FONDAZIONE ENI ENRICO MATTEI

NOTA DI LAVORO

79.2016

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Climate Change: Economic Impacts and Adaptation
Series Editor: Francesco Bosello

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Keywords: CGE Models, Climate Change, Agriculture, Irrigation, Water Resources

JEL Classification: C68, Q54, Q15, Q25

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Climate Change, Water Scarcity in Agriculture and the Economy-Wide Impacts in a CGE framework.

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Abstract

This paper analyzes the economic impacts of changes in water availability due to climate change. We develop a new modeling approach as an alternative to include water as a production factor within a global CGE model. We tailor the structure of the ICES model to characterize the key features of the world economy with a detailed representation of the agricultural sector. In order to reach this objective, a new database has been built to explicitly consider water endowments, precipitation changes, and unitary irrigation costs. Results suggest different economic consequences of climate change depending on the specific region. Impacts are related to change in crop production, endowment demands, and international trade.

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1. Introduction

Among all natural resources available, water resources are one of the most important for human activities. Besides the relevance of water as a key element to sustain life, water is one of the most important inputs for many economic activities, and it is present in many traded products.

Even though more than 75% of the earth is covered by water, it is a scarce resource. In fact, less than 1% is available for human consumption (UNESCO 2003). Thus, any policy addressing water resources should consider its scarce nature.

Among all potential water uses, agriculture is by far the most water intensive, accounting for more than 70% of global water withdrawals. Therefore, we must consider the wide scientific consensus about how climate change will affect water resources, including its uneven consequences across the world, especially within the agricultural sector. Expected climate change impacts on the agricultural sector are variations in precipitation and temperature patterns, along with an increase of extreme weather events (floods and droughts), among others (Parry, et al. 2007, Bates, et al. 2008).

In economic terms, the agricultural sector is a principal player within international trade. In developing countries, this sector has been increasing in relevance, while for developed countries it has shown a slight decreasing pattern throughout the last decade (Aksoy and Ng 2010). The deep connection provided by international markets implies that shocks in agricultural production have important consequences across the globe. Climate Change is not the only threat to the agricultural sector. Considering only expected population increases, a large investment in the agricultural sector, specifically in irrigation schemes, will be needed in order to assure the food supply, which implies re-allocating resources from other economic sectors.

Due to the global consequences of climate change, as well as the strong dependency of the agricultural sector on international trade, an approach that represents the deep connections among different sectors of the economy in order to account for the economic consequences of changes in water availability is necessary. In this regard, the general equilibrium approach seems to be an appropriate framework to analyze water related issues along with climate change impacts, specifically for the agricultural sector (Weyant 1985). Computable general equilibrium (CGE) models simulate the equilibrium theory (Arrow and Debreu, 1954) with real economic data, aiming to numerically solve for economic variables (supply, demand, and prices) that achieve equilibrium across specific market sets.

Water resources have been widely analyzed using CGE models. In a recent review of CGE studies, Ponce, *et al*. (2012) presented a detailed description of several exercises carried out at two scales: global and national At the global scale, the most relevant studies are those conducted using the GTAP framework (Berrittella, *et al.* 2005, Calzadilla *et al*. 2011). These studies are focused on the global welfare consequences of changes in agricultural trade patterns, due to changes in water availability. On the other hand, the studies conducted at national scale are focused on the evaluation of different policy instruments, such as: water pricing, irrigation policies, and water allocation, among others (Decaluwé, *et al* 1999, Lennox and Diukanova 2011, Strzepek, *et al.* 2008, Hassan and Thurlow 2011). In addition to the difference in scale, another important difference between these two modeling approaches is the level of detail/assumptions in which the economy is depicted.

In this paper we develop a new modeling approach as an alternative to include water as a production factor within a global CGE framework. We tailor the structure of the ICES model to characterize the key features of the world economy with a detailed representation of the agricultural sector.

The paper is structured as follows: section two presents a description of the modeling approach, highlighting the new production structure, as well as the methodology used. In section three, the model is used to quantify the economic impacts of climate change on the agricultural sector in Latin America. Section four concludes.

2. The ICES-W Model

2.1 Model overview

The Intertemporal Computable Equilibrium System (ICES) is a recursive dynamic multi-region and multi-sector CGE model developed at the Fondazione Eni Enrico Mattei (Parrado and De Cian, 2014 and Eboli, *et al.* 2010). The model is based on the GTAP model (Hertel 1997), and its further modification GTAP-E (Burniaux and Truong 2002). The model solves a series of equilibrium points across time assuming a dynamic myopic behavior by economic agents. In this section we present the main features of ICES-W, which is based on the static version of ICES. The model has been extended to account explicitly for the role played by both an irrigation sector and a water endowment in each region in order to cope with climate change impacts on agriculture. Thus, climate change impacts considered in the model are only those which affect water availability. The modeling approach does not account for further climate change impacts described by the literature such as temperature changes, CO_2 fertilization, changes in growth periods, and extreme weather events. (Bates, et al. 2008, Parry, et al. 2007).

At this stage, the analysis is limited to the agricultural sector since it is the largest water consumer worldwide. In this regard, the modeling approach follows the GTAP-W model (Calzadilla, *et al.* 2008), which considers two types of agriculture depending on the way in which water is provided: rainfed agriculture and irrigated agriculture. Regardless of this similarity, the current approach includes irrigation activities, as well as the role played by the availability of a water endowment.

ICES-W considers two different ways in which water flows to the agricultural sector: irrigation and precipitation. There is a large body of literature that justifies the inclusion of irrigation schemes as one of the major adaptation options to cope with climate change impacts, specifically for developing countries (Smit and Skinner 2002, Hallegatte 2009, Bryan, et al. 2009, Dinar, et al. 2008).

Considering the development of irrigation schemes as an adaptation strategy to climate change, it would be reasonable to expect diverse impacts for both rainfed crops and irrigated crops (FAO 2011). The model considers these diverse impacts, accounting for productivity differences between rainfed and irrigated land.

Despite the relevance of water as a key input for the agricultural sector, one major challenge remains when trying to to account for water within a CGE framework. Water does not have a price that reflects its marginal productivity. Furthermore, in most cases water simply has no price at all. Empirical evidence shows that the lack of a competitive market price is one of the drivers of water's inefficient use (Johansson, et al. 2002).

In order to overcome this shortcoming, water is modeled as a physical endowment that affects the productivity of the agricultural sector. Thus, it is not necessary to set an explicit price for the water endowment in the benchmark model calibration. Nevertheless, it is assumed that, due to changes in precipitation, this endowment and its variations would influence the agricultural sector's productivity.

Water affects agricultural productivity depending on the type of agriculture. In rainfed agriculture, productivity depends directly on precipitation. In irrigated agriculture, productivity depends on the specific investments made to provide irrigation services, and on the water endowment in the water reservoirs (FAO 2011). In addition to water, three new endowments are considered: *Irrigation Capital, Irrigated Land, and Rainfed Land*.

Irrigation capital includes investments made in a specific type of capital devoted to deliver water from the reservoir to the field. Within this framework, changes in water availability will have different impacts depending on the agricultural sector. For irrigated agriculture, changes in water availability are modeled as changes in the water endowment available for irrigation. For rainfed agriculture changes in water availability are modeled as changes in precipitation.

2.2 Model Structure

The ICES-W model is a multi-region and muti-sector model using the GTAP 7 database (Narayanan and Walmsley 2008) with 2007 as benchmark for the economic equilibrium.

The model asumes perfect competition to simulate adjustment processes. All sectors are modeled using a representative firm maximizing profits. Production processes are specified using nested Constant Elasticity of Substitution (CES) functions. The model uses the ‘‘Armington assumption’’, implying that there is no perfect substitution across domestic and foreign inputs/commodities, therefore allowing for differences among products.

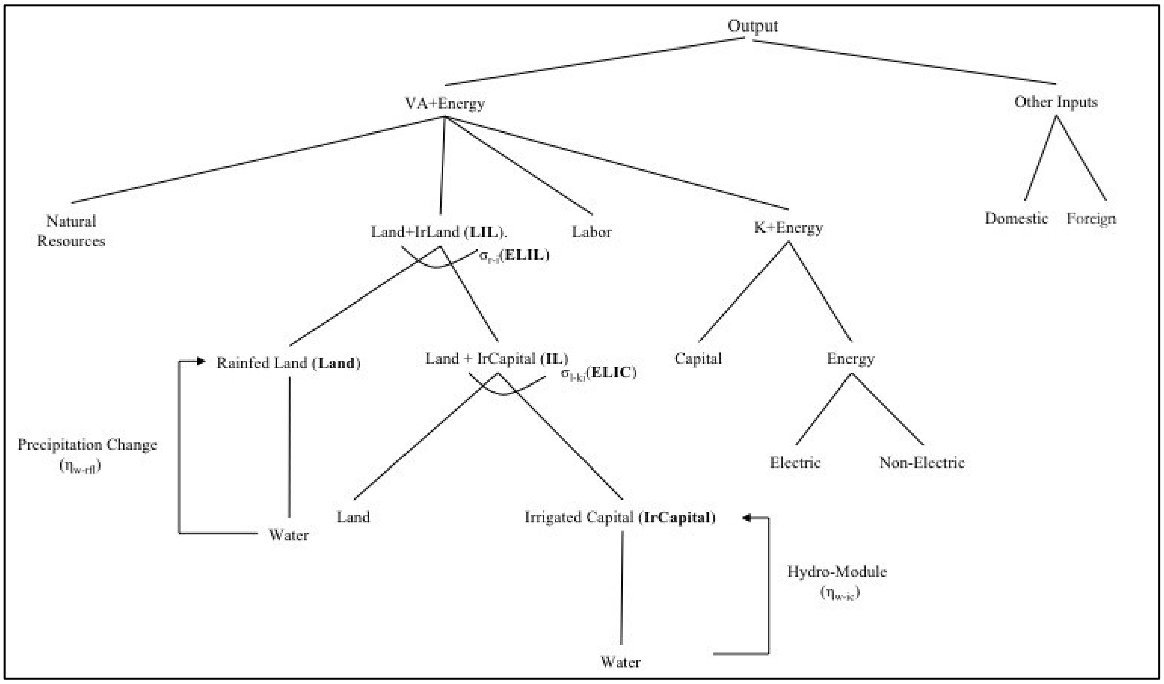
The consumer side of the economy is represented through a representative agent in each region receiving income as the value of national primary factors. In the case of capital and labor, the model assumes they are perfectly mobile domestically, but immobile internationally. National income is allocated between aggregate household consumption, public consumption, and savings.

