



Global Trade Analysis Project

Climate change impacts on agriculture using improved multi-region input-output framework

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Outline

1. Motivation
2. Agricultural sector representation in GTAP MRIO
3. New approach to the agricultural production targeting
4. Climate change policy simulations and results
5. Concluding remarks

1. Motivation

- **Key role of the agricultural sector in the climate change adaptation and mitigation strategies.**
 - Agriculture contributes 12% of the global GHG emissions.
 - High vulnerability to climate impacts (Porter et al., 2014; Fisher et al., 2005).
- **MRIO framework for climate change impacts assessment in agriculture.**
 - Is widely used to capture interactions between adaptation and mitigation strategies (Lample et al., 2014; AgMIP, 2014).
 - Faces several limitations: low regional and sectoral representation, out of date/obsolete data.
- **Focus on improvements for agricultural sector representation in the Global Trade Analysis Project (GTAP) MRIO and assessment of climate change impacts on agriculture.**

2.1. Overview of the GTAP Data Base

- **International database for analysis of international policy issues:**
 - National IO tables.
 - Energy data (IEA), macro data.
 - Reconciled bilateral trade flows.
 - “FIT” process to make consistent world accounting framework.
- **GTAP 9.2 Base year: 2011 (plus 2007 & 2004).**
- **141 regions, of which 121 are countries.**
- **57 sectors:**
 - 14 agriculture, 8 processed foods, 6 energy.
- **8 factors of production:**
 - Labor (professionals, technicians, clerks, service workers, unskilled workers).
 - Capital, land (agriculture), natural resources.

2.3. Commodity coverage – GTAP v9.2

Paddy rice	Coal	Wood products	Electricity
Wheat	Oil	Pulp, paper etc.	Gas distribution
Other cereals	Gas	Refined oil etc.	Water
Vegetables & fruits	Other minerals	Chemicals	Construction
Oil seeds	Red meat	Other mineral prod.	Trade
Sugar cane & beet	White meat	Ferrous metals	Land transportation
Plant-based fibers	Vegetable oils	Other metals	Sea transportation
Other crops	Dairy products	Metal products	Air transportation
Beef etc.	Processed rice	Mot. vehicles & parts	Communication
Poultry, pork, etc.	Refined sugar	Other trp. eqpt.	Financial services
Raw milk	Other food	Electronic eqpt.	Insurance
Wool etc.	Beverages & tobacco	Other mach. & eqpt.	Other bus. services
Forestry	Textiles	Other manu.	Recr. & other serv.
Fishing	Clothing		Public services
	Leather products		Dwellings

2.4. Treatment of the agricultural sector in GTAP

- **Detailed representation of the agriculture sector is one of the key GTAP features:**
 - Agricultural and food IO table is used to split sectors if required (Peterson, 2016).
 - Agricultural production targeting (APT) for 12 agricultural sectors is applied to selected countries (Zekarias et al., 2016), using OECD (OECD, 2017) and EU data (Boulangier et al., 2016).
- **Limitations of the current APT approach:**
 - OECD-derived input data (OECD, 2017) includes high share of unclassified/undistributed commodities (e.g. 40% in case of China).
 - APT covers 46 countries (70% of global agricultural output), but misses most developing countries (e.g. India).
 - Some agricultural commodities are not reported by OECD and food output is used for targeting (e.g. sugar output is used to derive targets for sugar cane).
- **Alternative data source for APT values – FAOSTAT.**

3.1. Benefits of using FAO data

- **High commodity coverage.**
 - 286 commodities, no unclassified/undistributed categories.
- **Rich country coverage.**
 - 217 countries fully cover 133 GTAP regions.
- **Price and quantity data available.**

3.2. Data processing

(1) Agricultural production data mapping

- **Data:** FAOSTAT values of agricultural production (FAO, 2017): 155 countries, 189 commodities, 4 years (2004, 2007, 2011 and 2014).
- Mapping to GTAP countries.

(2) Output quantities data mapping

- **Data:** FAOSTAT data on quantities produced (crops, processed crops, processed livestock, primary livestock): 217 countries, 286 commodities, 4 years.
- Mapping to GTAP countries.

(3) Price estimates

- **Data:** FAOSTAT commodity prices, agricultural export and import values and quantities, agricultural commodity production values and quantities.
- Estimation of country and commodity specific prices; world average agricultural commodity prices estimation.

