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The Impact of Trade Liberalization and Removal of Non-Tariff Barriers on Water Use and Agricultural Production: A CGE Analysis of the Nile Basin Countries

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Abstract

A multi-country multi-sector computable general equilibrium (CGE) model is used to evaluate the economic and water resource scarcity effects of trade liberalization (removal of import barriers) and facilitation (removal of non-tariff barriers) among the Nile Basin countries. The analysis uses the new version of the GTAP-W model that distinguishes between rainfed and irrigated agriculture and implements water as a factor of production directly substitutable in the production process of irrigated agriculture. The GTAP Africa Data Base, which includes data for the Nile Basin countries, is used for the analysis. A full trade liberalization scenario coupled with trade facilitation is considered. The findings of the study reveal that water use in irrigated agriculture tends to decline or remain stable in most agricultural sectors in the Nile Basin countries. With the decline of water use in the irrigation-intensive agricultural sectors in Egypt and Sudan, trade liberalization is expected to reduce the pressure on scarce water resources in the Nile River Basin. Consistent with neoclassical trade theory, trade liberalization and facilitation is

expected to stimulate economic growth and improve welfare in the Nile Basin countries. The simulated trade policy measures enhance agricultural production in Ethiopia and Sudan and stimulates manufacturing in Egypt and to some extent in the Equatorial Lakes region.

1. Introduction

After many years of negotiations, members of the World Trade Organization (WTO) adopted an Agreement on Trade Facilitation at the Bali Ministerial Conference in December 2013. The agreement contains provisions for faster and more efficient customs procedures and provisions for technical assistance and capacity building in this area. While the subject of trade facilitation has received academic attention from a development perspective (e.g. Wilson et al. 2005), little research has yet focused on the relationship between trade facilitation and the environment. The present research contributes to filling this gap by empirically assessing the effects of trade facilitation (and trade liberalization) on scarce water resources in the Nile river basin.

Neoclassical (Hecksher-Ohlin) theory of international trade posits that international trade is largely driven by differences in countries' resources endowments (Krugman and Obstfeld, 1997; Farmer and Schelnast, 2013). In its simplest form the theory would predict that countries tend to export goods whose production is intensive in factors with which they are abundantly endowed, and import those that are intensive in factors that are relatively scarce in supply. Lowering trade barriers, therefore, increases the production of the commodity favored by factor endowment so that freer trade increases the use of the abundant factor relative to the scarce factor of production. The generality of the Heckscher-Ohlin theory in the case of scarce water resources has been questioned (Ansink, 2010), but it remains a powerful hypothesis that can be empirically tested.

The Nile river basin provides an interesting testing ground for the Heckscher-Ohlin hypothesis on trade facilitation and the environment in the case of scarce water resources. The River Nile, the longest river in the world, supports the livelihood of some 238 million people who live

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within the boundaries of the basin (NBI, 2012). The Nile Basin's population growth rate is among the highest in the world (FAO, 2011). Egypt has the biggest economy in the basin, followed by Sudan (including South Sudan) and Ethiopia (WDI, 2012). During the period 2000-2010, all the Nile Basin countries saw a positive growth in GDP, but the average growth rates vary widely across countries. Agriculture plays a significant role in the Nile Basin economies in terms of employment and contribution to GDP. However, the significance of this sector also varies considerably between the Nile countries (FAO, 2013). Unlike the upstream countries, the downstream Nile Basin countries (Egypt and Sudan) have an industrializing economy. The Nile Basin countries' trade performance for the period 2000–2010 reveals that both its export and import increased substantially, with a strong emphasis of exports on only a few primary commodities and concentration of imports on a few manufactured products (WDI, 2012).

Despite its extraordinary natural endowments and the positive economic growth rates, the Nile Basin remains characterized by massive poverty, social instability, and environmental degradation. Population growth combined with increased agricultural and industrial development are putting pressure on the Basin's water resources through increased storage and diversion of surface water, in order to serve the increasing demand for energy and agricultural produce (e.g. Hammond, 2013). Situated in an arid environment with sparse and insignificant rainfall, downstream countries Egypt and Northern Sudan are heavily dependent on the Nile for their water supply. The 1959 Nile Waters Agreement allocated the Nile's annual flow between Egypt (55.5 km^3) and Sudan (18.5 km^3), with the remaining 10 km^3 assumed to be lost to evaporation and seepage at the Aswan High Dam (Salman, 2013). With annual water withdrawal of 55.5 km^3 and 13.8 km^3, respectively, (Blackmore and Whittington, 2008), Egypt and Sudan remain

the major users of the Nile waters. Little of the Nile flow is used in the upstream reaches although upstream countries like Ethiopia have begun to consider using the Nile waters in an attempt to mitigate the effects of weather uncertainties and initiate economic development. According to recent data (FAO, 2013), the water supply conditions in the Nile basin can be classified as 'scarce' for Egypt, Kenya and Rwanda, and 'stressed' for Eritrea, Burundi, Ethiopia and Sudan according to the Falkenmark indicator for water stress (Falkenmark, 1989). At present, 'virtual' water trade among the Nile Basin countries does not significantly help to decrease the freshwater deficits of the most water-stressed basin countries (Zeitoun et al., 2010). With most of the Nile Basin countries already water scarce or water stressed, proper management and development of the Nile waters in an efficient, equitable and sustainable manner is imperative to prevent potential water-related conflicts in the basin.

