water data can be downloaded at: http://www.fnu.zmaw.de/GTAP-EF-W.5680.0.html. Section 4 lays down the three base simulation scenarios with no constraints on water availability. Section 5 concludes.

2 Economic models of water use

Economic models of water use have generally been applied to look at the direct effects of water policies, such as water pricing or quantity regulations, on the allocation of water resources. Indirect effects through economic change, initiated by e.g. trade liberalization, have not been the focus.

In order to obtain insights from alternative water policy scenarios on the allocation of water resources, partial and general equilibrium models have been used. While partial equilibrium analysis focus on the sector affected by a policy measure assuming that the rest of the economy is not affected, general equilibrium models consider other sectors or regions as well to determine the economy-wide effect; partial equilibrium models tend to have more detail. Most of the studies using either of the two approaches analyze pricing of irrigation water only (for an overview of this literature see Johannson *et al*., 2002). Rosegrant *et al*. (2002) use the IMPACT-Water model to estimate demand and supply of food and water to 2025. Fraiture *et al.* (2004) extend this to include virtual water trade, using cereals as an indicator. Their results suggest that the role of virtual water trade is modest. While the IMPACT-Water model covers a wide range of agricultural products and regions, other sectors are excluded; it is a partial equilibrium model.

Studies using general equilibrium approaches are generally based on data for a single country or region assuming no effects for the rest of the world of the implemented policy. Decaluwe *et al.* (1999) analyze the effect of water pricing policies on demand and supply of water in Morocco. Daio and Roe (2003) use an intertemporal CGE model for Morocco focusing on water and trade policies. Seung *et al*. (2000) use a dynamic CGE model to estimate the welfare gains of reallocating water from agriculture to recreational use for the Stillwater National Wildlife Refuge in Nevada. Letsoalo *et al.* (2007) study the effects of water charges on water use, economic growth, and the real income of rich and poor households in South Africa. For the Arkansas River Basin, Goodman (2000) shows that temporary water transfers are less costly than building new dams. Strzepek *et al.* (2006) estimate the economic benefits of the High Aswan Dam. Gómez *et al*. (2004) analyze the welfare gains by improved allocation of water rights for the Balearic Islands. Feng *et al*. (in press) is an interesting study for China using a two-region recursive dynamic general equilibrium approach based on the GREEN model (Lee *et al*., 1994) to assess the economic implications of the increased capacity of water supply through the Chinese South-to-North Water Transfer (SNWT) project.

Berrittella *et al.* (2007) are an exception. They use a *global* CGE model including water resources (GTAP-W) to analyze the economic impact of restricted water supply for water-short regions. They contrast a market solution, where water owners can capitalize their water rent, to a non-market solution, where supply restrictions imply productivity losses. They show that water supply constrains could improve allocative efficiency, as agricultural markets are heavily distorted. The welfare gain may more than offset the welfare losses due to the resource constraint. Berrittella *et al.* (2005) use the same model to investigate the economic implications of water pricing policies. They find that water taxes reduce water use, and lead to shifts in production, consumption and international trade patterns. Countries that do not levy water taxes are nonetheless affected by other countries' taxes. Like Feng *et al.* (in press), Berrittella *et al.* (2006) analyze the economic effects of the Chinese SNWT project. Their analysis, based on GTAP-W, offers less regional detail but focuses in particular on the international implications of the project. This paper extends the previous papers of Berrittella *et al*. by looking at the impact of trade liberalisation on water use. The studies described above focus at the direct link between changes in water policies and the allocation of water resources. Unlike those analyses, the present study is concerned with the indirect effect of economic change through trade liberalization and the allocation of water resources.

3 Modeling framework and data

As in all CGE models, the GTAP-W model makes use of the Walrasian perfect competition paradigm to simulate adjustment processes.[3] Industries are modeled through a representative firm, which maximizes profits in perfectly competitive markets. The production functions are specified via a series of nested CES functions (*Figure A1 in the Annex*). Domestic and foreign inputs are not perfect substitutes, according to the so-called "Armington assumption", which accounts for product heterogeneity.

A representative consumer in each region receives income, defined as the service value of national primary factors (natural resources, land, labour and capital). Capital and labour are perfectly mobile domestically, but immobile internationally. Land (imperfectly mobile) and natural resources are industry-specific. The national income is allocated between aggregate household consumption, public consumption and savings (*Figure A2 in the Annex*). The expenditure shares are generally fixed, which amounts to saying that the top level utility function has a Cobb-Douglas specification. Private consumption is split in a series of alternative composite Armington aggregates. The functional specification used at this level is the Constant Difference in Elasticities (CDE) form: a non-homothetic function, which is used to account for possible differences in income elasticities for the various consumption goods. A money metric measure of economic welfare, the equivalent variation, can be computed from the model output.

In our modeling framework, water is combined with the value-added-energy nest and the intermediate inputs as displayed in *Figure A1 (Annex)*. As in the original GTAP model, there is no substitutability between intermediate inputs and value-added for the production function of tradeable goods and services. In the benchmark equilibrium, water supply is supposed to be unconstrained, so that water demand is lower than water supply, and the price for water is zero. Water is supplied to the agricultural industry, which includes primary crop production and livestock, and to the water distribution services sector, which delivers water to the rest of the economic sectors. Note that *distributed* water can have a price, even if primary water

[3] The model is a refinement of the GTAP model in the version modified by Burniaux and Truong (2002). The GTAP model is a standard CGE static model distributed with the GTAP database of the world economy (www.gtap.org). For detailed information see Hertel (1997) and the technical references and papers available on the GTAP website.

resources are in excess supply. Furthermore, water is mobile between the different agricultural sectors. However, water is immobile between agriculture and the water distribution services sector, because the water treatment and distribution is very different between agricultural and other uses.

The key parameter for the determination of regional water use is the water intensity coefficient. This is defined as the amount of water necessary for a sector to produce one unit of commodity. This refers to water directly used in the production process, not to the water indirectly needed to produce other input factors. To estimate water intensity coefficients, we first calculated total water use by commodity and country for the year 1997. For the agricultural sector the FAOSTAT database provided information on production of primary crops and livestock. This includes detailed information on different crop types and animal categories. Information on water requirements for crop growth and animal feeding was taken from Chapagain and Hoekstra (2004). This information is provided as an average over the period from 1997 to 2001. The CGE is calibrated for 1997. The water requirement includes both the use of blue water (ground and surface water) as well as green water (moisture stored in soil strata). For crops it is defined as sum of water needed for evapotranspiration, from planting to harvest, and depends on crop type and region. This procedure assumes that water is not short and no water is lost by irrigation inefficiencies. For animals, the virtual water content is mainly the sum of water needed for feeding and drinking. The water intensity parameter for the water distribution sector is based on the country’s industrial and domestic water use data provided by AQUASTAT. This information is based on data for 2000. By making use of this data we assume that domestic and industrial water uses in 2000 are the same as in 1997.

Finally, we make the link between output levels and water demand sensitive to water prices. In other words, we assume that more expensive water brings about rationalization in usage and substitution with other factors. The opposite happens if more water would be available. The actual capability of reducing the relative intensity of water demand is industry-specific, and captured by a price elasticity (*Table A3 in the Annex*), or rather the production cost elasticity to water demand. Note that the elasticities are little more than informed guesses, derived from Rosegrant *et al.* (2002).

The mechanism through which the demand for water reacts to trade liberalization is the following: if the import tax on water intensive agricultural products in one region decreases, the demand for water in that region decreases as well and increases in other regions. As the import of water intensive products from abroad has become less expensive the region substitutes imports with domestic inputs for production. On the contrary, if c.p. the import tax for products not using water in their production decreases, the demand for water in water intensive sectors increases.