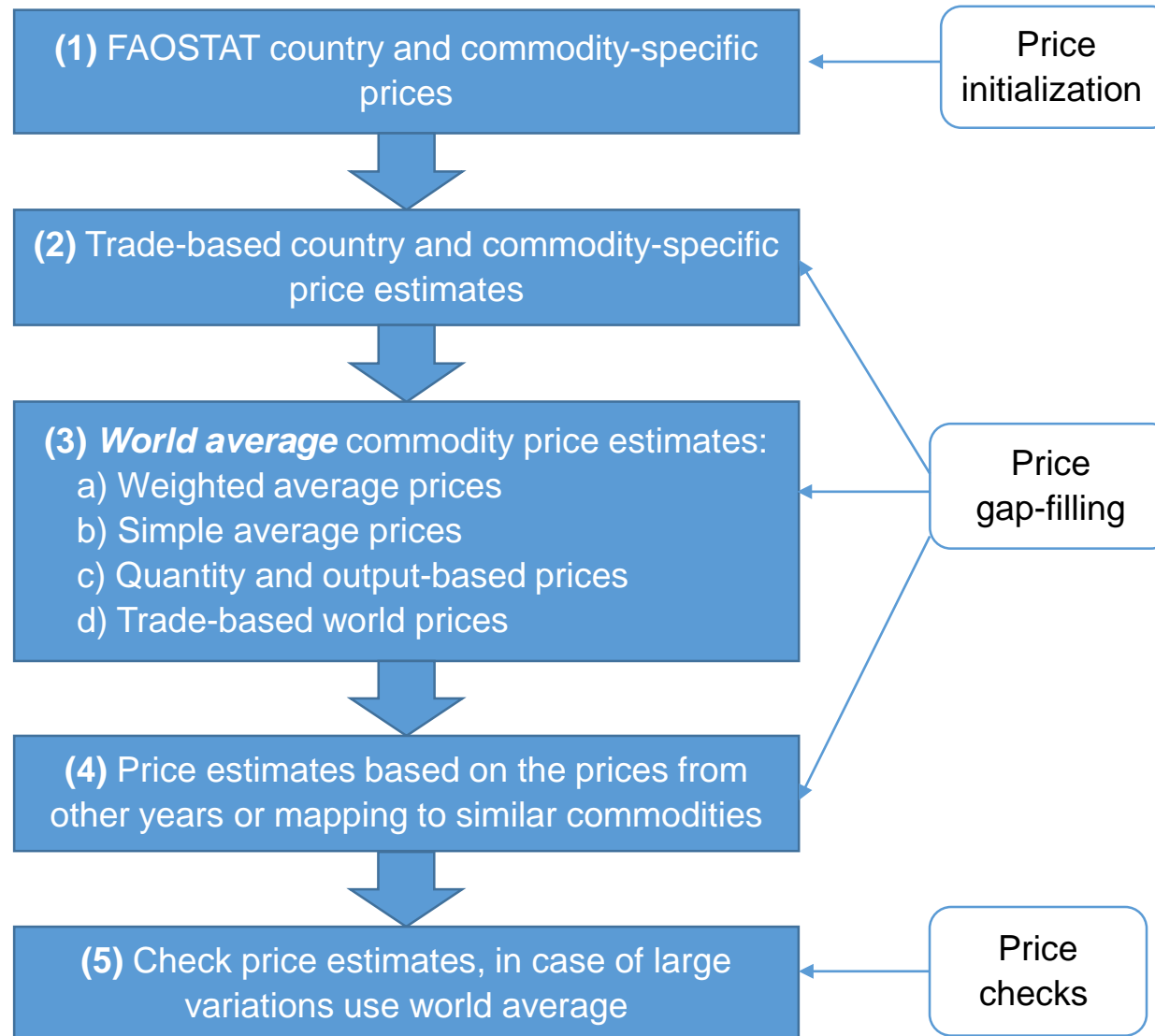
(4) Agricultural output gap-filling

- **Data:** Agricultural commodity production quantities and prices estimation.
- Agricultural production output gap-filling, data mapping to GTAP countries.