In the original ICES formulation, the production structure is represented through a series of CES nested production functions as shown in Figure 1. Final output is produced by combining other inputs with a value-added energy composite, which combines primary endowments with a capital-energy composite on the third level

The main changes in ICES-W are included below the third level of Figure 1. On the fourth level, the model differentiates between rainfed land and irrigated land, in order to account for productivity differences, as well as for climate change impacts.

On the next level, irrigated land is a composite of land itself, and capital devoted to irrigation, which is a sector-specific input associated with irrigated land. Finally, the model assumes that the productivity of capital devoted to irrigation as well as the productivity of rainfed land depend on the endowment of water and the precipitation level, respectively. The substitution elasticities ELIL and ELIC were defined based on guesstimates due to lack of empirical evidence supporting specific values. In order to allow for substitution among the new inputs, the elasticity of substitution Rainfed Land-Irrigated Land (ELIL) is greater than the elasticity of substitution Land-Irrigated Capital (ELIC).

Figure 1. ICES-W Production Tree



The production structure presented above applies to the agricultural sector only, which includes the following commodities: rice, wheat, cereals, vegetables and fruits, oilseeds, sugar cane, sugar beets, and plant fibers. For the other sectors, the production structure is the same as the ICES model.

Including water within this new framework implies gathering additional information to incorporate it in the existing database. This comprises the following steps:

a. Split the land endowment into:

- Rainfed land (*Land*)
- Irrigated Land (*IrLand*)

b. Split the capital endowment for agricultural sectors into:

- Irrigation capital (*IrCapital*)
- Rest of physical capital (*Capital*)

c. Build an external module linking the behavior of the irrigation sector with the water endowment in each region.

Each of these steps is explained below.

a. Splitting the land endowment

Irrigated land (*ILND* $_{i,r}$) was computed using the share of area actually irrigated over the total cultivated area (*SHRILND* $_{i,r}$), by commodity *i* in region *r*, according to the information contained in the global groundwater irrigation inventory (Siebert, et al. 2010). The inventory includes information about the area equipped for irrigation (AEI), the area actually irrigated (AAI), and consumptive water use for irrigation (ICWU). The information is available for 204 countries worldwide.

b. Splitting the capital endowment for the agricultural sector

The capital devoted to irrigation represents the investments made in building irrigation schemes. Within the GTAP framework, the capital endowment represents the capital rents associated with each sector. Thus, in order to identify the share of capital devoted to irrigation (*IrCapital*) it is necessary to quantify this type of capital's economic returns. This information was computed using a database containing more than 1,200 irrigation projects worldwide. Four main sources of information were used: FAO (FAO 2003), IWMI (Inocencio, et al. 2007), You *et al* (2009), and the World Bank Implementation, Completion and Results Report (2007a).

FAO (2003) published information for 248 irrigation projects. The geographical disaggregation includes 5 regions: Eastern Asia (EA); Southern Asia (SA); Sub-Saharan Africa (SSA); Near East & North Africa (NENA); Latin America and the Caribbean (LAC). The database is focused on developing countries (33 countries). The information includes: type of investment (rehabilitation/ new development) and investment cost (expressed in 2000 USD), among other information. The represented projects include investments for USD 8 billion and an irrigated area of 7.3 million hectares during the 1980-2000 period.

Inocencio, *et al.* (2007) presented a comparative study of investment costs for different regions. The sample includes 314 irrigation projects in 6 regions: Sub-Saharan Africa (45), the Middle East and North Africa (51), Latin America and the Caribbean (41), South Asia (91), Southeast Asia (68), and East Asia (18). The total sample includes 51 countries. The report includes information about: year when the project started, area under new construction, area under rehabilitation, and total irrigation costs (expressed in 2000 USD), among others. The study reports projects for USD 43.9 billion and 53.6 million hectares from 1965 to 1998.

You, *et al.* (2009) presented a study regarding irrigation spending needs in Africa in order to reach the irrigation potential within the region. The study includes large and small-scale irrigation facilities as operational alternatives. Regarding large-scale irrigation, the study considers 620 dams, in 41 countries. Information about dams includes: number of dams (operational, rehabilitated, planned), hydroelectric capacity (operational, rehabilitated, planned), reservoir capacity (operational, rehabilitated, planned), and investment expenditure, among others.

The internal rates of return for the irrigation projects were extracted from the World Bank Implementation, Completion and Results Report (The Word Bank 2007a). When this information was not available for a specific country, the interest rate from the GTAP database was used.

Information about water storage capacity was collected from the International Commission on Large Dams (ICOLD 2012). The ICOLD database has information for more than 33,000 dams worldwide. Considering that dams could have multiple uses, the model considers only those that have irrigation as one of their possible uses: 18,353 dams in 104 countries.

Using the merged information presented above, it is possible to compute both the total investment in irrigation in each region, (II_r) (see equation 1), and the capital rents associated with irrigation capital *($IKRNT_r$)* (see equation 2).

$$II_r = UIC_r * AEI_r \qquad [1]$$

$$IKRNT_r = II_r * IRR_r \qquad [2]$$

Where UIC_r is the unitary investment cost in irrigation in region *r ($/ha)*, AEI_r is the area equipped for irrigation *(ha)*, and IRR_r is the irrigation projects' internal rate of return in region *r*. The model assumes that the unitary investment cost is the same for all the agricultural commodities within the same region, and that irrigation projects' internal rate of return is the same for all the agricultural commodities within the same region.

Then, we use these capital rents associated to irrigation capital to compute the corresponding share of total capital rents in each region ($TKRNT_r$).

$$SHRKRNT_r = \frac{IKRNT_r}{TKRNT_r} \qquad [3]$$

In order to split the original ICES database it is necessary to modify three value flows in the database: $VFM_{i,j,r}$ represents the producer's expenditure on commodity *i* in sector *j* in region *r* valued at market prices; $EVOA_{i,r}$ represents the value of endowment commodity *i* output in region *r,;* and $EVFA_{i,j,r}$ represents value of purchases of endowment commodity *i* by firms in sector *j* of region *r* evaluated at agents' prices. These values are modified using the computed shares for $SHRIKRNT_r$ and $SHRILND_{i,r}$, as is shown below.

$$VFMI_{IrCapital,j,r} = VFM_{Capital,j,r} * SHRIKRNT_r \quad [4]$$

$$VFMI_{Irland,j,r} = VFM_{land,j,r} * SHRILND_{j,r} \quad [5]$$

$$EVFAI_{IrCapital,j,r} = EVFA_{Capital,j,r} * SHRIKRNT_r \quad [6]$$

$$EVFAI_{Irland,j,r} = EVFA_{land,j,r} * SHRILND_{j,r} \quad [7]$$

$$EVOAI_{IrCapital,r} = EVOA_{Capital,r} * \overline{SHRIKRNT}_r \quad [8]$$

$$EVOAI_{Irland,r} = EVOA_{land,r} * \overline{SHRILND}_r \quad [9]$$

where $VFMI_{i,j,r}$, $EVFAI_{i,j,r}$, $EVOAI_{i,j,r}$ are the modified headers associated with the agricultural commodities. Since $EVOA_{i,r}$ represents the aggregated value paid for the use of capital and land from agricultural commodities, a weighted average share was computed to split these flows: $\overline{SHRIKRNT}_r$ for irrigated capital, and $\overline{SHRILND}_r$ for irrigated land. The procedure is described below:

$$\overline{SHRIKRNT}_r = \frac{\sum_r SHRIKRNT_r * VFM_{IrCapital,r}}{\sum_r VFM_{Capital,r}} \quad [10]$$

$$\overline{SHRILND}_r = \frac{\sum_r SHRILND_r * VFM_{Irland,r}}{\sum_r VFM_{land,r}}$$

[11]

For simplicity it is assumed that the new endowments (*IrCapital*, *IrLand*) face the same tax level as the original ones (Capital, Land).

c. External module linking the behavior of the irrigation sector with the water endowment in each region

The model differentiates between the expected impacts of changes in water availability for both rainfed and irrigated land. For rainfed land, a decrease in precipitation will have impacts on the rainfed land productivity on the same amount, assuming a direct link between precipitation and the agricultural land productivity (η_{w-rfl}).

For irrigated land, this direct relationship does not hold, considering that the capital devoted to irrigation moderates the impact of precipitation changes. A decrease in precipitation affects the productivity of irrigated land by changing the productivity of the capital devoted to irrigation. The hydrologic module links the decreases in precipitation with the changes in water availability that affect the productivity of the capital devoted to irrigation. Finally, the impact of climate change on the productivity of capital for irrigation was computed as the change in irrigated areas due to changes in water availability.

The hydrologic module represents the output flow used for irrigation as a function of changes in precipitation, river flow, temperatures, evapotranspiration, and the evolution of the reservoir's capacity. The module assumes that each region has a unique water storage device (reservoir), with a capacity that is equal to the sum of the reservoirs' capacities of the different countries within the region. It also assumes that the water storage capacity is equivalent to the current water endowment.

The current water balance, relating input and output flows, is depicted in equation [12].

$$Q_{EA} + P_A = Q_{SA} + E_A \qquad [12]$$

where Q_{EA}represents the current input flow, P_A the current precipitation levels, $Q_{SA}$the current output flow, and E_A the current evapotranspiration of the reservoir. On the other hand the current output flow is a function of the irrigation demand plus other water uses, as is shown in equation [13].

$$Q_{SA} = ID_A + OU \qquad [13]$$

The irrigation demand uses share α of the total output flow

$$ID_A = \alpha * Q_{SA} \quad [14]$$

The future climate change scenario implies changes in both river flows and precipitation:

$$Q_{EF} = (1 + x) * Q_{EA} \quad [15]$$

$$P_F = (1 + \gamma) * P_A \quad [16]$$

where Q_{EF} represents the future input flow, P_F is the future precipitation level, and x, γ represent the expected changes in these variables. The changes in the current values of both input and output flows will drive a change in the reservoir's water volume. The change in the reservoir's water volume, ΔV, is the difference between future input flows and current output flows, and it is related to the maximum water volume in the reservoir:

$$\Delta V = R * V_{MAX} = Q_{EF} + P_F - Q_{SA} - EA \quad [17]$$

where R is the proportion to which the volume of water in the reservoir will change. R could be written as:

$$R = \frac{-x * Q_{EA} - \gamma * P_A}{V_{MAX}} \quad [18]$$

The greater the R value, the greater the impacts of climate change on the water volume in the reservoir. Regions with small water endowments, V_{MAX}, will face large changes in their reservoir's water volume.