4 Results

Design of model experiments

As the Doha negotiations are still ongoing, the modalities of the possible agreement are uncertain. It is clear that the parties involved have very different interests. Agricultural exporters aim for open foreign markets and reductions in distorting subsidies elsewhere. Industrial exporters in emerging economies want to remain protected. Countries with comparative advantages in services wish the GATS negotiations would be successful in reducing national regulatory in services. Therefore, any analysis investigating scenarios of trade liberalisation have to take all three aspects into account. However, as our study focuses on trade liberalisation in agriculture, we account for liberalisation in services and non-agricultural sectors, but vary the levels of liberalisation for the agricultural sectors only. The cut in tariffs for sensitive products in the service sector is 25% while for the other non-agricultural sectors a cut of 36% is implemented.

In scenario 1, a 25% tariff reduction is chosen for all agricultural sectors. In addition, we assume zero export subsidies and a 50% reduction in domestic farm support. Scenarios 2 and 3 are variants of scenario 1: tariffs are reduced by 50% and 75% respectively.[4] This last scenario is the most ambitious one. In scenario 4 developed and developing countries are treated differently. For industrialised countries the tariff reduction is set to 75% while developing countries reduce tariffs by 50% only.

According to the negotiations so far, export subsidies will be phased out over a few years. Tariff reductions will also not be implemented at once but phased in. To account for this procedure, we designed our above described scenarios for the year 2010. As GTAP-W is calibrated to 1997 we had to derive a hypothetical dataset for 2010 before analysing the impact of trade liberalisation. The scenarios are calculated as deviations from the 2010 baseline. This entails forecasting values for some key economic variables including land and labour productivity, population, labour force and capital stock in order to identify a hypothetical general equilibrium state in the future. The data as well as the procedure applied is explained in detail in Appendix II.

Simulation results

Figure 1 shows the effect of the four trade liberalisation scenarios on water use. As the tariff reductions are differentiated between developed and developing countries, the figures are split accordingly.

Trade liberalisation would imply an increase in water use in Canada, Australia and New Zealand, and Eastern Europe; and a reduction in Western Europe, Japan and South Korea, and the former Soviet Union. The USA would see a decrease in water use for a partial liberalisation, but an increase for a more complete liberalisation; China would see an increase first, and then a decrease. Among the developing regions, the Middle East, South America, Southeast Asia and Sub-Saharan Africa would see an increase in water use; and Central America, South Asia, and North Africa a decrease. In all cases, changes in water use due to trade liberalisation are less than 10%.

The pattern of water use in the USA can be understood when one looks at production per crop. With modest liberalisation, rice production decreases in the USA, Japan and Western Europe. However, with more substantial liberalisation, rice production falls further in Japan and Western Europe – and the gap in demand is made up by extra production in the USA and Australia and New Zealand. Also for vegetables and cotton, the USA reduces production for modest liberalisation, but then regains its competitiveness as it makes up for deeper cuts in the production in the former Soviet Union and China with deeper trade liberalisation. The water use pattern in China is the result of increases in production in most crops, but decreases in vegetables, fruits, and cotton.

Figure 2 shows that trade liberalisation enhances the current pattern in virtual water trade, that is, regions that are currently substantial exporters of virtual water, use even more water; while regions that presently import virtual water, use even less domestic water. Tariffs restrain, but do not reverse the comparative advantages of regional agricultural production.

[4] A scenario with a complete removal of agricultural tariffs could not be solved. Recall that GTAP-W is a static computable general equilibrium model.

However, Figure 3 and 4 reveal there is no obvious relationship between the absolute water scarcity (in cubic metre per person per year) or in the implied value of water (in value added per year per cubic metre). This is as expected, because water is not a market good. The scarcity of water is not taken into consideration in decisions on agricultural production.

Trade liberalization would reduce water use in South Asia and North Africa, two regions that unsustainably use fossil ground water (cf. Berrittella et al., 2007). China and the USA are also depleting their fossil water resources, but water use goes up in some trade liberalization scenarios, and down in others. Water use decrease due to trade liberalization in water scare Japan and South Korea. The same is true for the water scarce Middle East, but the reduction in water use is largest for the most modest tariff reduction. Although trade liberalization reduce water stress for the world as a whole and for most regions, this is by happenstance rather than design.

5 Discussion and conclusion

In this paper, we estimate the effect of reductions in subsidies and import tariffs for agricultural production on water consumption, using a global static computable general equilibrium model with 16 regions and 17 sectors. We find that trade liberalization has a small effect (less than 10%) on water use. Water use for some crops and some regions goes up, and it goes down for other crops and regions. This can lead to mixed pattern in total water use for some regions. For example, a modest liberalization increases (decreases) water use in the USA (China), but the sign switches for more substantial trade liberalization. Although the changes in water use are unrelated to either physical notions of water scarcity (here, water resource per capita) or economic notions of water scarcity (here, value added per water use), it so happens that trade liberalization reduces water use in places where it is scarce, and increases water use in places where it is abundant.

A number of caveats apply to the above results. The model is static. A dynamic model may find larger effects of trade liberalization with further specialization through capital stock adjustments. Water is treated as a technology parameter, rather than an input factor. This implies that substitution away from water is limited – but note that water scarcity does not play a prominent role in this analysis. Water is treated as a homogenous good with regions, which increases substitutability. The limited disaggregation of crops and regions may hide larger shifts in agricultural production and water use due to trade liberalization. The importance of these factors will need to be tested with future version of the current model and with other models. Trade liberalization is the only policy considered. Future applications should consider liberalization along with the creation of water markets or the introduction of water charges.

These caveats notwithstanding, the current analysis shows that agricultural trade liberalization would have a small and largely beneficial effect on the use of water resources.

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References

Ahmad, M. (2000). Water pricing and markets in the Near East: policy issues and options, *Water Policy* **2** 229-242.

Allan, J.A. (1992). Fortunately there are substitutes for water otherwise our hydro-political futures would be impossible. In: Proceedings of the Conference on Priorities for Water Resources Allocation and Management: Natural Resources and Engineering Advisers Conference, Southampton, July 1992, pp. 13-26.

Allan, J.A. (1993). Overall perspectives on countries and regions. In: Rogers, P. and Lydon, P. (Eds.) Water in the Arab World: Perspectives and Prognoses, Cambridge, Massachusetts, pp. 65-100.

Anderson, K., Martin, W. and van der Mensbrugghe, D. (2006) Would Multilateral Trade Reform Benefit Sub-Saharan Africans? *Journal of African Economies* **15**, 626-670.

Berrittella, M., Hoekstra, A., Rehdanz, K., Roson, R. and Tol, R.S.J. (2007) The economic impact of restricted water supply: A computable general equilibrium analysis, *Water Research*, **42**, 1799-1813.

Berrittella, M., Rehdanz, K., Roson, R. and Tol, R.S.J. (2005) *The Economic Impact of Water Pricing: A Computable General Equilibrium Analysis*, Research unit Sustainability and Global Change **FNU-96,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg.

Berrittella, M., Rehdanz, K. and Tol, R.S.J. (2006) *The Economic Impact of the South-North Water Transfer Project in China: A Computable General Equilibrium Analysis*, Research unit Sustainability and Global Change **FNU-117,** Hamburg University and Centre for Marine and Atmospheric Science, Hamburg.

Bureau, J.-C., Jean, S. and Matthews, A. (2006) The Consequences of Agricultural Trade Liberalisation for Developing Countries: Distinguishing between Genuine Benefits and False Hopes. *World Trade Review* **5**, 225-249.

Chapagain, A.K. and Hoekstra, A.Y. (2004). Water Footprints of Nations, Value of Water Research Report Series No. 16, UNESCO-IHE Delft, The Netherlands.

Chichilnisky, G. (1994) North-South Trade and the Global Environment. *American Economic Review* **84** (4), 851-874.