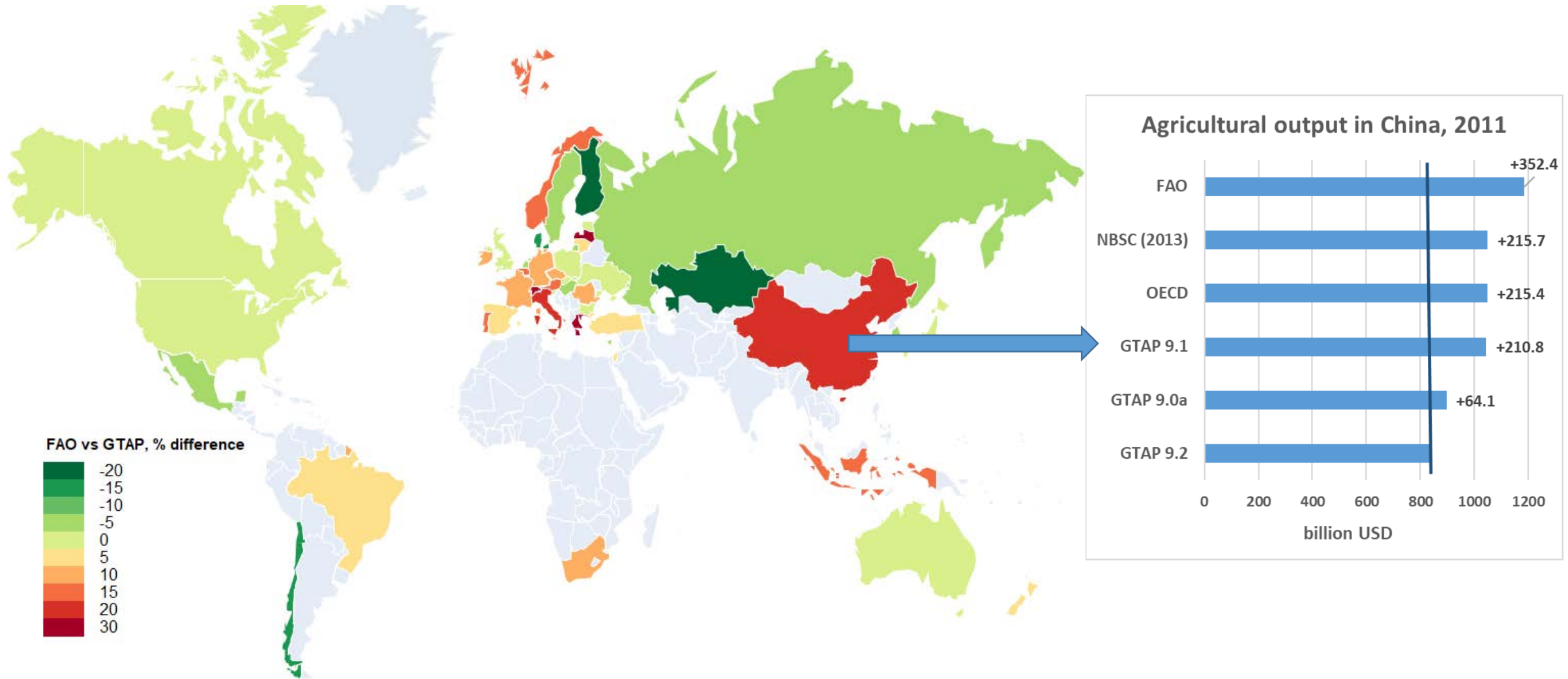
(5) Final gap-filling and data mapping

- **Data:** Agricultural output for floriculture (Eurostat, 2017; country reports) and forage products (Eurostat, 2017).
- Gap-fill values of agricultural production for floriculture, data checks, mapping to GTAP regions and agricultural sectors.