In the face of potential conflict and regional instability, the Nile Basin countries have been seeking cooperative solutions through basin-wide dialogues, the most recent in the form of the Nile Basin Initiative (NBI). In pursuit of the sustainable development and management of the Nile waters, the initiative seeks to achieve a shared vision of "sustainable socio-economic development through the equitable utilization of, and benefit from, the common Nile Basin water resources" (Nile-COM, 1999, NBI, 2012). Recent decades have witnessed increased efforts of the Nile Basin countries to facilitate the move towards liberalized trade. Yet, they remain far from free trade. According to the GTAP Africa database, bilateral tariffs on intra Nile Basin merchandise trade, especially on food products, are widespread and substantial, in particular within the upstream Equatorial Lakes region (DR Congo, Uganda, Tanzania, Kenya) and between Egypt and Ethiopia and Ethiopia and Sudan. In addition to tariffs, non-tariff barriers such as delays and related costs in customs clearance, sanitary and phyto-sanitary measures,

standards, poor infrastructure and high transportation and communication costs limit trade among the Nile Basin economies. According to the World Bank Doing Business Report (2012), it takes, on average, 30 days to export from a Nile basin country and as much as 36 days to import to a Nile Basin country. In contrast, it takes, on average, 10 and 11 days respectively, to export to and import from a high income OECD (Organization for Economic Co-operation and Development) country.

To investigate the impact of trade liberalization and trade facilitation among the Nile Basin countries, this study adopts a computable general equilibrium (CGE) methodology. CGE models have been widely used to analyze various water related issues. For example, CGE models have been applied to evaluate economy-wide effects of water markets (Diao and Roe, 2003; Diao et al., 2005), investigate linkages between water and trade policies (Diao and Roe, 2003), assess the socio-economic impact of water transfers between regions (Feng et al., 2007), analyze the economic impacts of reduced water supply in water-scarce countries (Berrittella et al., 2007), and analyze the effect of potential water savings and the welfare implications of improvements in irrigation efficiency (Calzadella et al., 2010). Only a few CGE models (e.g. Berrittella et al., 2008; Calzadilla et al., 2011a) have addressed the issue of trade liberalization and its effect on agricultural water use. Berrittella et al. (2008) used a global CGE model that treats water as a factor of production non-substitutable to other factors in production to estimate the impact of agricultural trade liberalization on water use. Their findings reveal that significant reductions in agricultural tariffs lead to relatively modest changes in regional water use. Patterns are found to be non-linear in that water use may go up for partial liberalization, and down for more complete liberalization. Moreover, trade liberalization tends to reduce water use in water scarce regions,

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and increase water use in water abundant regions. Calzadilla et al., (2011a) assess the potential impacts of climate change and trade liberalization, using the new version of the GTAP-W model, which implements water as a factor of production directly substitutable with other factors of production. Their findings are similar to that of Berrittella et al. (2008).

None of the literature above addresses basin-level water resource management issues in a global CGE context. This study represents one of the first efforts to use a global CGE model to analyze basin-scale water resources management issues. It applies the revised version of the GTAP-W model (Calzadilla et al., 2010) to the transboundary water resources management problems of the Nile River Basin. Moreover, this study models the water resource implication of trade liberalization in a novel fashion in the sense that it considers both tariff and non-tariff barriers (i.e. trade facilitation) to intra-basin trade in a multi-sector and multi-country CGE setting.

The remainder of the paper is organized as follows. The next section presents the theoretical modeling framework and details of the data aggregation procedure. Section 3 introduces the trade liberalization and facilitation policy scenarios. Section 4 discusses the results and section 5 concludes.

2. Modeling framework and data

The modeling framework applied for the study is the GTAP -W model (Calzadilla et al., 2010), a daughter of the well-known Global Trade Analysis Project (GTAP) model, a static comparative, multi-region, multi-sector CGE model of the world economy (Hertel, 1997). In comparison to the standard GTAP model, GTAP-W distinguishes between rainfed and irrigated agriculture and

implements water as a factor of production directly substitutable in the production process of irrigated agriculture.