Decaluwé, B., Patry, A. and Savard, L. (1999). When water is no longer heaven sent: Comparative pricing analysis in a AGE model, Working Paper 9908, CRÉFA 99-05, Départment d'économique, Université Laval.

Diao, X. and Roe, T. (2003). Can a water market avert the "double-whammy" of trade reform and lead to a "win-win" outcome? *Journal of Environmental Economics and Management **45*** 708-723.

Feng, S., Li, L.X., Duan, Z.G. and Zhang, J.L. (in press) Assessing the impacts of South-to-North Water Transfer Project with decision support systems. *Decision Support Systems*.

Fraiture, C. de, Cai, X., Amarasinghe, U., Rosegrant, M. & Molden, D. (2004). Does international cereal trade save water? The impact of virtual water trade on global water use. Comprehensive Assessment Research Report 4, Colombo, Sri Lanka.

Francois, J., van Meijl, H. and van Tongeren, F. (2005) Trade Liberalization in the Doha Development Round. *Economic Policy* (April), 349-391.

George, C. and Kirkpatrick, C. (2004) Trade and Development: Assessing the Impact of Trade Liberalisation on Sustainable Development. *Journal of World Trade* **38**, 441-469.

Gómez, C.M., Tirado, D. and Rey-Maquieira, J. (2004). Water exchange versus water work: Insights from a computable general equilibrium model for the Balearic Islands, *Water Resources Research* **42** W10502 10.1029/2004WR003235.

Goodman, D.J. (2000). More reservoir or transfer? A computable general equilibrium analysis of projected water shortages in the Arkansas River Basin, *Journal of Agricultural and Resource Economics* **25** (2) 698-713.

Johannson, R.C., Tsur, Y., Roe, T.L., Doukkali, R. and Dinar, A. (2002). Pricing irrigation water: A review of theory and practice, *Water Policy* **4** 173-199.

Kirkpatrick, C. and D. Parker (2005) Domestic Regulation and the WTO: The Case of Water Services in Developing Countries, *World Economy* **28**, 1491-1508.

Lee, H., Oliveira-Martins, J. and van der Mensbrugghe, D. (1994) The OECD GREEN Model: An updated overview, Working Paper No. 97, OECD, Paris.

Letsoalo, A., J. Blignaut, T. de Wet, M. de Wit, S. Hess, R.S.J. Tol and J. van Heerden (2007) Triple Dividends of Water Consumption Charges in South Africa. *Water Resources Research*, **43**, W05412.

Rosegrant, M.W., Cai, X. and Cline, S.A. (2002). World water and food to 2025: Dealing with scarcity. International Food Policy Research Institute, Washington.

Seung, C.K., Harris, T.R., Eglin, J.E. and Netusil, N.R. (2000). Impacts of water reallocation: A combined computable general equilibrium and recreation demand model approach, *The Annals of Regional Science* **34** 473-487.

Strzepek, K.M., G.W. Yohe, R.S.J. Tol and M. Rosegrant (2006), *The Value of the High Aswan Dam to the Egyptian Economy*, Research unit Sustainability and Global Change **FNU-111**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg.

Watson, C. (2004) Trade and Water – The Role of WTO and GATS: Opening the Water Sector to new Service Providers, WaterAid.

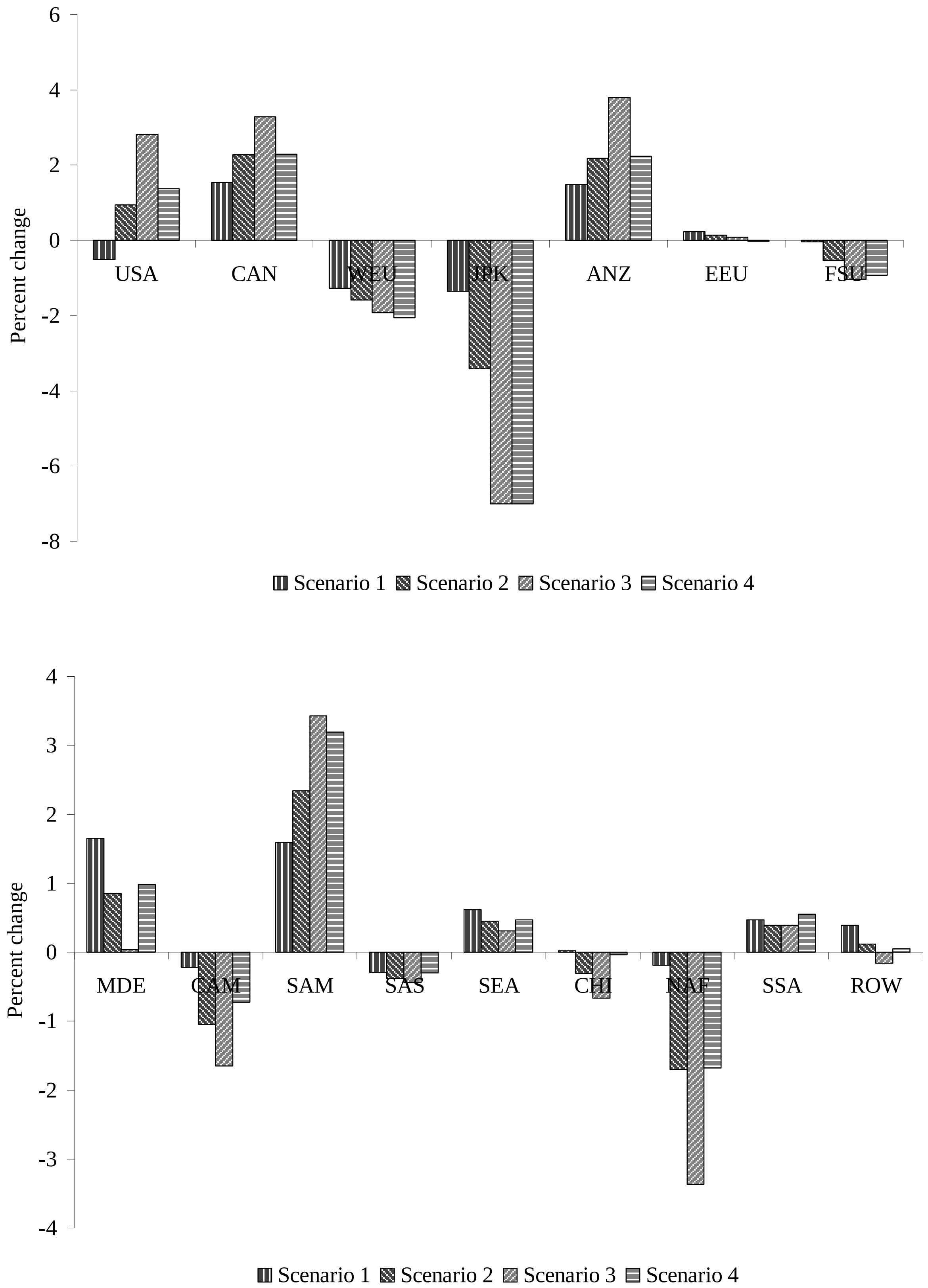


Figure 1. Changes in water use in the 4 alternative trade liberalization scenarios, for developed (top panel) and developing (bottom panel) economies.