The future irrigation demand, ID_F, is:

$$ID_F = \sum_{i=1}^{N} C_i * A_{iF} = \sum_{i=1}^{N} C_i * (1 - z) * A_{iA} \quad [19]$$

were C_i represents the irrigation requirements for crop i, A_{iA} represents the current area of crop I under irrigation, while A_{iF} represents the future irrigated area of crop i, and z represents the change in the irrigated area. Using equations [11] to [17], the change in the irrigated area can be written as:

$$z = 1 - \frac{\alpha * \left(\frac{DR_A}{\alpha} - \frac{DR_A}{\alpha} * x + P_A * x - E * x - P_A * \gamma \right)}{\sum_{i=1}^{N} C_i * A_i} \qquad [20]$$

According to equation [19], negative changes in both precipitation and river flows have negative impacts on the irrigated area, reducing the productivity of the capital devoted to irrigation by the same amount.

3. Comparing outputs from ICES and ICES-W.

To account for the additional information that ICES-W can provide compared to the standard version of ICES, we run a simulation where both models are affected by the same productivity shock. In the standard ICES model the climate shock implies a decrease in land productivity of 15%, while in the ICES-W model the productivity changes are -15% for rainfed land and -15% for irrigated land. The analysis of both models is restricted to input relationship (rainfed/irrigated land), crop production, crop prices, international trade, and the impact on the global GDP.[6]

Regarding inputs, in the standard version of ICES the decrease in land productivity generates an increase of 74.5% in the average price paid for land. At the regional level, EU27 shows the main increase in the price paid for land in the rice sector (139%), while SEA shows the small increase in the price paid for land in the wheat sector (33.18%). Regarding land demand, on average it increases by 2.7%. However, the SEA region shows a decrease in its demand (-13.69%), while in the EU27 the demand for land increases by 21.51%. This result is consistent with each area's cost structure, in which the cost share of land for rice production in the EU27 is the smallest (6%). On the other hand, the cost share of land for wheat production in SEA is the greatest (34.6%).[7] Tables 1 and 2 present details about land demand and land prices, respectively.

In order to sustain the level of production, the standard ICES model allows for substitution among inputs at the top level of the production tree. The increase in land prices drives a substitution between land and other inputs, such as labor and capital. The model generates an increase in labor

[6] A detailed breakdown of regions and sectors is presented in Annex 1.

[7] Details regarding baseline information are shown in Annex 2.

demand by 3.23% and capital demand by 3.48%. Rice production in the EU27 region presents the higher substitution between land and labor, as well as between land and capital. Both changes are driven by the large increase in land prices faced by the EU27 (Details in Tables 3 and 4).

Table 1. Changes in Land Demand (%): Standard ICES Model.

Commodities	Rice	Wheat	CerCrops	VegFruits	OilSeeds	SugarC_B	PlantFiber
Oceania	15.6	0.7	7.9	7.3	2.7	3.6	2.1
China	4.3	2.6	4	3.6	-0.2	4	5
EastAsia	2.3	-3.3	-0.2	1.1	-12.1	1.4	2.4
SEA	6.3	-13.7	-3.3	0.3	-1.7	6.6	-9.7
SouthAsia	6.4	4.2	2.6	5.8	-0.1	6.7	3.2
India	3	0.1	0.3	1	2.4	3.4	1
USA	7.8	-5	2.6	4.2	2	4.7	-0.2
RoNAmerica	-3.6	11.4	2.1	1.5	13.7	3.9	2.8
Argentina	5.6	-0.7	3.2	2.3	3.7	1.5	1.2
Bolivia	1.5	5.1	3.1	2.6	1.6	1.8	12.5
Brazil	0.6	6.5	2.4	2.2	6.1	0.6	1.3
Chile	2.8	2	4.5	1.9	5.1	2.9	2.5
Peru	5.6	-4.3	0.9	3.3	2.9	5.6	3.1
RoLAC	3.7	-2.9	3	4.4	2.3	4.1	3.4
EU27	21.5	4.6	2.7	1.4	2.4	0.6	-1.2
MENA	5.2	4	9	2.1	2.5	0.4	3.7
SSA	3.4	4.2	2.2	1.3	0.3	0.4	2.3
RoW	5	1.4	2	2.6	0.8	3.2	4.5

Table 2. Changes in Land Prices (%): Standard ICES Model

Commodities	Rice	Wheat	CerCrops	VegFruits	OilSeeds	SugarC_B	PlantFiber
Oceania	91.6	66.9	78.9	77.9	70.3	71.7	69.3
China	73.7	70.9	73.2	72.5	66.3	73.3	75
EastAsia	100.7	89.8	95.8	98.4	72.6	99	100.9
SEA	64	33.2	49.3	54.8	51.8	64.6	39.4
SouthAsia	49.4	46.3	44.1	48.6	40.4	49.9	44.9
India	76.6	71.7	72	73.1	75.6	77.3	73.3
USA	85.6	63.6	76.7	79.5	75.7	80.4	71.9
RoNAmerica	65.2	91	75	74.1	95	78.1	76.1
Argentina	70.9	60.8	67.1	65.6	67.9	64.3	63.8
Bolivia	57.7	63.3	60.1	59.3	57.8	58.2	74.7
Brazil	83.7	94.5	87.1	86.7	93.7	83.6	85
Chile	82	80.7	85.1	80.5	86.1	82.3	81.6
Peru	69	53.1	61.5	65.4	64.7	69	65
RoLAC	66	55.4	64.9	67.1	63.7	66.7	65.6
EU27	139.5	106.1	102.4	99.9	101.8	98.2	94.7
MENA	88.5	86.3	95.2	82.9	83.6	79.9	85.8
SSA	91.2	92.6	89	87.3	85.5	85.7	89.1
RoW	70	64.2	65.1	66.2	63.3	67.1	69.2

Table 3. Changes in Labor Demand (%): Standard ICES Model

Commodities	Rice	Wheat	CerCrops	VegFruits	OilSeeds	SugarC_B	PlantFiber
Oceania	18.3	-0.1	8.8	8	2.4	3.4	1.7
China	4.8	2.7	4.4	3.9	-0.7	4.5	5.7
EastAsia	5.8	-1.1	2.7	4.3	-12.1	4.8	6
SEA	5.7	-18.1	-5.8	-1.5	-3.9	6.2	-13.4
SouthAsia	4	1.3	-0.5	3.2	-3.7	4.4	0.1
India	5	1.4	1.6	2.4	4.2	5.5	2.5
USA	9.5	-6.2	3.1	5.1	2.4	5.7	-0.4
RoNAmerica	-4.5	14.1	2.5	1.8	17	4.7	3.3
Argentina	5.8	-1.8	2.9	1.8	3.5	0.8	0.4
Bolivia	0.1	4.5	2	1.4	0.1	0.5	13.5
Brazil	2.1	9.5	4.4	4.1	9	2.1	3
Chile	4.1	3.2	6.3	3	7	4.3	3.8
Peru	5.5	-6.5	-0.2	2.7	2.2	5.5	2.4
RoLAC	3	-5	2.2	3.9	1.3	3.6	2.7
EU27	30.8	8.8	6.4	4.8	6	3.7	1.5
MENA	7.5	5.9	12.1	3.5	4.1	1.5	5.6
SSA	5.8	6.7	4.3	3.1	1.9	2	4.3
RoW	4.9	0.5	1.2	2	-0.2	2.7	4.3

Table 4. Changes in Capital Demand (%): Standard ICES Model

Commodities	Rice	Wheat	CerCrops	VegFruits	OilSeeds	SugarC_B	PlantFiber
Oceania	18.3	-0.1	8.8	8	2.4	3.4	1.6
China	5	3.1	4.7	4.2	-0.4	4.8	6.1
EastAsia	5.8	-1.1	2.7	4.3	-12.1	4.8	5.9
SEA	5.8	-18	-5.6	-1.4	-3.7	6.5	-13.2
SouthAsia	4.4	1.8	-0.2	3.5	-3.4	4.8	0.5
India	5.2	2.1	2.1	2.9	4.7	5.9	3
USA	9.5	-6.3	3	5.1	2.3	5.7	-0.4
RoNAmerica	-4.5	14.1	2.5	1.8	17	4.7	3.3
Argentina	6.1	-1.6	3.1	1.9	3.7	1	0.7
Bolivia	0.2	4.6	2.1	1.4	0.2	0.6	13.6
Brazil	2.1	9.5	4.4	4.1	9	2.1	3
Chile	4.1	3.2	6.3	3	7	4.3	3.8
Peru	5.5	-6.5	-0.1	2.8	2.3	5.6	2.5
RoLAC	3.1	-4.9	2.3	4	1.4	3.7	2.8
EU27	30.8	8.7	6.3	4.7	6	3.6	1.4
MENA	7.5	6	12.2	3.6	4.1	1.5	5.6
SSA	6	6.9	4.5	3.3	2.1	2.2	4.5
RoW	5	0.7	1.4	2.1	0	2.8	4.5

As a consequence of the decrease in productivity, the price paid for both types of land (rainfed and irrigated) increases in the ICES-W. On average, rainfed land increases its prices by 70.4%, while irrigated land increases its prices by 86.2%. The EU27 shows the higher increase in rainfed land price (140%) while South Asia the smallest increase (27.6%). In general, under the ICES-W structure most of the products and regions pay lower prices for rainfed land, with the exception of rice production in the EU (details can be found in Table 5).