The GTAP Africa Data Base, which includes data for most of the Nile Basin countries, is used for the analysis. For the purpose of the present study, the GTAP Africa Data Base is aggregated into seven regions: Egypt, Ethiopia, Sudan, the Equatorial Lakes (EQL) region, Rest of North Africa, Rest of Sub-Sahara Africa and Rest of the World (ROW) (see Appendix B for an overview of regions and countries). The four Nile Equatorial Lakes countries covered in the GTAP Africa Data Base include the Democratic Republic of Congo, Kenya, Tanzania and Uganda, and are aggregated in the EQL region. Since the focus of the study is exclusively on water resources management of the Nile River Basin, the regional aggregation highlights the importance of the Eastern Nile region, where the overwhelming proportion of the Nile water resource is generated and used. The 57 sectors in the GTAP Africa Data Base are aggregated for the purpose of this study into 17 sectors, of which 8 are agricultural sectors and 9 non-agricultural sectors (see the overview in Appendix C).

Following Calzadilla *et al*. (2011b), the agricultural land endowment in the standard GTAP database is disaggregated into rainfed land, irrigable land, and irrigation water based on IFPRI data. The relative share of rainfed and irrigated production in total production is used to split the land rent in the original GTAP database into a value for rainfed land and a value for irrigated land for each crop in each region. In the next step, the ratio of irrigated yield to rainfed yield is used to split the value of irrigated land into the value of irrigable land and the value of irrigation water.

In the GTAP-W model, as in the standard GTAP model, primary factors of production are assumed to substitute for one another according to a CES substitution elasticity parameter. The factor substitution elasticity parameter, which defines the relationship between changes in the ratio of factor inputs used in the production of a given level of output and the inverse ratio of their marginal products (their inverse price ratio in equilibrium), describes the flexibility of a production technology to allow changes in the quantity ratios of factors used in the production of a given level of output as relative factor prices change. For example, in the GTAP-W model where water and irrigable land are substitutes in production, the parameter describes the ease with which producers can hire more irrigable land and use less water when the price of irrigable land falls relative to that of water.

Estimates of the elasticity of substitution between irrigable land and irrigation for the regions considered in this study are not available. The data required to estimate the parameter, such as the price elasticity of demand for water, are not available either. Hence, the elasticity values used in this study are adapted from Calzadilla et al. (2011b), which derive the substitution elasticity between irrigable land and irrigation water using estimates of the price elasticity of water use for 15 world regions provided by Rosegrant et al. (2002). These values are shown in Table 1. The elasticity of substitution between irrigable land and irrigation is higher in Egypt compared to the other basin countries. Due to its more advanced irrigation practice, Egypt has relatively flexible production technology that allows better substitution possibilities. Sensitivity analysis of model results with respect to the elasticity parameters is conducted to test the sensitivity of the results to alternative values of the parameters. The model results are found to be robust with respect to

changes in the elasticity parameters[1].

Table 1. Elasticity of substitution between irrigable land and irrigation

Regions	Substitution elasticity
Egypt	0.08
Ethiopia	0.05
Sudan	0.05
EQL Region	0.05
Rest of North Africa	0.08
Rest of Sub-Sahara Africa	0.05
Rest of the World	0.07

Source: Adapted from Calzdilla et al. (2011)

According to the neoclassical theory of trade, comparative advantage determines the pattern of inter-industry trade among countries. In theoretical models, comparative advantage is expressed in terms of relative prices evaluated in a hypothetical pre-trade environment, knows as autarky. Since relative prices are not observed in the absence of trade (autarky), in practice comparative advantage is measured indirectly using revealed comparative advantage (RCA) (Balassa, 1965). RCA implies inferring comparative advantage from observed trade patterns and is computed using the following index (Mukhopadhyay and Thomassin, 2010):

$$\text{RCA} = (\frac{\text{xij}}{\text{xwj}})/(\frac{\text{sumxij}}{\text{sumxwj}})$$

Where xij , xwj, sum xij , and sum xwj stand for country i's export of commodity j, world's export of commodity j, country i's total exports, and world's total exports, respectively.

Table 2 depicts the RCA of the Nile Basin countries for selected commodities for multiple years. Identifying the goods with RCA in each country throws some light on the structure of specialization

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[1] Test results are available from the authors upon request.

of the countries and the prospects of trade liberalization in alleviating water scarcity in the basin through

its potential effect on the pattern of trade between them. A value of greater than one reveals that the

country has revealed comparative advantage in a particular sector. The figures in Table 2 reveal

that Egypt has a comparative advantage in rice, vegetables and fruits, and manufactured goods.

Ethiopia's comparative advantage lies in a wide range of agricultural products, such as livestock and

meat, cereals (for most of the period under consideration), vegetables and fruits, and oil seeds. In the case

of Sudan the commodities are restricted to livestock and meat and oil seeds. For the EQL region, the

comparative advantage list covers rice and cereals (for most of the period under consideration),

vegetables and fruits, oil seeds, as well as manufactured goods.