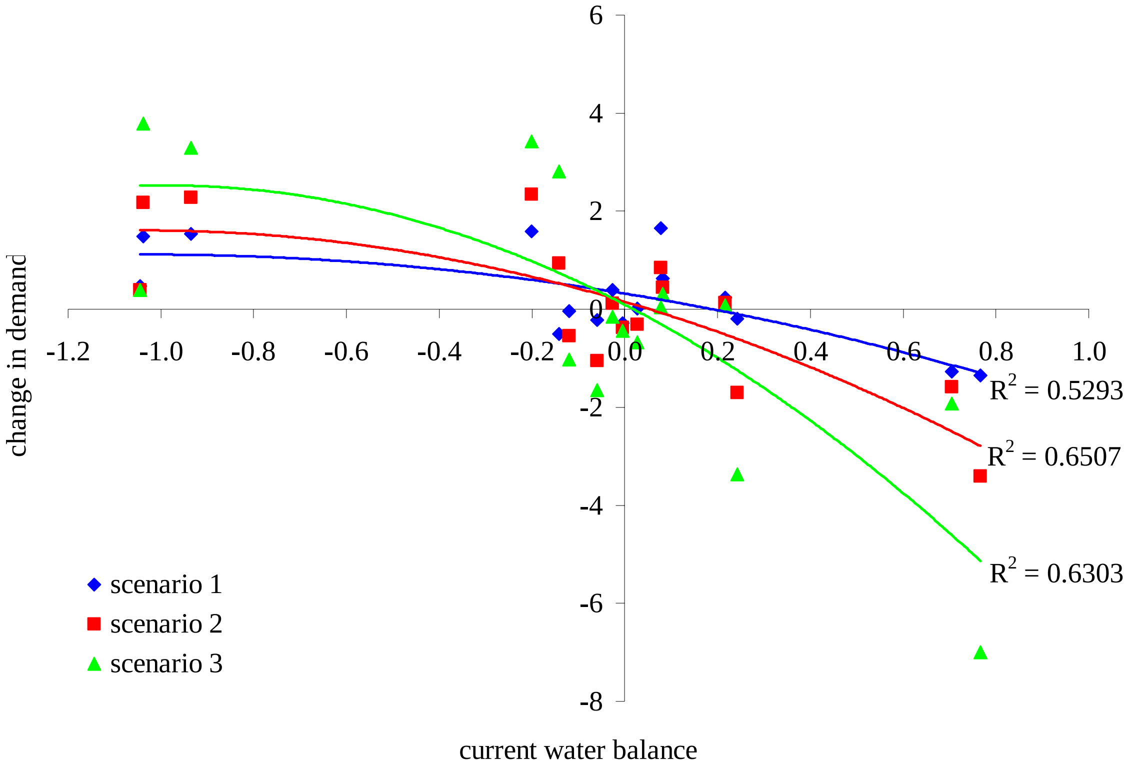


Figure 2. The change in water demand as a function of the water balance before trade liberalization. The current water balance is defined as virtual water import minus virtual water export over total water use; -1 means that all water is used for exports; +1 means that water imports double the water available in the region itself.

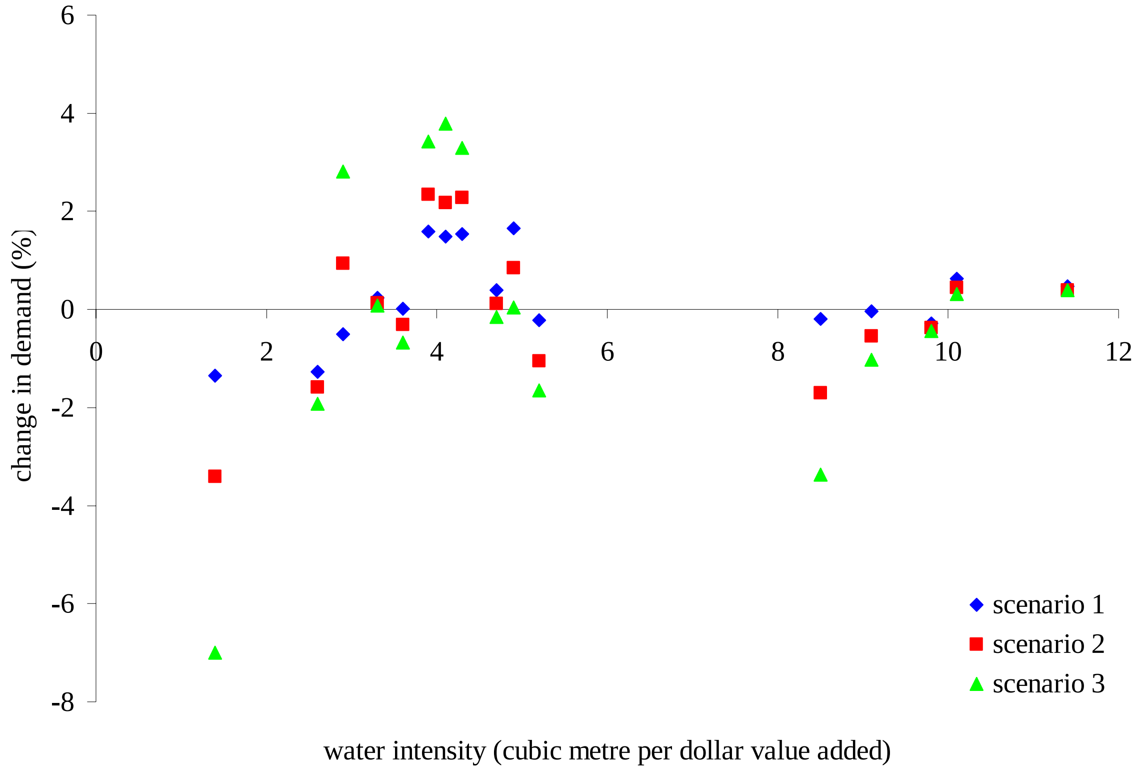


Figure 3. The change in water demand as a function of the water intensity before trade liberalization.

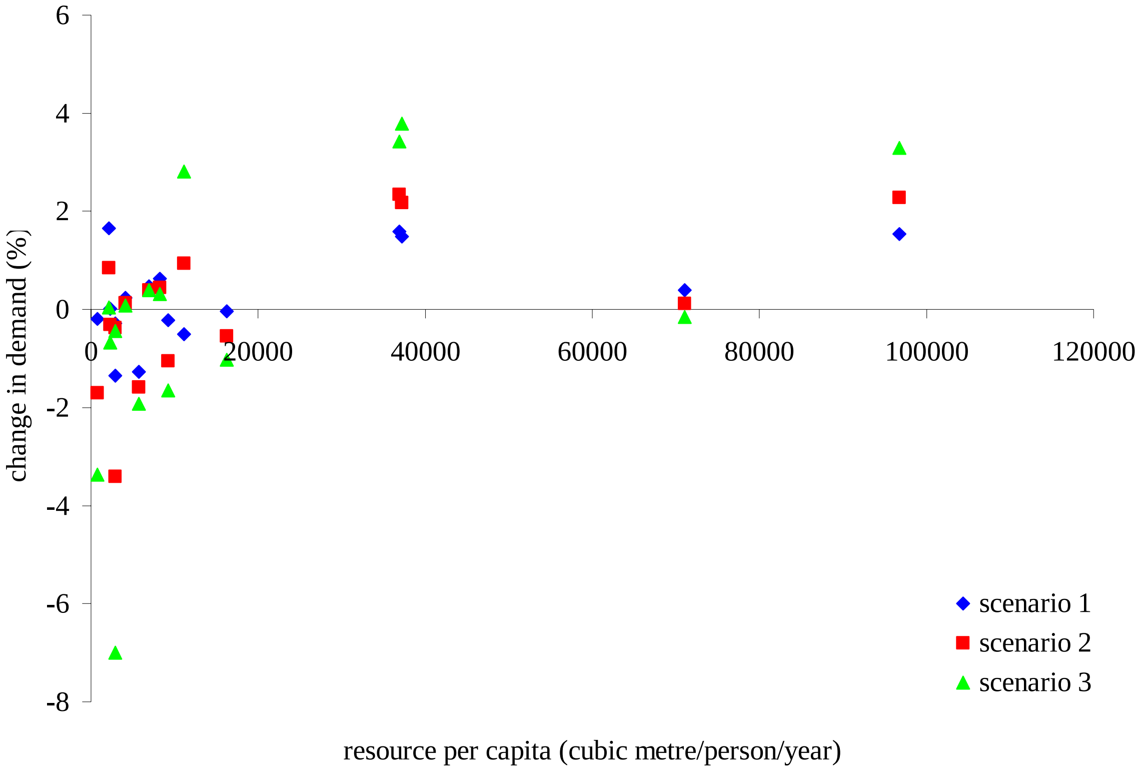


Figure 4. The change in water demand as a function of the renewable water resource per capita.