At the country level, the main differences in land prices are reported for Chile's cereal production and for the EU27's rice production. In the first case, the land's price is higher under the standard ICES, while in the latter the land's price is larger under ICES-W. In general, the lower prices showed by ICES-W are due to the new substitution options presented in the model.

Rainfed land and irrigated land are substitutes if an increase in the price of rainfed land drives an increase of the demand for irrigated land. According to the ICES-W model, the demand for irrigated land presents a small increase of 0.06%. A closer look at the country level shows that in those countries with large irrigated land endowment, the substitution is more likely. An example in this regard is Chile with 63% of its agricultural land under irrigation. In this case the substitution between rainfed and irrigated land holds for six out of seven agricultural products. For those countries with small areas under irrigation, such as Bolivia (3.4%), Argentina (4%), and Brazil (4.6%), the substitution, from rainfed land to irrigated land, does not hold due to the relative scarcity of irrigated land (details can be found in Tables 6 and Table 7).

In general terms both models, ICES and ICES-W, present similar results in terms of change in production, international trade, and the impact on global GDP. Regarding production, agricultural production decreases by the same proportion (1.8%). At the regional scale, differences in production are negligible. As a result of this decrease in production, prices increase by around 15% in both models. At the GDP level, simulations show a decrease of 0.4% in both cases (details can be found in Annex 4).

There is a quite clear substitution between irrigated and rainfed land for agricultural production. Due to this feature of ICES-W, the increase in the price paid by land is smaller than the increase showed by the standard ICES. It is worth noticing that the analysis presented here constrains the substitution options within ICES-W because the productivity shock faced by irrigated land is the same as that faced by rainfed land, taking no notice of the role played by the water endowment, which reduces the shock for the irrigated land through changes in irrigation capital productivity.

Table 5. Changes in Rainfed Land Prices (%): ICES-W Model.

Commodities	Rice	Wheat	CerCrops	VegFruits	OilSeeds	SugarC_B	PlantFiber
Oceania	91.4	66.7	78.5	77.4	70.1	71.1	68.7
China	65.4	62.4	63.7	63.9	57.5	64.9	66
EastAsia	94.7	84.1	89.9	92.4	67.3	92.9	94.9
SEA	62.8	32.3	48.3	53.8	50.6	63.4	38.4
SouthAsia	37.8	34.1	31.6	36.6	27.6	38.6	32.7
India	71.3	66.5	66.9	67.9	70.4	71.9	67.9
USA	84	61.9	74.8	77.6	73.9	78.5	70.1
RoNAmerica	64.2	90	73.9	73	93.8	76.9	75
Argentina	70.7	60.7	66.8	65.3	67.6	63.9	63.4
Bolivia	57	62.7	59.5	58.7	57.1	57.4	74.4
Brazil	80.3	90.9	83.6	83.2	90.3	80.3	81.7
Chile	66.5	65.3	68.3	64	70	66.8	65.8
Peru	64.9	49.3	57.5	61.3	60.6	64.9	60.9
RoLAC	64.2	53.6	63.1	65.3	61.9	64.9	63.9
EU27	140	105.5	101.6	99.1	101.1	97.3	93.9
MENA	81.3	78.8	87.6	75.8	76.4	73	78.6
SSA	90.7	92.1	88.5	86.6	84.9	84.9	89
RoW	67.7	61.7	62.8	63.6	60.8	64.4	66.5

Table 6. Changes in Rainfed Land Demand (%): ICES-W Model.

Commodities	Rice	Wheat	CerCrops	VegFruits	OilSeeds	SugarC_B	PlantFiber
Oceania	16.2	1.1	8.3	7.6	3.2	3.8	2.4
China	10.4	8.5	9.3	9.4	5.2	10.1	10.8
EastAsia	5	-0.7	2.4	3.7	-9.8	4	5.1
SEA	7.1	-13	-2.5	1.2	-0.9	7.5	-9
SouthAsia	15	11.9	9.8	14	6.5	15.6	10.7
India	5	2.1	2.3	3	4.4	5.4	3
USA	9.1	-4	3.6	5.3	3.1	5.8	0.8
RoNAmerica	-2.8	12.4	2.9	2.3	14.7	4.7	3.5
Argentina	6	-0.3	3.5	2.6	4	1.7	1.4
Bolivia	1.7	5.4	3.3	2.8	1.8	2	13
Brazil	0.9	6.8	2.7	2.5	6.5	0.9	1.7
Chile	11.1	10.3	12.3	9.4	13.4	11.3	10.7
Peru	8	-2.3	3.1	5.6	5.1	8	5.4
RoLAC	4.9	-1.9	4.1	5.5	3.4	5.3	4.6
EU27	23	5.3	3.3	2	3.1	1.1	-0.6
MENA	8.2	6.8	12	4.9	5.3	3.3	6.6
SSA	3.6	4.4	2.4	1.4	0.5	0.4	2.7
RoW	6	2.2	2.9	3.4	1.6	3.9	5.2

Table 7. Changes in Irrigated Land Demand (%): ICES-W Model.

Commodities	Rice	Wheat	CerCrops	VegFruits	OilSeeds	SugarC_B	PlantFiber
Oceania	10	-4.3	2.4	1.9	-2.4	-1.7	-3.1
China	1	-0.8	0	0.1	-3.8	0.7	1.3
EastAsia	1.2	-4.2	-1.2	0	-13	0.4	1.3
SEA	4.9	-14.8	-4.5	-0.9	-3	5.3	-10.8
SouthAsia	2.3	-0.5	-2.3	1.4	-5.3	2.9	-1.5
India	1.5	-1.3	-1.1	-0.4	1	1.9	-0.4
USA	5.3	-7.3	0.1	1.7	-0.4	2.2	-2.6
RoNAmerica	-6.7	8.5	-1.1	-1.7	10.8	0.5	-0.5
Argentina	2.8	-3.3	0.4	-0.5	0.9	-1.3	-1.6
Bolivia	-0.9	2.7	0.7	0.2	-0.8	-0.6	10.1
Brazil	-2.4	3.3	-0.7	-0.9	3	-2.5	-1.7
Chile	1.1	0.3	2.1	-0.5	3.2	1.2	0.6
Peru	4	-5.9	-0.7	1.7	1.2	4	1.4
RoLAC	0.2	-6.3	-0.5	0.8	-1.2	0.6	0
EU27	19.7	2.4	0.5	-0.7	0.3	-1.7	-3.3
MENA	2	0.6	5.6	-1.1	-0.7	-2.7	0.5
SSA	1.4	2.6	0.4	-0.4	-1.5	-1.2	0.5
RoW	2.2	-1.1	-0.7	0.2	-1.7	0.7	2.1

4. The Economy-Wide Impacts of Climate Change on the Latin American Agricultural Sector.

Climate change is already happening in the Latin American Region. The region has shown an increase in the median temperature within the 1906-2005 period (CEPAL 2010). Regarding precipitations, within the same period, some countries in the region (Paraguay, Uruguay, and Bolivia) faced increases in precipitation, while in the north, northeast, and northwest regions precipitation has decreased. Furthermore, there is evidence showing a decrease in glaciers' surface areas, threatening long-term water supply.

The expected impacts of climate change during the current century imply an increase in temperatures, ranging from 1 to 6 degrees depending on the scenario analyzed, along with a change in precipitations within the range -40% to 10%. According to those projections, the most vulnerable sectors are: agriculture, health, coastal zones, and biodiversity (Parry, et al. 2007).

The Latin American Region, like many developing regions, has based its development on rural natural resource activities (agriculture, forestry and fishing). Agriculture is a key economic sector within the Latin American region, accounting for 6% of the GDP in 2010, and 15% of the total employment in 2009 (The World Bank 2007b). The agricultural sector also plays an important role in international markets: Argentina and Brazil are major producers of sugar cane, wheat, maize, and fruits, among other products (FAO 2010). Within this context, any shock in agricultural production in the Latin American region will have regional and global consequences.

This section presents the application of the ICES-W model that was described in section 2; it aims at accounting for the economy-wide impacts of climate change on the Latin American agricultural sector. The modeling framework differentiates between rainfed and irrigated agricultural, accounting for different climate change impacts, the former through changes in precipitations, and the latter through changes in irrigated areas.

4.1 Regional aggregation

For this assessment, we setup ICES-W for 18 regions (6 in Latin America: Argentina, Brazil, Bolivia, Chile, Peru, Rest of Latin America and the Caribbean – RoLAC), and 19 sectors (7 in agriculture: rice, wheat, cereals, vegetables and fruits, oilseeds, sugar cane and sugar beet, and plant fibers).

In the baseline scenario (2007) average irrigated land (*ILND*) is 22%, while capital devoted to irrigation (*KRNT*) represents 2.1% of total capital rents. Details per region are presented in Table 8.

Table 8. Baseline Irrigated Land and Capital for Irrigation

Region	ILND	KRNT
Oceania	2%	1.8%
China	43%	1.5%
EastAsia	49%	0.5%
SEA	19%	1.4%
SouthAsia	49%	9.6%
India	34%	6.6%
USA	14%	1.1%
RoNAmerica	8%	0.8%
Argentina	4%	1.3%
Bolivia	3%	1.5%
Brazil	5%	1.7%
Chile	63%	0.5%
Peru	34%	1.9%
RoLAC	11%	1.0%
EU27	9%	0.5%
MENA	27%	1.6%
SSA	3%	1.3%
RoW	11%	3.9%

Regarding climate shocks, we follow Calzadilla, *et al.* (2010) who reported how both precipitation and river flows would change according to the A2 IPCC scenario in 2040 (Intergovernmental Panel on Climate Change 2000). According to this information, it is expected that global precipitation would increase by 1.2%, while global river flow is likely to decrease by 0.2%, driving a decrease of irrigated land (-0.21%). In Latin America a decrease of 6.1% in precipitation is expected, while the river flows are predicted to decrease by 11.3%, driving a reduction of 11.3% in the irrigated area.