Table 2: RCA of the Nile Basin countries for selected commodities, 2003-2010.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Egypt										
Livestock & meat	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Rice	17.4	26.7	22.7	17.0	17.5	5.2	9.3	9.3	0.6	1.8
Cereals	0.1	0.0	0.1	0.2	0.2	0.2	0.1	0.2	0.1	0.0
Vegetables & fruits	3.9	4.6	4.6	3.5	4.3	5.7	6.9	6.9	7.2	6.8
Oil seeds	0.5	0.9	0.8	0.6	0.4	0.5	0.7	0.5	0.5	0.4
Manufactured goods	1.4	1.6	1.4	1.2	1.1	1.3	1.4	1.4	1.4	1.4
Ethiopia										
Livestock & meat	2.0	2.9	6.3	7.2	6.5	6.7	6.7	10.6	14.0	11.1
Rice	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cereals	5.3	3.8	4.4	1.0	0.2	0.1	0.0	1.8	1.6	2.6
Vegetables & fruits	6.2	8.1	5.6	7.5	11.4	19.1	19.6	20.5	19.9	20.7
Oil seeds	34.7	45.2	93.5	83.3	46.0	42.5	55.9	36.9	37.3	36.8
Manufactured goods	0.7	0.2	0.3	0.4	0.6	0.4	0.3	0.4	0.5	0.4
Sudan										
Livestock & meat	9.5	4.8	3.2	3.0	1.2	1.0	3.6	2.0	3.3	5.1
Rice	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cereals	0.5	0.2	0.0	0.1	0.1	0.9	0.0	0.1	0.3	0.5
Vegetables and fruits	2.1	1.2	0.5	0.6	0.2	0.4	0.2	0.1	0.2	0.9
Oil seeds	11.9	14.8	8.3	11.9	6.6	5.3	5.2	3.6	3.9	11.1
Manufactured goods	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.2
EQL Region										
Livestock & meat	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Rice	0.4	0.3	0.8	0.7	1.2	1.0	1.3	1.5	2.0	1.7
Cereals	1.7	1.5	1.3	2.0	1.6	0.6	0.7	1.0	0.7	1.2
Vegetables and fruits	6.9	6.5	5.6	5.8	6.1	5.7	4.6	5.2	4.4	5.0

| Oil seeds | 2.1 | 2.2 | 2.1 | 2.2 | 2.5 | 2.3 | 2.5 | 1.8 | 2.9 | 2.5 |
| Manufactured goods | 1.5 | 1.5 | 1.4 | 1.5 | 1.5 | 1.6 | 1.4 | 1.9 | 1.9 | 2.4 |

Source: Computed from United Nations Conference on Trade and Development (UNCTAD) database

3. Policy scenarios

A full trade liberalization scenario coupled with trade facilitation is considered for model implementation. The full trade liberalization scenario involves a 100 percent reduction in import tariffs on intra-Nile Basin countries' trade. Although tariff liberalization is important in improving trade, the importance of other trade-related factors, such as transport and communication services, customs procedures, port efficiency, standards and technical regulations, etc. are equally important in enhancing trade performance. Hence, a full trade liberalization scenario combined with improvements in non-tariff barriers in the form of traded facilitation is considered.

Cumbersome trade procedures cause significant delays and constitute trade transaction costs to traders. Trade facilitation is incorporated into the GTAP model by splitting these trade transactions costs into two parts: the indirect trade transaction costs (also referred to "iceberg costs") and a tax component, capturing the direct costs (Fox et al., 2003; OECD, 2003). The direct costs include costs incurred in providing necessary information and documentation, customs fees, and direct charges for trade-related services, such as form-filling services, while the indirect costs are related to time delays due to burdensome and inefficient procedures. Following Hertel et al. (2001), Fox et al (2003) and OECD (2003), this study models trade facilitation via a technical change in trading activities, which is considered appropriate for capturing the indirect cost component of trade transaction costs (OECD, 2003). According to this approach, indirect transaction costs are associated with higher costs and a melting down of the

value of the good in proportion to the length of its transit time so that reducing delays related to inefficient trade procedures through trade facilitation efforts would result in lower associated costs and hence lower destination prices of the traded goods.

The gains that would accrue from the implementation of trade facilitation among the Nile Basin countries is modeled using data on time required to import into a Nile Basin country from the World Bank Doing Business Report (2012). Data on trade costs are from Minor and Tsigas (2008). Their measure of trade costs provides trade-weighted average tariff equivalents of time savings per day as a percentage of the value of a good. Goods are differentiated because the cost of time depends on the product, with average time cost ranging from zero for cereals and fossil fuels to 1.1 percent ad valorem per day for perishable products like vegetables and fruits (Minor and Tsigas, 2008).

Our trade facilitation experiment consists of reducing the average time required to import to Nile Basin countries and hence the associated indirect cost of trade by half. This involves a 50 percent technical change in import trade among the Nile Basin countries in appropriate sectors. In the simulation we assume that trade facilitation can be achieved at no cost, although the countries may have to invest in infrastructure (e.g. equipments to improve port handling and customs procedures) and manpower to implement it. Moreover, direct trade transactions costs are not considered due to lack of data.