Table 1. Results for Scenario 1: a 25% reduction in agricultural tariffs.

	Water demand (%)	**Rice (%)**	**Wheat (%)**	**Other cereals (%)**	**Other crops (%)**
USA	-0.51	-11.42	0.19	-0.32	-2.24
CAN	1.54	15.97	4.15	-0.46	0.81
WEU	-1.27	-5.39	-1.49	-1.67	-3.02
JPK	-1.35	-0.78	-21.67	-6.88	-2.02
ANZ	1.48	8.62	-0.03	1.67	-0.43
EEU	0.23	-0.63	0.89	-0.42	0.16
FSU	-0.04	-0.50	0.68	-0.36	-0.66
MDE	1.65	0.05	1.91	0.85	1.41
CAM	-0.22	1.60	-2.76	-2.49	3.48
SAM	1.59	0.29	1.02	2.35	0.80
SAS	-0.29	0.10	-0.95	-0.64	-0.18
SEA	0.62	0.72	-0.07	-0.48	0.46
CHI	0.02	0.54	0.44	2.31	0.04
NAF	-0.19	3.04	-0.20	-0.44	0.33
SSA	0.47	-0.80	-2.41	0.36	1.49
ROW	0.39	-0.07	-2.34	-0.35	1.17

Table 2. Results for Scenario 2: a 50% reduction in agricultural tariffs.

	Water demand (%)	**Rice (%)**	**Wheat (%)**	**Other cereals (%)**	**Other crops (%)**
USA	0.94	-9.73	0.53	0.16	-0.39
CAN	2.28	16.23	7.82	-0.41	-0.38
WEU	-1.58	-14.17	-1.83	-1.92	-4.52
JPK	-3.41	-2.42	-42.31	-15.02	-4.67
ANZ	2.18	23.82	-0.85	3.84	-1.90
EEU	0.13	-0.87	1.13	-0.93	-0.33
FSU	-0.54	-0.51	0.70	-0.95	-1.67
MDE	0.85	0.06	2.48	-1.35	1.14
CAM	-1.05	0.72	2.37	-4.51	5.81
SAM	2.34	0.31	0.97	3.61	1.19
SAS	-0.38	0.16	-1.09	-0.91	-0.13
SEA	0.45	1.01	-2.46	-1.41	0.25
CHI	-0.31	1.16	0.45	4.70	-0.64
NAF	-1.70	2.82	-1.59	-2.41	0.11
SSA	0.39	-0.82	-4.11	-0.33	2.22
ROW	0.12	-0.10	-2.42	-1.17	1.24

Table 3. Results for Scenario 3: a 75% reduction in agricultural tariffs.

	Water demand (%)	**Rice (%)**	**Wheat (%)**	**Other cereals (%)**	**Other crops (%)**
USA	2.81	-4.61	0.73	0.39	2.25
CAN	3.29	16.89	12.24	-0.07	-1.60
WEU	-1.92	-23.38	-2.42	-2.10	-6.22
JPK	-7.00	-6.62	-60.86	-24.75	-7.94
ANZ	3.79	70.38	-2.31	7.38	-3.63
EEU	0.08	-1.09	1.53	-1.40	-0.87
FSU	-1.03	-0.53	0.72	-1.43	-2.69
MDE	0.04	0.09	3.22	-3.58	0.84
CAM	-1.65	-0.35	11.7	-6.66	9.00
SAM	3.43	0.35	1.04	5.18	1.74
SAS	-0.44	0.20	-1.22	-1.20	0.25
SEA	0.31	1.61	-4.91	-2.09	-0.13
CHI	-0.67	3.44	0.46	8.66	-1.70
NAF	-3.37	2.35	-3.06	-4.59	-0.12
SSA	0.39	-0.87	-5.99	-1.05	3.31
ROW	-0.16	-0.12	-2.53	-1.97	1.37

Table 4. Results for Scenario 4: a 75% reduction in agricultural tariffs in developed countries, and a 50% reduction in agricultural tariffs in developing countries.

	Water demand (%)	**Rice (%)**	**Wheat (%)**	**Other cereals (%)**	**Other crops (%)**
USA	1.38	-4.56	0.68	-0.05	0.48
CAN	2.29	16.97	10.13	-1.24	-1.70
WEU	-2.06	-23.37	-2.69	-2.19	-6.30
JPK	-7.00	-6.61	-61.00	-24.68	-7.98
ANZ	2.24	70.72	-1.82	3.43	-3.07
EEU	-0.02	-1.05	0.96	-1.47	-0.89
FSU	-0.92	-0.53	0.51	-1.28	-2.59
MDE	0.98	0.06	2.51	-0.90	1.03
CAM	-0.73	0.61	11.58	-5.92	8.95
SAM	3.19	0.24	0.85	5.44	1.51
SAS	-0.30	0.19	-1.10	-1.14	0.47
SEA	0.47	1.58	-2.36	-2.19	0.12
CHI	-0.04	3.25	0.31	9.61	-0.41
NAF	-1.68	3.43	-1.61	-2.42	0.24
SSA	0.55	-0.90	-4.19	-0.91	3.46
ROW	0.05	-0.14	-2.45	-1.44	1.16

Annex I

Table A1. Aggregations in GTAP-W

A. Regional Aggregation

Developed Regions

1. USA – United States

2. CAN – Canada

3. WEU – Western Europe

4. JPK – Japan and Korea

5. ANZ – Australia and New Zealand

6. EEU – Eastern Europe

7. FSU – Former Soviet Union

Developing Regions

8. MDE – Middle East

9. CAM – Central America

10. SAM – South America

11. SAS – South Asia

12. SEA – Southeast Asia

13. CHI – China

14. NAF – North Africa

15. SSA – Sub-Saharan Africa

16. ROW – Rest of the world

B. Endowments

1. Land

2. Labour

3. Capital

4. Natural Resource

C. Sectoral Aggregation

Agriculture

1. Rice – Rice

2. Wheat – Wheat

3. CerCrops – Other cereals and crops

4. VegFruits – Vegetable, Fruits

5. Animals – Animals

6. Forestry – Forestry

7. Fishing – Fishing

Non-agricultural sectors

8. Coal – Coal Mining

9. Oil – Oil

10. Gas – Natural Gas Extraction

11. Oil_Pcts – Refined Oil Products

12. Electricity – Electricity

13. Water – Water collection, purification and distribution services

14. En_Int_ind – Energy Intensive Industries

15. Oth_ind – Other industry and services

16. MServ – Market Services

17. NMServ – Non-Market Services

Table A2. Regional characteristics

	Population	GDP/cap	Renewable water resource[a]		Water use	Water intensity in agriculture[c]	Water intensity other[d]	Water imports	Water exports
	mln	$	10^9m^3 per year	M^3/person[b]	10^9m^3 per year	M^3/$	m^3/$	10^9m^3	10^9m^3
USA	276	28786	3069	11120	479	2.9	3.7	57	125
CAN	30	20572	2902	96733	46	4.3	5.2	8	51
WEU	388	24433	2227	5740	227	2.6	3.5	256	96
JPK	172	35603	500	2907	107	1.4	1.6	82	0
ANZ	22	21052	819	37227	26	4.1	1.2	3	30
CEE	121	2996	494	4083	60	3.3	13.6	19	6
FSU	291	1556	4730	16254	284	9.1	28.0	27	61
MDE	227	3150	483	2128	206	4.9	6.8	35	19
CAM	128	2938	1183	9242	101	5.2	13.6	25	31
LAM	332	4830	12246	36886	164	3.9	5.9	35	68
SAS	1289	416	3685	2859	918	9.8	47.5	21	25
SEA	638	4592	5266	8254	279	10.1	12.8	58	35
CHI	1274	790	2897	2274	630	3.6	38.5	33	16
NAF	135	1284	107	793	95	8.5	39.5	27	4
SSA	605	563	4175	6901	113	11.4	6.4	14	132
ROW	42	3338	2984	71048	75	4.7	2.7	6	8

[a] 2001 estimates taken from Aquastat.