Table 9. Precipitation Changes and Water Endowment

Region	Precipitation Change (%)	Water Endowment (1,000 m3)	River Flow Changes (%)	Change on Irrigated Area (*z*)
Oceania	-6.1%	43,952,190	6.1%	6.10%
China	1.9%	353,014,985	-0.7%	-0.67%
EastAsia	5.4%	32,091,159	10.7%	10.67%
SEA	3.0%	110,067,892	2.3%	2.30%
SouthAsia	2.6%	29,686,787	9.0%	8.99%
India	12.0%	250,733,288	35.0%	35.00%
USA	3.0%	358,361,628	2.3%	2.30%
RoNAmerica	9.7%	90,670,783	4.2%	4.22%
Argentina	-1.5%	186,000,000	-6.0%	-6.00%
Bolivia	-6.0%	161,500	-12.0%	-12.00%
Brazil	-6.0%	68,239,288	-12.0%	-12.0%
Chile	-1.5%	7,741,090	-6.0%	-6.00%
Peru	-6.0%	3,104,600	-12.0%	-12.00%
RoLAC	-15.4%	65,000,720	-19.9%	-19.85%
EU27	1.5%	80,355,319	-0.5%	-0.47%
MENA	25.3%	218,429,701	20.7%	20.70%
SSA	-1.5%	322,517,661	-25.3%	-25.26%
RestofWorld	0.5%	411,038,083	0.3%	0.27%

Source: Based on Calzadilla et al 2012.

Table 9 presents details associated with the shocks imposed to the model: precipitation changes, water endowment, river flow changes, and the expected change in irrigated land according to the reduced form hydro-module.The model assumes that the current level of precipitation is the optimum for the current level of agricultural production. In this regard, the model simulates only impacts of a decrease in precipitation, while an increase in precipitation has no impact on agricultural production. On the other hand, the data collected from the ICOLD database (ICOLD 2012) contains dams that have irrigation as only one of their purposes. Thus, it is possible to have dams that provide water for both irrigation and power generation uses. Considering this feature, the model assumes that 60% of the water endowment in each region is used for irrigation.

4.2 Results

Climate change impacts are not the same across regions, generating diverse impacts on water availability. The expected change in precipitation at the global level (1.2%) would drive an increase in the price paid for rainfed land in all regions (5.1% on average). For the Latin American region, the expected change is 10.9%, consistent with the large climate shock faced by this region. At the regional level, the main increase in rainfed land prices is reported in Rest of Latin America (RoLAC), which is also the region facing the largest decrease in precipitation. On the other hand, Argentina and Sub Saharian Africa (SSA) report almost the same increase in rainfed land prices, 5% and 6.1% respectively, which is consistent with their decreases in precipitation (Table 10).

Table 10. Changes in Rainfed Land Price. (%).

Commodities	Rice	Wheat	CerCrops	VegFruits	OilSeeds	SugarC_B	PlantFiber
Oceania	8.7	4.8	8.2	9.6	6.5	10.4	8.1
China	0.4	0.7	0.9	0.4	0.8	0.4	0.6
EastAsia	0.7	1.5	1	0.7	1.1	0.6	0.9
SEA	0.8	1.6	1.2	0.9	0.9	0.8	1.3
SouthAsia	0.4	0.7	0.7	0.4	0.9	0.3	0.5
India	0.4	0.5	0.5	0.4	0.4	0.4	0.4
USA	4.5	2.8	2.9	2.5	2.8	2.2	2.3
RoNAmerica	2.4	3.4	2.5	2.7	3.3	2.1	2.1
Argentina	8.9	3.9	4.4	4.5	4.5	4.4	4.6
Bolivia	14.7	13.9	14.3	13.9	14.1	14.7	13.9
Brazil	16.7	11.5	15.1	15.7	15.2	16.6	13.7
Chile	3.2	3.2	4.1	3.9	3.5	3.2	3.2
Peru	8.1	6.1	7.2	7.5	8	8.1	7.6
RoLAC	21.6	11.9	18.2	20.9	19.7	26.2	21.3
EU27	3	2.5	2.8	2.8	3.2	2.2	2.3
MENA	1.1	1.5	1.7	1.2	1.7	1	1.3
SSA	6.1	6.1	6.2	6.3	6.2	6.5	5.7
RoW	0.8	1	1	0.9	1.3	0.8	1

Irrigated land prices increase by an average of 2.8% worldwide, while the Latin American region presents a larger increase in this price (6.3%). At the regional level, the RoLAC region presents the largest regional increase in prices (12.63%). This is explained, in part, by the small proportion of capital available for irrigation (1%), which drives a large reduction in irrigated areas (-19.8%). On the other hand, China shows the smallest average increment in the irrigated land's price (0.68%), this is expected due to the small decrease in irrigated land (-0.67%) (see Table 11).

Table 11. Changes in Irrigated Land Price (%).

Commodities	Rice	Wheat	CerCrops	VegFruits	OilSeeds	SugarC_B	PlantFiber
Oceania	7.4	3.6	7	8.3	5.3	9.2	6.8
China	0.5	0.7	1	0.5	0.9	0.5	0.7
EastAsia	0.7	1.6	1	0.7	1.2	0.7	0.9
SEA	0.9	1.7	1.2	0.9	1	0.8	1.3
SouthAsia	0.6	1	0.9	0.7	1.1	0.6	0.8
India	0.4	0.5	0.5	0.4	0.4	0.4	0.4
USA	4.8	3	3.2	2.8	3.1	2.5	2.6
RoNAmerica	2.7	3.7	2.8	3	3.5	2.4	2.4
Argentina	7.3	2.4	2.9	3	3	2.8	3.1
Bolivia	9.1	8.4	8.7	8.4	8.6	9.1	8.4
Brazil	5.2	0.5	3.7	4.3	3.9	5.1	2.5
Chile	3.6	3.6	4.5	4.3	3.9	3.6	3.6
Peru	6	4.1	5.2	5.4	6	6	5.6
RoLAC	14.1	5.1	11	13.5	12.4	18.5	13.9
EU27	3.1	2.7	2.9	2.9	3.3	2.4	2.4
MENA	1.3	1.7	1.9	1.4	1.9	1.2	1.4
SSA	-8.2	-9	-8.4	-8.6	-8.4	-8.8	-8.6
RoW	0.9	1.1	1.1	1	1.4	0.9	1.1

The main improvement gained by using the ICES-W model is related to the new substitution options between land types within the agricultural sector. Results show that the substitution feature is a function of the share of irrigated land, water endowment (through the change in irrigated areas), and the productivity shock.

Nevertheless, the substitution feature does not hold for Chile since it is the country with the largest irrigated land share (63%). A closer look into the Chilean agricultural structure shows that the small share of irrigation capital drives a large decrease in irrigated land productivity, which is four times the decrease in rainfed land productivity. For this reason, the substitution options are constrained by the large decrease in the productivity of the substitute input.

For Brazil, a major player in the agricultural sector, the substitution between irrigated and rainfed land holds for rice, cereals, and sugar cane/beets. On average, the irrigated land demand decreases by 0.3% in Brazil. This could be explained by the small share of irrigated land (5%), and by the large decrease in irrigated land agriculture (12%).

Table 12. Changes in Irrigated Land Demand. (%).

Commodities	Rice	Wheat	CerCrops	VegFruits	OilSeeds	SugarC_B	PlantFiber
Oceania	0.4	-3.2	0	1.3	-1.6	2	-0.2
China	-0.1	0.2	0.4	-0.1	0.3	-0.1	0.1
EastAsia	-0.1	0.8	0.2	-0.1	0.4	-0.1	0.1
SEA	-0.1	0.7	0.2	-0.1	0	-0.1	0.3
SouthAsia	-0.1	0.2	0.1	-0.1	0.4	-0.2	0
India	0	0	0	0	0	-0.1	0
USA	1.8	0.1	0.2	-0.2	0.1	-0.5	-0.4
RoNAmerica	-0.2	0.7	-0.1	0.1	0.6	-0.5	-0.5
Argentina	4.3	-0.5	0	0	0.1	-0.1	0.2
Bolivia	0.5	-0.2	0.1	-0.2	0	0.5	-0.2
Brazil	1.2	-3.3	-0.2	0.4	0	1.2	-1.4
Chile	-0.6	-0.6	0.4	0.1	-0.2	-0.6	-0.6
Peru	0.7	-1.1	-0.1	0.2	0.7	0.7	0.3
RoLAC	1.3	-6.7	-1.5	0.7	-0.2	5.2	1.1
EU27	0.2	-0.2	0	0	0.4	-0.5	-0.4
MENA	-0.2	0.2	0.4	-0.1	0.4	-0.3	0
SSA	0.3	-0.5	0.1	-0.1	0.1	-0.4	-0.1
RoW	-0.2	0	0.1	0	0.3	-0.2	0

Oceania is affected differently by the impacts of climate change, depending on the land type: there is a null impact for irrigated land, and a negative impact for rainfed land. In this case, the demand for irrigated land decreases when the rainfed land price increases. Nevertheless, there are signs to move from rainfed land to irrigated land (due to the relatively large water endowment); however, the region has little space to do this due to the small share of irrigated land (Table 12).

Climate change would drive a decrease of 0.5% in the agricultural output at the global level. For the Latin American region, this change would be -1.6%. At the regional level, in the RoLAC region, a decrease of 6.3% in agricultural output is expected, which is explained by the large productivity shock in both types of land, both rainfed (-15.4%) and irrigated (-19.9%). On the other hand, regions that do not face productivity shocks (East Asia, SEA, South Asia, India, USA, RoNAmerica, and MENA) show an output increase.

Brazil and Bolivia show the main reductions within the Latin American region (-1.6% and -1.7%). For Chile, nevertheless, a decrease in the irrigated land demand is expected, causing quite large productivity impacts. Chile also shows an increase of 0.23% in its agricultural output, which also occurred in Argentina. This increase in production is reached through an increase of land (0.47%), labor (0.47%), and capital demand (0.48%). These demand increases compensate for the productivity shock faced by both rainfed and irrigated land. At the activity level, Argentina shows the main increase in rice production (5%), while the RoLAC region shows the largest decrease in wheat production (-13.3%). In general, wheat it the most affected activity with a decrease in production of -1.3% (Table 13).