The base year of the GTAP Africa Data Base used for the study is 2001 so that the baseline equilibrium is based on data for this year. An 11-year macro-projection (2001-2011) that reflects

the developments in terms of population growth, the size of man-made endowments (labor and

capital), and economic growth that have taken place inside and outside the Nile Basin since 2001

is, therefore, implemented in order to identify future baseline conditions and outcomes. In effect,

the projection imposes a new macroeconomic equilibrium on the world economy with higher

levels of population, capital, labor, and GDP. The shocks used to construct the baseline with a

projection of the world economies from 2011 onwards are given in Table 3. Existing water

infrastructures in the Basin and major macroeconomic data are then updated and the effect of

trade liberalization and facilitation in the Nile Basin region is evaluated relative to this updated

baseline equilibrium.

Table 3: Cumulative growth rates (%) in factor endowments, productivity and GDP, 2001-2011

Region	Population	Gross Domestic Product (GDP)	Capital*	Labor** Unskilled	Skilled
Egypt	17.4	63.4	11.2	35	35
Ethiopia	22.4	139.9	47.9	41	41
Sudan	23.1	75.5	9.9	30	30
EQL Region	29.3	87.7	11.0	33	33
Rest of North Africa	12.1	55.7	3.7	20	20
Rest of Sub-Sahara Africa	24.9	67.2	10.7	30	30
Rest of the world	11.2	31.6	3.4	15	15

Source: Computed using data from the World Bank Database
*Source: Computed using data from FAOSTAT (2001-2007)
** Due to lack of data on skilled and unskilled labor, data on total labor force (2001-2010) is used to
calculate the cumulative growth rates for both skilled and unskilled labor. That is, it is assumed that
no significance change in the composition of the two categories of labor has occurred during the
projection period.

4. Simulation results

A substantial effect of removing trade barriers is that resources are reallocated to sectors in each

country where there is a comparative advantage. Output effects due to trade liberalization and

improved trade facilitation among the Nile Basin economies reported in Table 4 testify this. Intra-Nile Basin countries' trade liberalization and facilitation enhances agricultural production in Ethiopia and Sudan while output declines in the manufacturing sector of both countries. In Ethiopia, output improves in all the agricultural sectors with largest improvements observed in the oil seeds, rice, sugar cane and sugar beet sectors. Similarly, output effects for all agricultural sectors in Sudan are positive except the vegetables and fruits sector where output declines slightly. Largest improvements in output are gained in Sudan's rice, oil seeds, and wheat sectors. The opposite is true for Egypt and to some extent the EQL region. Egypt shifts its pattern of production from agricultural sectors towards the manufacturing sector. In the EQL region, output declines or remains stable in the agricultural sectors and improves slightly in the manufacturing sector. Although the output effects vary widely across sectors and countries, overall the Nile Basin countries would, on average, enhance output via multilateral trade liberalization. Moreover, consistent with neoclassical trade theory, the Nile Basin economies tend to specialize in products favored by their resource endowments.

Table 4: Percentage change in production relative to baseline output levels, results for agricultural and manufacturing sectors

Sectors	Egypt	Ethiopia	Sudan	EQL Region
Rice	-0.23	2.8	6.18	-0.05
Wheat	-1.19	1.23	2.24	-1.57
Cereal grains	-0.33	0.47	0.48	0.11
Other grains & crops	-0.28	0.78	1.27	-0.09
Vegetables & Fruits	-0.06	0.68	-0.33	0.02
Oil seeds	-0.9	3.96	4.95	0.1
Sugar cane & sugar beet	0.16	1.93	0.76	-0.08
Livestock & meat products	-0.35	1.39	1.36	0.63
Manufactured products	0.84	-2.48	-2.24	0.24

Reallocation of resources among sectors of production resulting from trade liberalization and facilitation are expected to lead to some adjustments in the factor markets.

Table 5 presents the potential effects of lowering trade barriers on the demand for irrigation water across sectors in the Nile Basin countries. Water use in irrigated agriculture tends to decline or remain stable in most of the agricultural sectors of all the Nile Basin countries. The simulation results reveal that irrigation water use decreases in most of the agricultural sectors in Ethiopia and remains mostly stable in the EQL region, although irrigated agriculture is not substantial in these regions. The demand for irrigation water falls or remains more or less stable in Egypt's agricultural sectors except for vegetables and fruits, sugar cane and sugar beet where water use increases slightly. In Sudan, irrigation water use falls in all agricultural sectors except for rice, sugar cane and sugar beet. In terms of percentage change, the decline in Sudanese irrigation water use is much more prominent than that in Egypt. Since agriculture is highly irrigation-intensive in the downstream Nile countries Egypt and Sudan, which use most of the Nile waters, the simulation results confirm that freer intra-Nile Basin countries' trade leads to an overall decrease in the scarcity of irrigation water in the Nile Basin.