[b] UN criterion for water resource scarcity degree: slightly scarce (1700-3000), middle scarce (1000-1700), severe scarcity (500-1000) and most severe scarcity (<500).

[c] Average water intensity covering crop/plant growth and animal production measured in water use/$ output. Numbers differ considerably between countries and sectors. Note that water use includes the use of different kind of sources; rain, soil moisture and irrigation water. However, farmers pay for irrigation water only.

[d] Note that in some countries only a low number of persons is connected to a distribution network. In others a number of self-supplied industries are not connected. However, both are included as users of the services the water distribution network provides. As a consequence, water use per $ of output is overstated in the above table.

Table A3. Water price elasticities

	Agricultural sectors	Water distribution services
1 USA	-0.14	-0.72
2 CAN	-0.08	-0.53
3 WEU	-0.04	-0.45
4 JPK	-0.06	-0.45
5 ANZ	-0.11	-0.67
6 EEU	-0.06	-0.44
7 FSU	-0.09	-0.67
8 MDE	-0.11	-0.77
9 CAM	-0.08	-0.53
10 SAM	-0.12	-0.80
11 SAS	-0.11	-0.75
12 SEA	-0.12	-0.80
13 CHI	-0.16	-0.80
14 NAF	-0.07	-0.60
15 SSA	-0.15	-0.80
16 ROW	-0.20	-0.85

Source: Our elaboration from Rosegrant et al.(2002).

Figure A1 – Nested tree structure for industrial production process

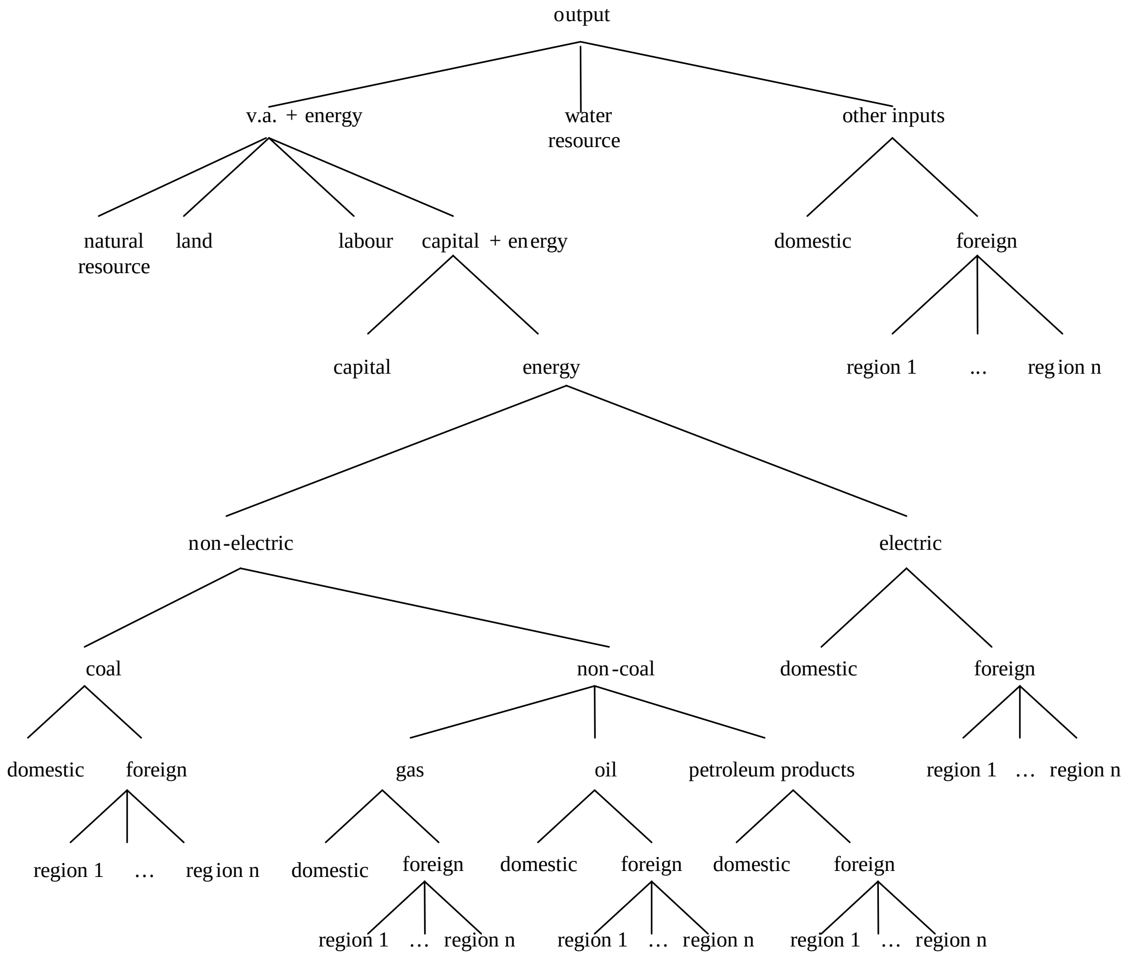
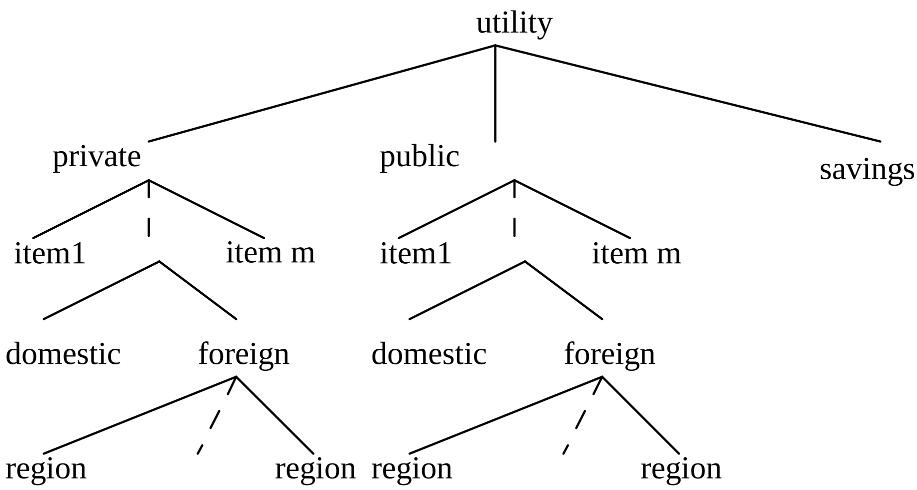


Figure A2 – Nested tree structure for final demand



<u>Annex II</u> Scenario for 2010

Population

Data on population projection was taken from the UN World Population Prospects (United Nations, 2004). This dataset covers demographic projections until 2050 for all countries. For most OECD countries changes in population are positive but much below world average. Negative changes are projected for Eastern Europe as well as the former Soviet Union. Highest positive changes are projected for Sub-Saharan Africa, South Asia and the Middle East.

Labour force

Information on changes in labour force was taken from ILO estimates and projections of the economically active population (5^{th} edition). Annual data is available for the period 1980-2020 on country level. Again, most OECD countries as well as for China changes are below average, negative changes are projected for Japan as well as for Eastern Europe. Positive changes are particularly pronounced for the Middle East, North Africa, South America and South Asia.