Table 13 Changes in Agricultural Production

	Rice	Wheat	CerCrops	VegFruits	OilSeeds	SugarC_B	PlantFiber
Oceania	-1.9	-6.0	-2.4	-0.9	-4.2	0.0	-2.6
China	0.0	0.3	0.6	0.0	0.5	0.0	0.3
EastAsia	0.0	1.1	0.4	0.1	0.6	0.0	0.3
SEA	0.0	0.9	0.4	0.1	0.1	0.0	0.5
SouthAsia	0.0	0.4	0.3	0.0	0.6	-0.1	0.1
India	0.0	0.1	0.1	0.1	0.0	0.0	0.1
USA	2.7	0.7	0.8	0.4	0.7	0.0	0.2
RoNAmerica	0.4	1.6	0.4	0.7	1.4	0.0	0.1
Argentina	5.0	-0.7	-0.1	-0.1	-0.1	-0.3	0.2
Bolivia	-1.2	-2.0	-1.7	-2.0	-1.8	-1.2	-2.0
Brazil	0.1	-5.1	-1.5	-0.8	-1.3	0.1	-2.9
Chile	-0.1	-0.1	1.0	0.7	0.3	-0.1	-0.1
Peru	-0.1	-2.2	-1.0	-0.8	-0.2	-0.1	-0.5
RoLAC	-4.6	-13.3	-7.6	-5.2	-6.3	-0.4	-4.8
EU27	0.9	0.4	0.7	0.7	1.2	0.0	0.1
MENA	0.1	0.6	0.8	0.2	0.8	0.0	0.3
SSA	-0.4	-0.4	-0.2	-0.2	-0.2	-0.1	-0.8
RoW	0.0	0.2	0.3	0.2	0.6	0.0	0.2

At the international level, it is expected an inverse relationship between change in the agricultural output and the direction of the international commerce. For those countries facing a decrease in their agricultural output, there is an increase of imports and a decrease of exports. At the global level, a decrease of 1.2% is expected in agricultural exports. For the Latin American region, the decrease in exports is 6%, while the increase in imports is 1.8%.

At the regional level, RoLAC shows the largest decrease in exports (17.7%), and the largest increase in imports (7.33%). At the activity level, Argentina's large increase in rice production drives a change in rice exports (17.3%), in fact only rice production increases in that country. Sugar and wheat trade is the most affected by the climate change impacts, with an increase in the dependency on the national production for Bolivia, India, Rest of North America (RoNAmerica), East Asia and SSA. On the other hand, only for Brazil, Chile and the United States are the changes in exports larger than the changes in imports (Table 14 and Table 15).

Table 14. Export Changes (%).

	Rice	Wheat	CerCrops	VegFruits	OilSeeds	SugarC_B	PlantFiber
Oceania	-8.9	-6.9	-5.1	-3.2	-4.5	-5.6	-5.8
China	2.9	5.6	2.6	1.6	2.5	2.3	2.6
EastAsia	2.7	3.5	3.1	1.3	2.0	2.3	2.8
SEA	1.9	0.9	1.6	0.5	1.2	1.3	0.0
SouthAsia	2.5	1.1	1.6	0.9	1.4	1.7	1.6
India	2.4	3.8	2.4	1.6	2.6	2.0	1.3
USA	8.1	0.9	1.8	0.8	1.5	17.1	0.8
RoNAmerica	0.0	1.7	3.3	1.8	1.9	0.9	1.8
Argentina	17.3	-0.9	-0.1	-0.2	0.3	-1.9	2.8
Bolivia	-16.5	-10.1	-12.1	-8.9	-2.2	-9.6	-3.5
Brazil	2.3	-7.6	-6.8	-3.3	-2.9	-7.5	-5.6
Chile	-0.5	-0.6	2.3	0.8	0.6	0.2	-2.5
Peru	-18.1	-13.1	-5.9	-2.4	-5.8	-7.7	1.7
RoLAC	-24.8	-23.1	-18.0	-12.3	-10.5	-21.0	-13.9
EU27	2.0	1.1	2.1	1.5	2.7	1.0	0.9
MENA	2.1	2.1	2.8	1.7	2.7	2.2	1.5
SSA	-3.1	-1.0	-0.6	-0.4	-0.6	-0.7	-1.0
RoW	1.4	1.5	2.2	1.5	2.4	1.2	1.1

Table 15. Import Changes (%).

	Rice	Wheat	CerCrops	VegFruits	OilSeeds	SugarC_B	PlantFiber
Oceania	3.3	1.3	1.9	1.9	0.8	3.0	2.0
China	-1.3	-1.2	-1.7	-0.5	-0.3	-3.5	-0.7
EastAsia	-1.8	-0.3	-0.6	-0.5	-0.2	-1.6	-0.5
SEA	0.6	-0.2	-0.2	0.0	-0.3	-1.3	-0.2
SouthAsia	-1.5	-1.6	-0.5	-0.2	-0.8	-1.6	-0.5
India	-1.0	-0.2	-0.7	-0.6	-0.7	-2.0	-0.8
USA	2.0	0.7	-2.7	-1.4	-0.4	-0.7	-0.4
RoNAmerica	-0.2	-0.1	-0.8	-0.2	-0.2	-1.0	-0.4
Argentina	1.6	2.1	-1.8	-2.0	-5.5	0.0	-1.0
Bolivia	7.8	0.2	5.0	3.7	3.0	3.2	-1.4
Brazil	-3.9	-0.1	2.3	2.2	-4.7	3.2	-0.2
Chile	-0.7	-0.4	-0.3	-2.7	-0.1	-1.0	-0.2
Peru	3.6	3.8	2.7	2.5	0.3	3.6	0.9
RoLAC	19.9	2.9	9.2	6.1	1.5	4.4	5.8
EU27	-0.2	-0.2	-0.9	0.0	-0.9	-0.9	-0.5
MENA	0.3	-0.9	-0.9	-0.3	-0.9	-0.9	-0.6
SSA	1.7	0.1	0.1	0.5	0.2	0.1	-0.4
RoW	-0.4	-0.7	-0.8	-0.9	-0.6	-0.4	-0.3

The climate shock drives an increase in prices for all regions and products. This is determined by the -0.5% decrease in agricultural production. The raise in agricultural prices is 1%, with rice increasing the most (1.2%), and wheat and plant fibers increasing the least (0.8%). At the regional level, the biggest change is reported in RoLAC (5.2%), followed by Bolivia (2.8%) and Peru (2.1%). Regarding agricultural commodities, the main increase in prices is related to the large decrease in production. An exception in this regard is the market price in Peru, where rice production decreases -0.1% and the price increases 2.6%. This situation could be explained by the change in international trade flows, in which the large decrease in exports is not compensated for by the increase in imports, pushing the price up (Table 16).

Table 16. Price Changes (%).

	Rice	Wheat	CerCrops	VegFruits	OilSeeds	SugarC_B	PlantFiber
Oceania	-1.9	-6.0	-2.4	-0.9	-4.2	0.0	-2.6
China	0.0	0.3	0.6	0.0	0.5	0.0	0.3
EastAsia	0.0	1.1	0.4	0.1	0.6	0.0	0.3
SEA	0.0	0.9	0.4	0.1	0.1	0.0	0.5
SouthAsia	0.0	0.4	0.3	0.0	0.6	-0.1	0.1
India	0.0	0.1	0.1	0.1	0.0	0.0	0.1
USA	2.7	0.7	0.8	0.4	0.7	0.0	0.2
RoNAmerica	0.4	1.6	0.4	0.7	1.4	0.0	0.1
Argentina	5.0	-0.7	-0.1	-0.1	-0.1	-0.3	0.2
Bolivia	-1.2	-2.0	-1.7	-2.0	-1.8	-1.2	-2.0
Brazil	0.1	-5.1	-1.5	-0.8	-1.3	0.1	-2.9
Chile	-0.1	-0.1	1.0	0.7	0.3	-0.1	-0.1
Peru	-0.1	-2.2	-1.0	-0.8	-0.2	-0.1	-0.5
RoLAC	-4.6	-13.3	-7.6	-5.2	-6.3	-0.4	-4.8
EU27	0.9	0.4	0.7	0.7	1.2	0.0	0.1
MENA	0.1	0.6	0.8	0.2	0.8	0.0	0.3
SSA	-0.4	-0.4	-0.2	-0.2	-0.2	-0.1	-0.8
RoW	0.0	0.2	0.3	0.2	0.6	0.0	0.2

Finally, the changes in both production and prices driven by climate change would have a negative impact on the global GDP. At the global level, the GDP would decrease 0.03%, with Bolivia and RoLAC facing the largest decreases, -0.2% and -0.17% respectively (Table 17). The final impact on these regions is explained by the international trade flow changes, with a large decrease in agricultural exports.

Table 17. GDP Changes (%)

Region	GDP Change
Oceania	-0.0205
China	-0.0021
EastAsia	-0.0001
SEA	-0.0012
SouthAsia	-0.0021
India	-0.0008
USA	-0.0007
RoNAmerica	-0.0051
Argentina	-0.0297
Bolivia	-0.204
Brazil	-0.0559
Chile	-0.0009
Peru	-0.0665
RoLAC	-0.1773
EU27	-0.003
MENA	-0.0017
SSA	-0.0323
RoW	-0.0022

A comparison between results computed here with previous studies (i. e Calzadilla, *et al*. 2010) shows that the impacts on agricultural production are of similar magnitude (-0.5%). However, the total impact on welfare, measured as changes on GDP, are lower with ICES-W (-0.03% versus -

0.28%). This could be explained by the way in which the irrigation sector is included within the ICES-W model.

5. Conclusions

Climate change poses a huge challenge to the agricultural sector with economic impacts that could be significant depending on the specific region. Since water is a key input for agriculture, a serious drawback for economic modeling is the lack of information about its market price.

In this regard, the relevance of the model presented in this paper is twofold. First, it considers water as a physical endowment that modifies agricultural productivity, differentiating between irrigated and rainfed agriculture. Secondly, it explicitly considers the investment in irrigation schemes. By considering the physical endowment of water, through a link between a CGE model and a hydro-module, allows us to overcome the "*non-market*" price feature of water resources.