Table 5: Percentage change in water demand in irrigated agriculture, results for agricultural sectors

Sectors	Egypt	Ethiopia	Sudan	EQL Region
Rice	0.08	0.04	2.59	0
Wheat	-0.73	-1.18	-0.49	-1.24
Cereal grains	-0.01	-1.65	-1.58	0.13
Other grains & crops	0.03	-0.77	-0.82	-0.05
Vegetables & Fruits	0.23	-0.85	-2.48	0.05
Oil seeds	-0.47	1.31	1.68	0.12
Sugar cane & sugar beet	0.40	-0.34	-1.65	-0.02

The rise in agricultural production in the face of declining irrigation water use in Ethiopia and Sudan is partly explained by the increased use of rainfed land (Figure 1). Both Ethiopia and Sudan see an increase in the use of rainfed land in their water-intensive agricultural sectors. Since these countries are abundantly endowed with land resources, freer intra-Nile Basin trade would imply specialization according to comparative advantages, which favors the expansion of rainfed agriculture in these countries. Enhancing agricultural produce through increased use of rainfed land is expected to render comparative cost advantages to these countries.

Figure 1: Percentage change in the demand for rainfed agriculture, results for agricultural sectors
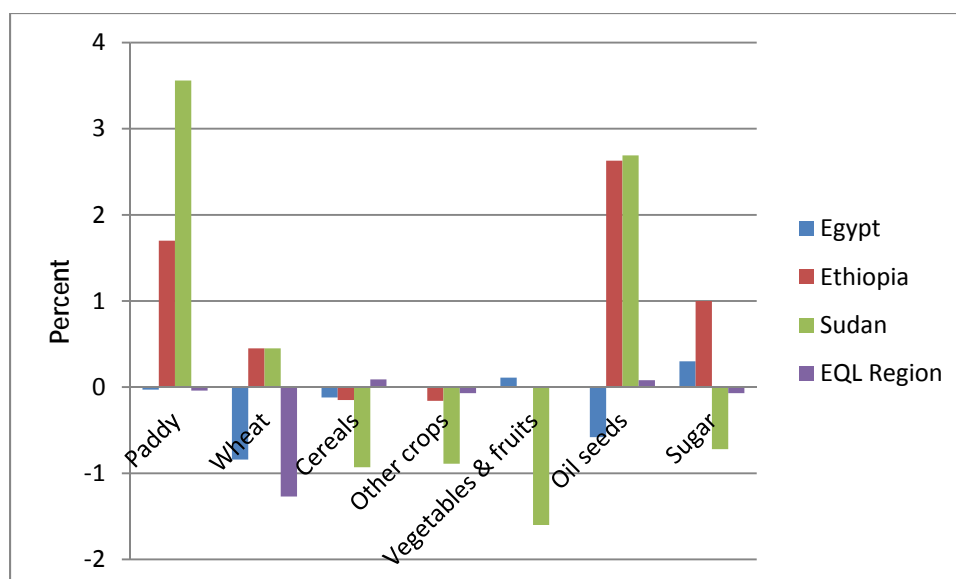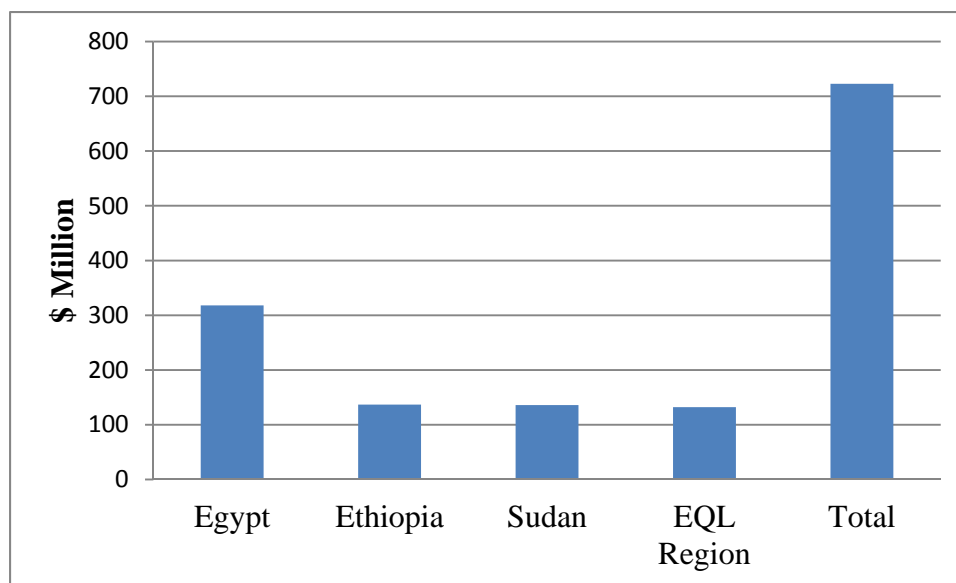
The simulation results reveal that liberalizing trade among the Nile Basin economies leads to more efficient distribution of endowment factors across sectors and shift the pattern of production towards the most competitive sectors of production, thereby resulting in a higher level of real output and hence positive growth effects for the countries. Real GDP increases in Ethiopia, Sudan and the EQL region and remains stable in Egypt. Ethiopia and Sudan experience a relatively greater increase in real GDP, 1.8 and 1.1 percent respectively, compared to EQL region's mere 0.2 percent.