Capital stock

To derive information on the capital stock in 2010, data from the World Development Indicators (WDI, 2006) on gross fixed capital formation was taken until the most recent year available which is 2004. This information was used to increase the capital stock from 1997 (provided by the GTAP database) to 2004. For depreciation, a rate of 4 % was assumed. In the next step the information on the average change in capital stock per country between 1997 and 2004 was used to calculate the capital stock in 2010. Data was interpolated for countries where observations were missing for some years between 1997 and 2004. For a number of countries data was unavailable. For those, regional averages are based on values for countries within a region where data was available.

A marked increase in capital stock is projected for China. This is due to the substantial annual increases in gross investment of about 10 per cent in the period 1997 to 2004. Regions with increases below world average are Middle East and Africa.

Labour productivity

A single factor productivity measures such as labour productivity is measured by calculating the ratio of a volume measure of output to a volume measure of input use. Mainly gross output or value added are used as output measures. I used output in value added per employed person per sector.

Data on employment by sector was taken from the ILO Labour Force Survey. They provide annual information until 2005 per country based on the ISIC Rev.3 classification, sometimes only on the older and less detailed ISIC Rev.2 classification. As our sectoral aggregation is different from the ISIC classification I collected data for two sectors only, agricultural sector and all other sectors together. In our aggregation of the energy intensive sectors, for example, sectors are included that refer to different ISIC classifications (omn/mining of uranium etc. is ISIC3 C (mining and quarrying) while crp/manufacture of basic chemicals etc. is ISIC3 D (manufacturing)).

Data on value added by sector and country was available from the World Development Indicators (WDI, 2006) until 2004. I calculated the value added for two sectors, agriculture and industry plus services. In a next step the annual labour productivity growth per country for the two sectors was calculated until 2004.

The information on the average growth per country between 1997 and 2004 was used to calculate the change in productivity until 2010. Data was interpolated for countries where observations were missing for some years between 1997 and 2004. For a number of countries data was unavailable. For those, regional averages are based on values for countries within a region where data was available.

For the agricultural sector, changes in labour productivity are above average for all OECD countries and particularly pronounced for the USA. However, other regions like Eastern Europe, the former Soviet Union and China show high increases as well. With respect to all other sectors, changes are less pronounced for most regions, except for China, the former Soviet Union and South Asia. Japan is the only OECD region with less than world average growth rates.

Land productivity

To calculate the growth in land productivity data on agricultural production and area harvested was taken from FAO's most recent agricultural statistics. Country level data on individual crop types is available until 2004. This information was aggregated to our four different crop sectors rice, wheat, cereals and other crops, fruits and vegetables. As information on area used for animal husbandry was not available the average growth in land productivity calculated for the four crop sectors together was used as an approximation.

To calculate the change in agricultural land productivity until 2010, the average growth rate between 1997 and 2004 was used.

For wheat and other crops and cereals increases in land productivity are significant for Eastern Europe and the former Soviet Union. For vegetables and fruits Central America and South and South East Asia show pronounced increases.

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Röckmann, C., M.A. St.John, U.A. Schneider, F.W. Köster, F.W. and R.S.J. Tol (2006), *Testing the implications of a permanent or seasonal marine reserve on the population dynamics of Eastern Baltic cod under varying environmental conditions,* **FNU-63-revised** (*Fisheries Research*, **85**, 1-13)

Letsoalo, A., J. Blignaut, T. de Wet, M. de Wit, S. Hess, R.S.J. Tol and J. van Heerden (2005), *Triple Dividends of Water Consumption Charges in South Africa,* **FNU-62** (*Water Resources Research*, **43**, W05412)

Zandersen, M., Termansen, M., Jensen,F.S. (2005), *Benefit Transfer over Time of Ecosystem Values: the Case of Forest Recreation,* **FNU-61** (submitted)

Rehdanz, K., Jung, M., Tol, R.S.J. and Wetzel, P. (2005), *Ocean Carbon Sinks and International Climate Policy*, **FNU-60** (*Energy Policy*, **34**, 3516-3526)

Schwoon, M. (2005), *Simulating the Adoption of Fuel Cell Vehicles*, **FNU-59** (submitted)

Bigano, A., J.M. Hamilton and R.S.J. Tol (2005), *The Impact of Climate Change on Domestic and International Tourism: A Simulation Study,* **FNU-58** (submitted)

Bosello, F., R. Roson and R.S.J. Tol (2004), *Economy-wide estimates of the implications of climate change: Human health*, **FNU-57** (*Ecological Economics,* **58**, 579-591)

Hamilton, J.M. and M.A. Lau (2004) *The role of climate information in tourist destination choice decision-making,* **FNU-56** (forthcoming, Gössling, S. and C.M. Hall (eds.), Tourism and Global Environmental Change. London: Routledge)

Bigano, A., J.M. Hamilton and R.S.J. Tol (2004), *The impact of climate on holiday destination choice*, **FNU-55** (*Climatic Change,* **76** (3-4), 389-406)

Bigano, A., J.M. Hamilton, M. Lau, R.S.J. Tol and Y. Zhou (2004), *A global database of domestic and international tourist numbers at national and subnational level*, **FNU-54** (*International Journal of Tourism Research,* **9**, 147-174)

Susandi, A. and R.S.J. Tol (2004), *Impact of international emission reduction on energy and forestry sector of Indonesia*, **FNU-53** (submitted)

Hamilton, J.M. and R.S.J. Tol (2004), *The Impact of Climate Change on Tourism and Recreation*, **FNU-52** (forthcoming, Schlesinger et al. (eds.), Cambridge University Press)

Schneider, U.A. (2004), *Land Use Decision Modelling with Soil Status Dependent Emission Rates*, **FNU-51** (submitted)

Link, P.M., U.A. Schneider and R.S.J. Tol (2004), *Economic impacts of changes in fish population dynamics: the role of the fishermen's harvesting strategies,* **FNU-50** (submitted)

Berritella, M., A. Bigano, R. Roson and R.S.J. Tol (2004), *A General Equilibrium Analysis of Climate Change Impacts on Tourism*, **FNU-49** (*Tourism Management*, **27** (5), 913-924)

Tol, R.S.J. (2004), *The Double Trade-Off between Adaptation and Mitigation for Sea Level Rise: An Application of* FUND, **FNU-48** (*Mitigation and Adaptation Strategies for Global Change,* **12** (5), 741-753)

Erdil, E. and Yetkiner, I.H. (2004), *A Panel Data Approach for Income-Health Causality,* **FNU-47**

Tol, R.S.J. (2004), *Multi-Gas Emission Reduction for Climate Change Policy: An Application of* FUND, **FNU-46** (*Energy Journal* (Multi-Greenhouse Gas Mitigation and Climate Policy Special Issue), 235-250)

Tol, R.S.J. (2004), *Exchange Rates and Climate Change: An Application of* FUND, **FNU-45** (*Climatic Change*, **75**, 59-80)

Gaitan, B., Tol, R.S.J, and Yetkiner, I. Hakan (2004), *The Hotelling's Rule Revisited in a Dynamic General Equilibrium Model*, **FNU-44** (submitted)

Rehdanz, K. and Tol, R.S.J (2004), *On Multi-Period Allocation of Tradable Emission Permits*, **FNU-43** (submitted)

Link, P.M. and Tol, R.S.J. (2004), *Possible Economic Impacts of a Shutdown of the Thermohaline Circulation: An Application of* FUND, **FNU-42** (*Portuguese Economic Journal*, **3**, 99-114)

Zhou, Y. and Tol, R.S.J. (2004), *Evaluating the costs of desalination and water transport,* **FNU-41** (*Water Resources Research,* **41** (3), W03003)

Lau, M. (2004), *Küstenzonenmanagement in der Volksrepublik China und Anpassungsstrategien an den Meeresspiegelanstieg*,**FNU-40** (*Coastline Reports* (1), 213-224.)