The use of ICES-W provides a wider economic impact assessment of climate change than previous global CGE models addressing water issues. For instance, the model accounts for distributional effects, not only across sectors, but also within sectors differentiating between rainfed and irrigated agriculture. Furthermore, the model quantifies the strong link between the agricultural sector and water endowment (through the capital needed for irrigation), highlighting the economic consequences of relatively small water storage facilities.

The study of the economic impacts of climate change on the Latin American agricultural sector shows the expected results in accordance with the shock imposed. There is an increase in the demand of endowments (land and capital for irrigation), a reduction in agricultural production, with only a slight change in GDP.

The ICES-W model could be used to assess the economic impacts of increasing investments in irrigation within the agricultural sector as an adaptation strategy. This is not a minor issue, considering the large amount of economic resources that should be extracted from other economic sectors. An example of the latter is the construction of the South North Water Transfer Project in China.

Climate change impacts are essentially dynamic over long time periods. In this regard, the static feature of the ICES-W model does not account for optimal path solutions, which we acknowledge as a limitation of the model. Nevertheless, it is possible to extend this model into a dynamic version, including the time variable in the hydro-module once the data becomes available.

Despite the high level of aggregation presented by both the CGE model and the hydro-module, the modeling approach represents the role played by the water endowment in order to cope with climate change impacts. To the best of our knowledge, this is the first global CGE model that considers both the water endowment and the irrigation sector as this model does. Nevertheless, some limitations remain. The analysis is restricted to the agricultural sector and does not account for water competition across sectors (industrial, municipal, environmental).

The model does not consider specific geographic conditions that could refine the results. The optimal solution would be working with data at river basin scale, but this information is very difficult to collect. One option in this regard is to extend the model to consider an agro-ecological zone disaggregation. On the other hand, the model assumes a coarse relationship between water and agricultural productivity (for both rainfed and irrigated land). By including region specific water response functions for agricultural productivity, following the same model structure it would be possible get better results.

Finally, an inherent feature of the CGE models is the level of aggregation used, in which the modeling approach does not consider the specific features of every sector under analysis. This approach is often criticized due to its inability to clearly reflect the real world, nevertheless its real usefulness is to provide a general picture of the situation under study, highlighting feedback effects that are otherwise impossible to identify.

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Annex 1. ICES-W: Regional and Commodity Disaggregation

Table A. 1.1 Regional Disaggregation: ICES-W Model.

Region	GTAP Region	Region	GTAP Region	Region	GTAP Region
Oceania	Australia	EU_27	Austria	SSA	Nigeria
	New Zealand		Belgium		Senegal
	Rest of Oceania		Cyprus		Rest of Western Africa
China	China		Czech Republic		Central Africa
EastAsia	Hong Kong		Denmark		South Central Africa
	Japan		Estonia		Ethiopia
	Korea		Finland		Madagascar
	Taiwan		France		Malawi
	Rest of East Asia		Germany		Mauritius
SEA	Cambodia		Greece		Mozambique
	Indonesia		Hungary		Tanzania
	Lao People's Democratic Rep.		Ireland		Uganda
	Myanmar		Italy		Zambia
	Malaysia		Latvia		Zimbabwe
	Philippines		Lithuania		Rest of Eastern Africa
	Singapore		Luxembourg		Botswana
	Thailand		Malta		South Africa
	Viet Nam		Netherlands		Rest of South African Customs
	Rest of Southeast Asia		Poland	ROW	Bangladesh
SouthAsia	Pakistan		Portugal		Rest of EFTA
	Sri Lanka		Slovakia		Albania
	Rest of South Asia		Slovenia		Belarus
India	India		Spain		Croatia
USA	USA		Sweden		Russian Federation
RoNAmerica	Canada		United Kingdom		Ukraine
	Mexico		Switzerland		Rest of Eastern Europe
	Rest of North America		Norway		Rest of Europe
Argentina	Argentina		Bulgaria		Kazakhstan
Bolivia	Bolivia		Romania		Kyrgyztan
Brazil	Brazil	MENA	Rest of Western Asia		Rest of Former Soviet Union
Chile	Chile				
Peru	Peru				Armenia
RoLAC	Uruguay		Egypt		Azerbaijan
	Venezuela				
	Rest of South America		Morocco		Georgia
	Costa Rica				
	Guatemala				
	Nicaragua		Tunisia		Iran Islamic Republic of
	Panama				
	Rest of Central America		Rest of North Africa		Turkey
	Caribbean				

Table A.1.2 Commodity Disaggregation: ICES-W Model.

N	New Code	Sector Description
1	Rice	Paddy rice
2	Wheat	Wheat
3	CerCrops	Cereal grains nec
4	VegFruits	Vegetables, fruit, nuts
5	OilSeeds	Oil seeds
6	SugarC_B	Sugar cane, sugar beet
7	PlantFiber	Plant-based fibers
8	Animals	Cattle,sheep,goats,horses
9	Coal	Coal
10	Oil	Oil
11	Gas	Gas
12	Oil_Pcts	Petroleum, coal products
13	Electricity	Electricity
14	En_Int_ind	Minerals nec
15	Oth_ind	Meat: cattle,sheep,goats,horse
16	Water	Water
17	MServ	Construction
18	NMServ	PubAdmin/Defence/Health/Educat

Annex 2. Baseline Information for ICES and ICES-W Models

Table A. 2.1 Cost Share: ICES Model (%)

Product	Oceania	China	EastAsia	SEA	SouthAsia	India	USA	RoNAmerica	Argentina	Bolivia	Brazil	Chile	Peru	RoLAC	EU27	MENA	SSA	RoW
	Cost Share Land																	
Rice	11.5%	19%	19%	39%	25%	39%	15%	21%	13%	21%	10%	14%	28%	17%	6%	9%	10%	21%
Wheat	13.5%	12%	11%	35%	22%	23%	15%	9%	16%	9%	7%	12%	25%	16%	5%	5%	8%	13%
CerCrops	12.3%	15%	15%	37%	32%	33%	17%	18%	16%	19%	10%	13%	23%	19%	7%	6%	10%	16%
VegFruits	12.0%	19%	17%	41%	29%	33%	15%	18%	18%	20%	9%	19%	24%	17%	7%	8%	10%	15%
OilSeeds	13.0%	19%	21%	39%	31%	33%	15%	8%	15%	18%	8%	3%	26%	16%	6%	7%	10%	14%
SugarC_B	12.3%	17%	13%	35%	26%	35%	20%	21%	17%	9%	8%	11%	21%	17%	6%	8%	7%	11%
PlantFiber	10.8%	11%	6%	32%	27%	33%	13%	5%	9%	11%	10%	2%	15%	12%	6%	6%	9%	8%
	Cost Share Labor																	
Rice	28%	38%	31%	34%	26%	34%	21%	36%	22%	35%	14%	23%	48%	29%	36%	47%	54%	24%
Wheat	33%	25%	28%	44%	19%	20%	21%	21%	27%	14%	11%	20%	43%	26%	20%	24%	39%	31%
CerCrops	29%	31%	31%	32%	29%	28%	23%	32%	27%	33%	15%	22%	40%	32%	33%	30%	51%	32%
VegFruits	32%	39%	32%	36%	25%	29%	21%	32%	30%	34%	13%	31%	40%	29%	35%	40%	54%	38%
OilSeeds	31%	39%	37%	34%	28%	28%	21%	19%	26%	30%	12%	5%	45%	27%	31%	37%	54%	32%
SugarC_B	30%	35%	33%	31%	23%	31%	27%	37%	28%	15%	13%	19%	37%	28%	26%	43%	31%	26%
PlantFiber	26%	23%	6%	28%	24%	29%	18%	10%	15%	18%	15%	4%	25%	20%	31%	30%	45%	18%
	Cost Share Capital																	
Rice	15%	8%	15%	5%	11%	16%	18%	20%	11%	19%	36%	12%	4%	15%	11%	26%	13%	12%
Wheat	18%	5%	17%	4%	9%	10%	19%	20%	14%	8%	28%	11%	4%	14%	6%	14%	13%	11%
CerCrops	16%	6%	17%	5%	13%	13%	20%	21%	14%	17%	37%	12%	3%	17%	10%	17%	15%	10%
VegFruits	16%	8%	16%	5%	12%	14%	19%	20%	16%	18%	32%	17%	3%	16%	11%	23%	16%	14%
OilSeeds	17%	8%	19%	5%	13%	13%	19%	20%	14%	16%	30%	3%	4%	14%	9%	21%	15%	11%
SugarC_B	16%	7%	18%	5%	11%	15%	24%	21%	15%	8%	31%	10%	3%	15%	8%	24%	12%	11%
PlantFiber	14%	5%	1%	4%	11%	14%	16%	7%	8%	10%	37%	2%	2%	11%	10%	17%	12%	8%

Annex 3. ICES and ICES-W Results

Table A. 3.1 Changes in Total Output (%): ICES Model

Product	Oceania	China	EastAsia	SEA	SouthAsia	India	USA	RoNAmerica	Argentina	Bolivia	Brazil	Chile	Peru	RoLAC	EU27	MENA	SSA	RoW
Rice	12.8	-0.9	-1.2	-3.2	-2.3	-4.4	3.7	-9.0	2.2	-4.7	-1.3	-1.9	-1.3	-2.1	26.5	4.7	2.6	-1.9
Wheat	-3.8	-2.3	-5.4	-22.2	-4.4	-5.3	-10.3	9.8	-6.1	-0.9	5.7	-2.6	-11.5	-9.1	4.8	3.3	3.6	-3.3
CerCrops	4.1	-1.2	-2.8	-12.5	-6.6	-6.7	-2.3	-2.5	-2.0	-3.1	0.8	0.1	-6.0	-2.8	2.8	9.3	1.2	-3.4
VegFruits	3.7	-1.7	-1.9	-9.0	-3.3	-6.0	-0.6	-3.2	-3.0	-3.6	0.7	-2.9	-3.6	-1.4	1.5	1.0	0.2	-2.0
OilSeeds	-1.7	-5.7	-16.7	-11.0	-9.1	-4.6	-3.1	12.8	-1.2	-4.7	5.1	0.7	-4.1	-3.6	2.7	1.6	-1.0	-4.1
SugarC_B	-0.5	-1.1	-0.2	-2.4	-2.2	-3.5	-0.2	-0.9	-4.0	-4.4	-1.2	-1.7	-1.1	-1.6	0.2	-0.9	-1.0	-1.2
PlantFiber	-2.2	0.5	-4.0	-18.8	-5.8	-5.8	-5.4	-0.8	-2.3	7.0	-0.4	-1.8	-3.6	-2.4	-1.5	3.1	1.2	1.4