Overall welfare effects, as measured by the equivalent variation (EV)[2], are also substantial. As it involves removing distortions, trade liberalization is generally expected to have a positive effect on welfare. Besides, comparative cost advantages due to specialization yield improvements in welfare. The total welfare gain in the Nile Basin countries is about USD 723 million annually. This equals 0.4% of the estimated combined GDP of the Nile Basin economies in the baseline

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[2] Equivalent variation measures the amount of income that would have to be given or taken away from an economy before trade liberalization so as to leave the economy as well off as it would be after the policy has been changed.

scenario. Yet, the gain in welfare is not distributed evenly among the countries. Welfare effects favor Egypt, which is expected to amass 44 percent of the total welfare gain resulting from the trade policy change (Figure 2) Improvements in commodity terms of trade and investment-savings terms of trade contributed the most to welfare gain in Egypt. Welfare gain in the other Nile countries emanates mainly from improved allocative efficiency and technical change.

Figure 2: Welfare effects of trade liberalization and facilitation across the Nile Basin countries

Overall the results reveal the important role of trade liberalization and facilitation in enhancing agricultural production, stimulating economic growth and improving welfare in the Nile Basin

countries. The change in trade policy is also predicted to reduce the pressure on scarce water resources of the Nile River Basin.

5. Discussion and conclusion

The findings of the study indicate that the Nile Basin countries would gain from multilateral trade liberalization and trade facilitation as resources are reallocated to sectors in each country where there is a comparative advantage. Freer intra-Nile Basin countries' trade is expected to change agricultural production in Ethiopia and Sudan. Increased demand for agricultural production in these countries increases the use of rainfed land with which they are abundantly endowed. The output effects of manufactured products in Egypt and EQL region are positive, but imports of agricultural produce increase in these regions to make up for declines in agricultural production.

The demand for irrigation water in most agricultural sectors of the Nile Basin countries tends to decrease or remain stable. Irrigation water use declines in Ethiopian agriculture and remains more or less stable in the EQL region. Downstream countries Egypt and Sudan that use almost the entire Nile waters are particularly expected to see negative adjustment or stability in water demand in their major water consuming sectors. The results thus confirm that intra-Nile countries trade liberalization and facilitation would reduce the pressure on scarce water resources of the Nile Basin.

The results of the study on the water resource implications of trade liberalization in the Nile Basin are more or less consistent to the findings of previous studies (Berrittella et al., 2008; and

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Calzadilla et al, 2011a). The findings of the present study, like that of the stated studies, reveal that significant trade liberalization results in modest decline in water use and, importantly, water use decreases in water scarce regions. However, contrary to the findings of Berrittella et al. (2008) and Calzadilla et al. (2011a), the findings of this study show that water use decreases in the relatively water abundant Ethiopia and Sudan as well. This could be because Ethiopia and Sudan are more abundant in land than water so that a shift in the pattern of production towards rainfed agriculture resulted in negative adjustment in the demand for irrigation water. Moreover, the comparative advantage of the Nile Basin economies predicted by the model is found to be consistent with the revealed comparative advantage (RCA) observed throughout the period 2008-2012 in the UNCTAD (United Nations Conference on Trade and Development) database. Both the predicted and RCA show that capital-abundant Egypt has comparative advantage in manufactured products while the comparative advantage of the remaining land-abundant Nile Basin economies lies in one or more agricultural products. The EQL region has a comparative advantage in manufactured as well some agricultural products. This is an expected result given the relative resource endowments of the Nile Basin countries.

Moreover, freer trade among the Nile Basin economies would enhance economic growth, and improve welfare. Total annual welfare gains resulting from the implementation of trade liberalization and facilitation are anticipated to be USD 723 million. The results are driven more by trade facilitation than trade liberalization so that improvements on nontariff barriers appear more important than tariff liberalization in promoting intra-Nile Basin economic cooperation and integration.

The static nature of the model constitutes a major limitation to the study. A dynamic model would, according to theoretical expectations, yield larger effects of trade liberalization and facilitation in the Nile Basin economies through adjustments in national capital stocks. Nevertheless, the results of the current analysis demonstrate that the role of trade liberalization and facilitation in generating basin-wide economic benefits and saving the Basin's scarce water resources is potentially substantial. Freer trade policy coupled with other relevant policy measures, such as improving irrigation efficiencies and adopting a basin-wide infrastructure development policy that would allow a significant reduction of evaporation losses by storing water upstream, would thus help to alleviate existing water scarcity conditions in the Basin.