Rehdanz, K. and D.J. Maddison (2004), *The Amenity Value of Climate to German Households*, **FNU-39** (submitted)

Bosello, F., Lazzarin, M., Roson, R. and Tol, R.S.J. (2004), *Economy-wide Estimates of the Implications of Climate Change: Sea Level Rise*, **FNU-38** (*Environmental and Resource Economics,* **37**, 549-571)

Schwoon, M. and Tol, R.S.J. (2004), *Optimal CO_2-abatement with socio-economic inertia and induced technological change*, **FNU-37** (*Energy Journal*, **27** (4), 25-60)

Hamilton, J.M., Maddison, D.J. and Tol, R.S.J. (2004), *The Effects of Climate Change on International Tourism*, **FNU-36** (*Climate Research*, **29**, 255-268)

Hansen, O. and R.S.J. Tol (2003), *A Refined Inglehart Index of Materialism and Postmaterialism*, **FNU-35** (submitted)

Heinzow, T. and R.S.J. Tol (2003), *Prediction of Crop Yields across four Climate Zones in Germany: An Artificial Neural Network Approach*, **FNU-34** (submitted, *Climate Research*)

Tol, R.S.J. (2003), *Adaptation and Mitigation: Trade-offs in Substance and Methods*, **FNU-33** (*Environmental Science and Policy*, **8** (6), 572-578)

Tol, R.S.J. and T. Heinzow (2003), *Estimates of the External and Sustainability Costs of Climate Change*, **FNU-32** (submitted)

Hamilton, J.M., Maddison, D.J. and Tol, R.S.J. (2003), *Climate change and international tourism: a simulation study*, **FNU-31** (*Global Environmental Change*, **15** (3), 253-266)

Link, P.M. and R.S.J. Tol (2003), *Economic impacts of changes in population dynamics of fish on the fisheries in the Barents Sea*, **FNU-30** (*ICES Journal of Marine Science*, **63** (4), 611-625)

Link, P.M. (2003), *Auswirkungen populationsdynamischer Veränderungen in Fischbeständen auf die Fischereiwirtschaft in der Barentssee*, **FNU-29** (*Essener Geographische Arbeiten*, **35**, 179-202)

Lau, M. (2003), *Coastal Zone Management in the People's Republic of China – An Assessment of Structural Impacts on Decision-making Processes*, **FNU-28** (*Ocean & Coastal Management*, No. 48 (2005), pp. 115-159.)

Lau, M. (2003), *Coastal Zone Management in the People's Republic of China – A Unique Approach?*, **FNU-27** (*China Environment Series*, Issue 6, pp. 120-124; http://www.wilsoncenter.org/topics/pubs/7-commentaries.pdf)

Roson, R. and R.S.J. Tol (2003), *An Integrated Assessment Model of Economy-Energy-Climate – The Model Wiagem: A Comment*, **FNU-26** (*Integrated Assessment*, **6** (1), 75-82)

Yetkiner, I.H. (2003), *Is There An Indispensable Role For Government During Recovery From An Earthquake? A Theoretical Elaboration*, **FNU-25**

Yetkiner, I.H. (2003), *A Short Note On The Solution Procedure Of Barro And Sala-i-Martin for Restoring Constancy Conditions*, **FNU-24**

Schneider, U.A. and B.A. McCarl (2003), *Measuring Abatement Potentials When Multiple Change is Present: The Case of Greenhouse Gas Mitigation in U.S. Agriculture and Forestry*, **FNU-23** (submitted)

Zhou, Y. and Tol, R.S.J. (2003), *The Implications of Desalination to Water Resources in China - an Economic Perspective*, **FNU-22** (*Desalination*, **163** (4), 225-240)

Yetkiner, I.H., de Vaal, A., and van Zon, A. (2003), *The Cyclical Advancement of Drastic Technologies*, **FNU-21**

Rehdanz, K. and Maddison, D. (2003) *Climate and Happiness*, **FNU-20** (*Ecological Economics*, **52** 111-125)

Tol, R.S.J., (2003), *The Marginal Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties*, **FNU-19** (*Energy Policy*, **33** (16), 2064-2074).

Lee, H.C., B.A. McCarl, U.A. Schneider, and C.C. Chen (2003), *Leakage and Comparative Advantage Implications of Agricultural Participation in Greenhouse Gas Emission Mitigation*, **FNU-18** (submitted).

Schneider, U.A. and B.A. McCarl (2003), *Implications of a Carbon Based Energy Tax for U.S. Agriculture*, **FNU-17** (submitted).

Tol, R.S.J. (2002), *Climate, Development, and Malaria: An Application of* FUND, **FNU-16** (forthcoming, *Climatic Change*).

Hamilton, J.M. (2003), *Climate and the Destination Choice of German Tourists*, **FNU-15** (revised and submitted).

Tol, R.S.J. (2002), *Technology Protocols for Climate Change: An Application of* FUND, **FNU-14** (*Climate Policy*, **4**, 269-287).

Rehdanz, K (2002), *Hedonic Pricing of Climate Change Impacts to Households in Great Britain*, **FNU-13** (*Climatic Change* **74**).

Tol, R.S.J. (2002), *Emission Abatement Versus Development As Strategies To Reduce Vulnerability To Climate Change: An Application Of* FUND, **FNU-12** (*Environment and Development Economics*, **10**, 615-629).

Rehdanz, K. and Tol, R.S.J. (2002), *On National and International Trade in Greenhouse Gas Emission Permits*, **FNU-11** (*Ecological Economics*, **54**, 397-416).

Fankhauser, S. and Tol, R.S.J. (2001), *On Climate Change and Growth*, **FNU-10** (*Resource and Energy Economics*, **27**, 1-17).

Tol, R.S.J.and Verheyen, R. (2001), *Liability and Compensation for Climate Change Damages – A Legal and Economic Assessment*, **FNU-9** (*Energy Policy*, **32** (9), 1109-1130).

Yohe, G. and R.S.J. Tol (2001), *Indicators for Social and Economic Coping Capacity – Moving Toward a Working Definition of Adaptive Capacity*, **FNU-8** (*Global Environmental Change*, **12** (1), 25-40).

Kemfert, C., W. Lise and R.S.J. Tol (2001), *Games of Climate Change with International Trade*, **FNU-7** (*Environmental and Resource Economics*, **28**, 209-232).

Tol, R.S.J., W. Lise, B. Morel and B.C.C. van der Zwaan (2001), *Technology Development and Diffusion and Incentives to Abate Greenhouse Gas Emissions*, **FNU-6** (submitted).

Kemfert, C. and R.S.J. Tol (2001), *Equity, International Trade and Climate Policy*, **FNU-5** (*International Environmental Agreements*, **2**, 23-48).

Tol, R.S.J., Downing T.E., Fankhauser S., Richels R.G. and Smith J.B. (2001), *Progress in Estimating the Marginal Costs of Greenhouse Gas Emissions*, **FNU-4**. (*Pollution Atmosphérique – Numéro Spécial: Combien Vaut l'Air Propre?*, 155-179).

Tol, R.S.J. (2000), *How Large is the Uncertainty about Climate Change?*, **FNU-3** (*Climatic Change*, **56** (3), 265-289).

Tol, R.S.J., S. Fankhauser, R.G. Richels and J.B. Smith (2000), *How Much Damage Will Climate Change Do? Recent Estimates*, **FNU-2** (*World Economics*, **1** (4), 179-206)

Lise, W. and R.S.J. Tol (2000), *Impact of Climate on Tourism Demand*, **FNU-1** (*Climatic Change*, **55** (4), 429-449).