3.3. Gap-filling of the agricultural commodity prices

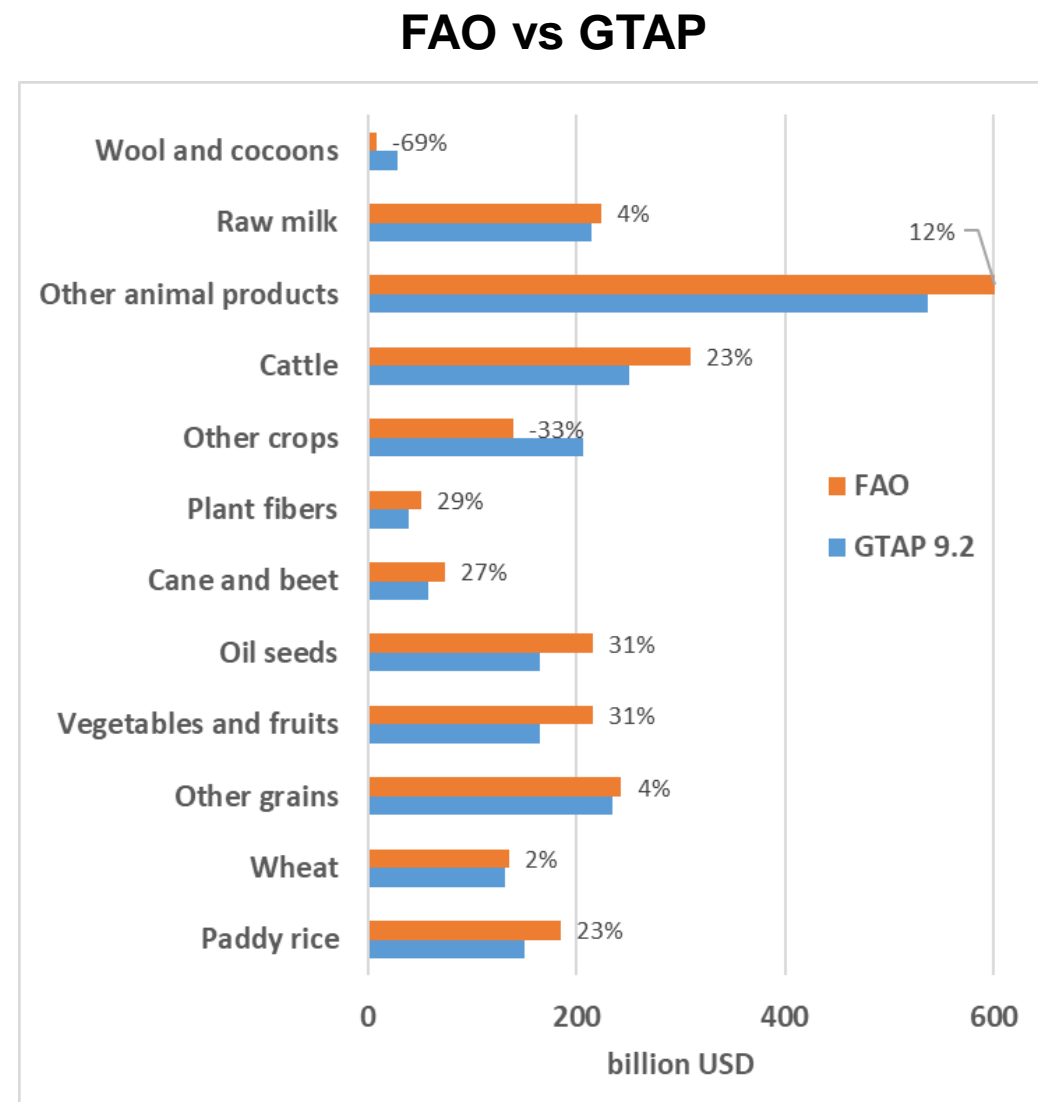


3.4. Total agricultural output comparison, 2011 (FAO vs GTAP, %)



3.5. Agricultural output sectoral comparison

- **Complicated by large shares of unclassified commodities.**
 - Associated with other crops, wool, plant fibers, vegetables and fruits.
- **Three sectors with <5% difference.**
 - Raw milk, Other grains and Wheat.
- **In most cases FAO data is closer to the national statistics/international reports than GTAP-based.**
 - Paddy rice (Indonesia).
 - Vegetables and fruits (Brazil, grapes in EU).
 - Oil seeds (olives in EU).
 - Wool and cocoons (major producers).
- **GTAP APT data is more relevant in some cases.**
 - China (cane and beet, plant fibers).



4.1. Modelling framework – input data

- **GTAP 9.2 Data Base** *with updated agricultural production targets (57 sectors, 141 regions)* <- agricultural production targeting, GTAP Data Base build procedure
- **Aggregated to 20 regions and 27 sectors**
- **Additional satellite accounts:**
 - *Emissions of other greenhouse gases (N₂O, CH₄, F-gases).*
 - *Air pollution database (10 types – BC, CO, NH₃, NMVB, NMVF, NO_x, OC, PM10, PM2.5, SO₂).*
 - *Shared Socioeconomic Pathways (SPP) database (GDP and population) – “middle of the road” SSP2 scenario.*