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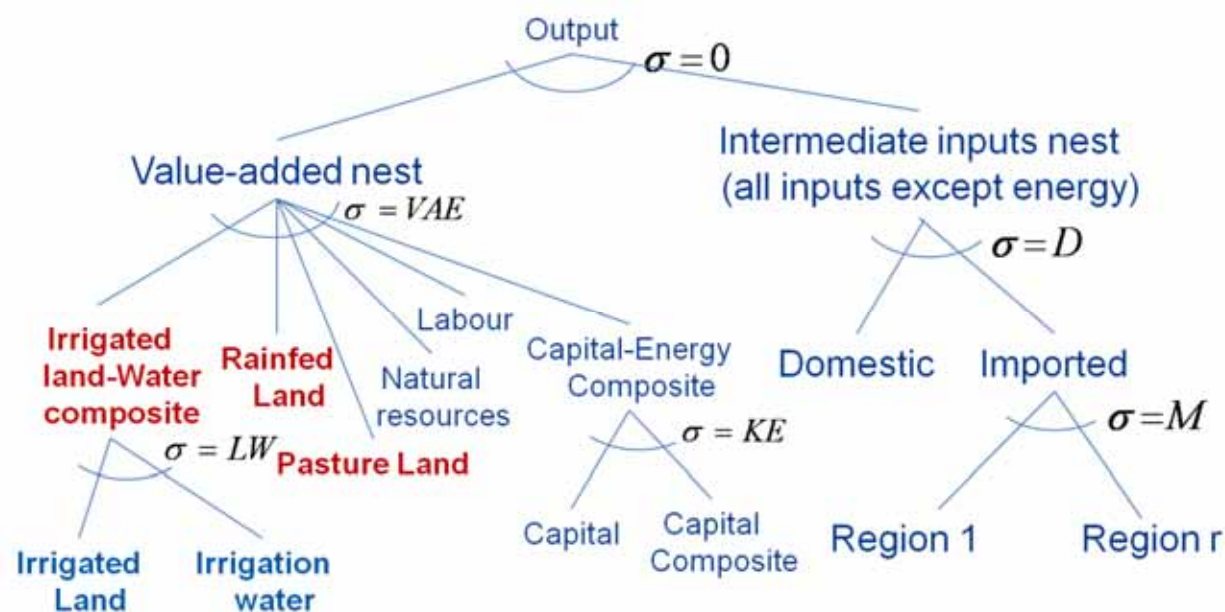

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Appendix A: Revised GTAP-W: Nested Tree Structure for Production Process

Appendix B: Regional Aggregation

Region	Description
Egypt (Egy)	Egypt
Ethiopia (Eth)	Ethiopia
Sudan (Sud)	Sudan
Equatorial Lakes Region (Eql)	DR Congo, Uganda, Kenya, United Republic of Tanzania
Rest of North Africa (Rnf)	Morocco, Tunisia, Rest of North Africa
Rest of Sub-Sahara Africa (Rss)	Cote d'Ivoire, Senegal, Rest of WAEMU, Ghana, Nigeria, Rest of ECOWAS, Cameroon, Rest of CAEMC, Rest of SADC, Rest of COMESA, Botswana, South Africa, Rest of South African CU, Madagascar, Malawi, Mauritius, Mozambique, Zambia, Zimbabwe, Rest of Sub-Saharan Africa
Rest of the World (ROW)	Oceania, East Asia, Southeast Asia, South Asia, North America, Latin America, European Union 25, Rest of Europe, Middle East,

Appendix C: Sectoral Aggregation

Sector	Detail Description
I. Agricultural Sectors	
Paddy	paddy
Wheat	wheat
Cereal	Cereal grains nec,
Othcrp	Plant-based fibers; crops nec; processed rice,
VegFr	Vegetables, fruit, nuts
Oilsd	Oil seeds
Sugar	Sugar cane, sugar beet
Livestock and Meat products (Animal)	Cattle, sheep, goats, horses; animal products nec; raw milk; wool, silk-worm, cocoons; meat: cattle, sheep, goats, horses; meat products nec;
II. Non-agricultural sectors	
Coal	Coal
Crude	Oil
Gasd	Gas; gas manufacturing, distribution
Petro	Petroleum, coal products
Electr	Electricity
Processed food (Pfood)	Vegetable oils and fats; dairy products; sugar; food products nec; beverages and tobacco products
Extraction and manufacturing (Manuf)	Forestry; fishing; minerals nec; textiles; wearing apparel; leather products; wood products; paper products, publishing; chemical, rubber, plastic prods; mineral products nec; ferrous metals; metals nec; metal products; motor vehicles and parts; transport equipment nec; electronic equipment; machinery and equipment nec; manufactures nec;
Water	Water
Services (servs)	Construction; trade; transport nec; sea transport; air transport; communication; financial services nec; insurance; business services nec; recreation and other services; public administration, defense, health, education; dwellings