Table A. 3.2 Changes in Total Output (%): ICES-W Model

Product	Oceania	China	EastAsia	SEA	SouthAsia	India	USA	RoNAmerica	Argentina	Bolivia	Brazil	Chile	Peru	RoLAC	EU27	MENA	SSA	RoW
Rice	13.2	-0.9	-1.2	-3.3	-2.6	-4.4	3.9	-8.9	2.3	-4.8	-1.3	-1.6	-1.3	-2.1	27.5	4.7	2.7	-1.9
Wheat	-3.6	-2.4	-5.3	-22.2	-5.3	-5.4	-10.2	10.1	-6.0	-0.8	5.7	-2.4	-11.6	-9.2	5.0	3.1	3.8	-3.3
CerCrops	4.3	-1.9	-2.7	-12.5	-8.0	-6.7	-2.3	-2.5	-1.9	-3.0	0.8	-0.4	-6.1	-2.9	2.9	9.3	1.3	-3.4
VegFruits	3.9	-1.9	-1.9	-8.9	-4.0	-6.1	-0.6	-3.2	-3.0	-3.6	0.7	-3.4	-3.6	-1.4	1.6	0.9	0.3	-2.0
OilSeeds	-1.4	-6.2	-16.7	-11.1	-10.8	-4.6	-3.0	13.1	-1.1	-4.6	5.2	0.7	-4.1	-3.6	2.9	1.5	-0.9	-4.1
SugarC_B	-0.5	-1.1	-0.2	-2.5	-2.3	-3.6	-0.2	-0.9	-4.0	-4.4	-1.3	-1.4	-1.1	-1.6	0.2	-0.9	-1.0	-1.2
PlantFiber	-2.2	0.1	-4.0	-18.8	-6.8	-5.9	-5.4	-0.7	-2.3	7.3	-0.4	-1.8	-3.6	-2.3	-1.4	3.1	1.6	1.5

Table A. 3.3 Changes in Market Prices (%): ICES Model

Product	Oceania	China	EastAsia	SEA	SouthAsia	India	USA	RoNAmerica	Argentina	Bolivia	Brazil	Chile	Peru	RoLAC	EU27	MENA	SSA	RoW
Rice	13.3	18.6	24.9	36.0	17.3	38.1	16.7	19.7	10.9	14.7	10.9	14.3	25.5	15.5	9.6	9.6	12.5	21.2
Wheat	12.5	11.5	13.4	18.2	14.6	21.2	13.3	9.7	12.7	7.7	9.3	11.9	20.0	13.1	6.5	7.3	9.1	12.1
CerCrops	13.2	16.8	18.7	27.1	20.0	30.8	17.0	17.7	14.1	14.7	11.5	13.8	21.2	16.3	9.0	6.7	11.2	15.1
VegFruits	12.3	18.4	21.8	31.4	19.0	31.5	16.0	17.5	15.4	15.3	10.2	18.9	22.2	15.1	9.0	8.4	11.0	13.2
OilSeeds	12.9	16.7	20.8	30.3	17.6	32.2	16.0	8.9	13.2	13.3	9.6	10.6	23.9	14.3	7.3	7.9	11.5	12.9
SugarC_B	12.1	16.3	15.7	30.5	20.5	34.7	21.0	22.3	13.3	9.4	9.1	13.3	21.1	14.9	7.5	7.8	7.5	11.0
PlantFiber	12.5	10.2	8.4	19.8	17.0	30.8	13.1	6.7	6.6	9.0	10.5	8.3	14.6	11.2	7.2	5.7	10.3	6.4

Table A.3.4 Changes in Market Prices (%): ICES-W Model

Product	Oceania	China	EastAsia	SEA	SouthAsia	India	USA	RoNAmerica	Argentina	Bolivia	Brazil	Chile	Peru	RoLAC	EU27	MENA	SSA	RoW
Rice	13.6	20.2	25.3	36.4	19.5	38.8	17.1	20.0	11.1	14.8	11.2	15.0	26.0	15.8	9.8	10.0	12.7	21.5
Wheat	12.7	12.4	13.7	18.5	16.3	21.7	13.5	10.0	13.0	7.8	9.6	12.6	20.4	13.4	6.6	7.5	9.2	12.3
CerCrops	13.5	18.0	19.0	27.5	22.4	31.4	17.3	18.0	14.4	14.8	11.8	14.3	21.6	16.6	9.1	7.0	11.3	15.3
VegFruits	12.6	19.9	22.2	31.9	21.5	32.1	16.3	17.8	15.7	15.5	10.5	19.6	22.7	15.5	9.1	8.8	11.2	13.4
OilSeeds	13.2	18.0	21.2	30.7	19.4	32.8	16.3	9.2	13.4	13.5	9.8	10.9	24.3	14.7	7.4	8.2	11.7	13.1
SugarC_B	12.4	17.7	16.0	30.9	23.2	35.4	21.4	22.7	13.5	9.4	9.3	14.0	21.5	15.2	7.6	8.1	7.6	11.2
PlantFiber	12.8	11.0	8.5	20.1	19.0	31.4	13.3	6.8	6.7	9.1	10.8	8.5	14.8	11.4	7.3	6.0	10.5	6.5

Table A. 3.5 Changes in Exports (%): ICES Model

Product	Oceania	China	EastAsia	SEA	SouthAsia	India	USA	RoNAmerica	Argentina	Bolivia	Brazil	Chile	Peru	RoLAC	EU27	MENA	SSA	RoW
Rice	66.2	37.3	-3.5	-72.7	-4.2	-79.0	10.8	-1.1	16.7	58.9	67.4	33.5	-48.0	-3.9	63.9	87.7	63.7	-20.7
Wheat	-4.3	7.7	-16.8	-39.3	-29.2	-50.1	-13.1	10.5	-6.5	14.4	5.9	-17.3	-55.5	-15.0	15.8	20.0	12.9	-10.3
CerCrops	9.5	-0.1	-9.0	-35.4	-19.8	-47.6	-5.3	-10.5	0.0	-5.9	8.9	2.8	-29.5	-3.6	11.5	33.1	8.6	-8.0
VegFruits	18.5	2.3	-2.2	-22.1	-1.4	-34.5	0.7	-4.9	-3.3	-7.4	10.7	-3.0	-6.6	0.1	5.2	15.0	10.2	-0.5
OilSeeds	-1.9	-10.7	-16.0	-38.0	-15.3	-49.7	-5.7	17.1	6.9	9.1	13.2	7.8	-36.2	-3.0	9.0	12.6	0.2	-6.5
SugarC_B	17.6	-14.8	-11.9	-54.4	-26.8	-61.6	-22.4	-23.6	-2.0	18.5	20.0	-1.8	-16.7	-5.7	18.1	25.1	30.1	3.4
PlantFiber	-4.0	5.3	12.1	-28.5	-19.8	-53.4	-8.0	15.9	13.1	15.5	1.6	-1.0	-14.7	-2.2	7.5	21.4	2.5	12.3

Table A. 3.6 Changes in Exports (%): ICES-W Model

Product	Oceania	China	EastAsia	SEA	SouthAsia	India	USA	RoNAmerica	Argentina	Bolivia	Brazil	Chile	Peru	RoLAC	EU27	MENA	SSA	RoW
Rice	68.4	26.9	-1.8	-72.6	-16.4	-79.2	11.2	1.4	17.4	62.9	68.8	30.7	-47.8	-3.9	66.6	88.0	67.0	-19.7
Wheat	-4.0	2.7	-16.7	-39.3	-36.4	-50.7	-13.0	10.9	-6.4	15.4	5.9	-19.7	-55.9	-15.2	16.3	19.4	13.4	-10.2
CerCrops	10.0	-3.4	-8.7	-35.3	-25.7	-48.0	-5.2	-10.4	0.3	-5.5	8.9	1.7	-29.8	-3.8	11.9	33.0	9.1	-7.9
VegFruits	19.1	-0.4	-1.8	-21.7	-5.9	-34.7	0.9	-4.8	-3.2	-7.1	10.8	-3.7	-6.6	0.1	5.4	14.9	10.6	-0.4
OilSeeds	-1.5	-13.6	-16.0	-38.0	-19.4	-50.2	-5.6	17.5	7.5	9.7	13.4	7.6	-36.4	-3.1	9.5	12.1	0.7	-6.4
SugarC_B	19.3	-19.1	-11.9	-54.5	-34.4	-62.3	-22.7	-23.7	-1.8	19.5	20.2	-3.8	-16.9	-5.8	18.5	24.3	31.0	3.5
PlantFiber	-3.8	3.0	12.9	-28.1	-24.7	-53.5	-7.8	16.6	13.7	16.0	1.8	-1.2	-14.7	-1.9	8.2	21.5	3.0	12.8

Table A. 3.7 Changes in Global GDP (%): ICES Model

Region	Change (%)
Oceania	-0.06
China	-0.48
EastAsia	-0.06
SEA	-0.68
SouthAsia	-1.06
India	-1.72
USA	-0.04
RoNAmerica	-0.13
Argentina	-0.40
Bolivia	-0.70
Brazil	-0.20
Chile	-0.18
Peru	-0.57
RoLAC	-0.33
EU27	-0.02
MENA	-0.13
SSA	-0.31
RoW	-0.25

Table A. 3.8 Changes in Global GDP (%): ICES-W Model

Region	Change (%)
Oceania	-0.06
China	-0.49
EastAsia	-0.06
SEA	-0.68
SouthAsia	-1.08
India	-1.72
USA	-0.04
RoNAmerica	-0.13
Argentina	-0.40
Bolivia	-0.70
Brazil	-0.20
Chile	-0.18
Peru	-0.57
RoLAC	-0.33
EU27	-0.02
MENA	-0.13
SSA	-0.31
RoW	-0.25

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