4.2. Modelling framework – regional aggregation

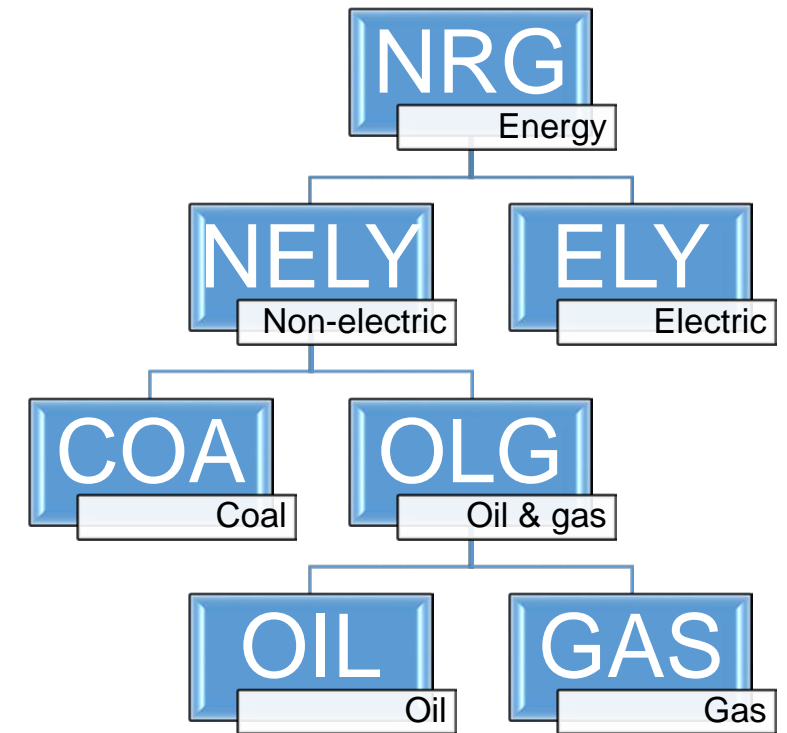
No.	Aggregate region	GTAP region
1	Australia & New Zealand (anz)	Australia (AUS), New Zealand (NZL)
2	Japan (jpn)	Japan (jpn)
3	Rest of high-income (xhy)	Hong Kong (HKG), Japan (JPN), Korea (KOR), Taiwan (TWN), Singapore (SGP), Rest of North America (XNA), Switzerland (CHE), Norway (NOR), Rest of EFTA (XEF), Israel (ISR)
4	Canada (can)	Canada (CAN)
5	United States (usa)	United States of America (USA)
6	EU28 (eur)	Austria (AUT), Belgium (BEL), Cyprus (CYP), Czech Republic (CZE), Denmark (DNK), Estonia (EST), Finland (FIN), France (FRA), Germany (DEU), Greece (GRC), Hungary (HUN), Ireland (IRL), Italy (ITA), Latvia (LVA), Lithuania (LTU), Luxembourg (LUX), Malta (MLT), Netherlands (NLD), Poland (POL), Portugal (PRT), Slovakia (SVK), Slovenia (SVN), Spain (ESP), Sweden (SWE), United Kingdom (GBR), Bulgaria (BGR), Romania (ROU)
7	China (chn)	China (CHN)
8	Indonesia (idn)	Indonesia (IDN)
9	Rest of East Asia (xea)	Rest of Oceania (XOC), Mongolia (MNG), Rest of East Asia (XEA), Brunei Darussalam (BRN), Cambodia (KHM), Laos (LAO), Malaysia (MYS), Philippines (PHL), Thailand (THA), Viet Nam (VNM), Rest of Southeast Asia (XSE)
10	India (ind)	India (IND)
11	Rest of South Asia (xsa)	Bangladesh (BGD), Nepal (NPL), Pakistan (PAK), Sri Lanka (LKA), Rest of South Asia (XSA)
12	Russia (rus)	Russian Federation (RUS)
13	Turkey (tur)	Turkey (TUR)
14	Rest of Europe & Central Asia (xec)	Kazakhstan (KAZ), Tajikistan (TJK), Azerbaijan (AZE), Albania (ALB), Belarus (BLR), Croatia (HRV), Ukraine (UKR), Rest of Eastern Europe (XEE), Rest of Europe (XER), Kyrgyzstan (KGZ), Rest of Former Soviet Union (XSU), Armenia (ARM), Georgia (GEO)
15	Middle East & North Africa (mna)	Bahrain (BHR), Iran (IRN), Kuwait (KWT), Oman (OMN), Qatar (QAT), Saudi Arabia (SAU), United Arab Emirates (ARE), Rest of Western Asia (XWS), Rest of North Africa (XNF), Jordan (JOR), Egypt (EGY), Morocco (MAR), Tunisia (TUN)
16	Sub-Saharan Africa (ssa)	Benin (BEN), Burkina Faso (BFA), Cameroon (CMR), Côte d'Ivoire (CIV), Ghana (GHA), Guinea (GIN), Nigeria (NGA), Senegal (SEN), Togo (TGO), Rest of Western Africa (XWF), Central Africa (XCF), South-Central Africa (XAC), Ethiopia (ETH), Kenya (KEN), Madagascar (MDG), Malawi (MWI), Mauritius (MUS), Mozambique (MOZ), Rwanda (RWA), Tanzania (TZA), Uganda (UGA), Zambia (ZMB), Zimbabwe (ZWE), Rest of Eastern Africa (XEC), Botswana (BWA), Namibia (NAM), South Africa (ZAF), Rest of South African Customs Union (XSC), Rest of the World (XTW)
17	Argentina (arg)	Argentina (ARG)
18	Brazil (bra)	Brazil (BRA)
19	Mexico (mex)	Mexico (MEX)
20	Rest of Latin America & Caribbean (xic)	Bolivia (BOL), Colombia (COL), Ecuador (ECU), Venezuela (VEN), Chile (CHL), Paraguay (PRY), Peru (PER), Uruguay (URY), Rest of South America (XSM), Costa Rica (CRI), Guatemala (GTM), Honduras (HND), Nicaragua (NIC), Panama (PAN), El Salvador (SLV), Rest of Central America (XCA), Dominican Republic (DOM), Jamaica (JAM), Puerto Rico (PRI), Trinidad and Tobago (TTO), Rest of Caribbean (XCB)

4.3. Modelling framework – sectoral aggregation

No.	Aggregate sector	GTAP sector
1	Rice (ric)	pdr, pcr
2	Wheat (wht)	wht
3	Other grains (gro)	gro
4	Vegetables & fruits (v_f)	v_f
5	Oil seeds (osd)	osd
6	Sugar (sug)	c_b, sgr
7	Other crops (ocr)	pfb, ocr
8	Cattle (ctl)	ctl, wol
9	Other livestock (oap)	oap
10	Raw milk (rmk)	rmk
11	Forestry (frs)	frs
12	Coal (coa)	coa
13	Oil (oil)	oil
14	Natural gas (gas)	gas, gdt
15	Other mining (omn)	omn
16	Red meat (cmt)	cmt
17	Other meat (omt)	omt
18	Vegetable oils (vol)	vol
19	Dairy products (mil)	mil
20	Other food (ofd)	fsh, ofd, b_t
21	Textile wearing apparel & leather goods (twp)	tex, wap, lea
22	Energy intensive manufacturing (ke5)	ppp, crp, nmm, i_s, nfm
23	Other manufacturing (xmn)	lum, fmp, mvh, otn, ele, ome, omf
24	Refined oil products (p_c)	p_c
25	Electricity (ely)	ely
26	Construction (cns)	cns
27	Services (srv)	wtr, trd, otp, wtp, atp, cmn, ofi, isr, obs, ros, osg, dwe

4.4. Modelling framework – ENVISAGE

- **Global recursive-dynamic CGE model**
 - 2011-2100 (2011-2050 for this study)
- **Calibrated to GTAP v9.2** (2011 base year)
- **Nested energy demand:**
 - energy preferences are agent-specific; substitution elasticities are vintage specific; autonomous energy efficiency improvement
- **Preference shift parameters**
 - Change the preference for one set of commodities in a demand system relative to other commodities, but without changing the aggregate cost
- **Dynamics:**
 - exogenous labor growth; capital growth a function of savings; exogenous land, energy and trade productivity
- **Current mapping:** 27 sectors and 20 regions



4.5. BaU path development: assumptions

- Macroeconomic and demographic assumptions – SSP2.
- GTAP 9.2 with *updated agricultural targets* (57 sectors, 141 regions) aggregated to 20 regions and 27 sectors.
- Technological and productivity changes.
- Agricultural yields efficiency are calibrated to the FAO GAPS partial equilibrium model (Kavallari et al., 2016).
- Preference assumptions:
 - Agricultural elasticities decline towards “0” with income increase (cross-section estimation using 2011 data).
 - Shift of the demand from raw food to processed food and services (meals in restaurants, café, etc).
- Autonomous energy efficiency improvement (AEEI parameter): commodity-specific.

4.6. Climate change scenarios

With two alternative GTAP Data Bases, we use *AgMIP scenarios* to simulate climate change impacts on agriculture.

We focus on the case with *SSP2 baseline* and median climate change impacts from *RCP6.0 without CO₂ fertilization*.

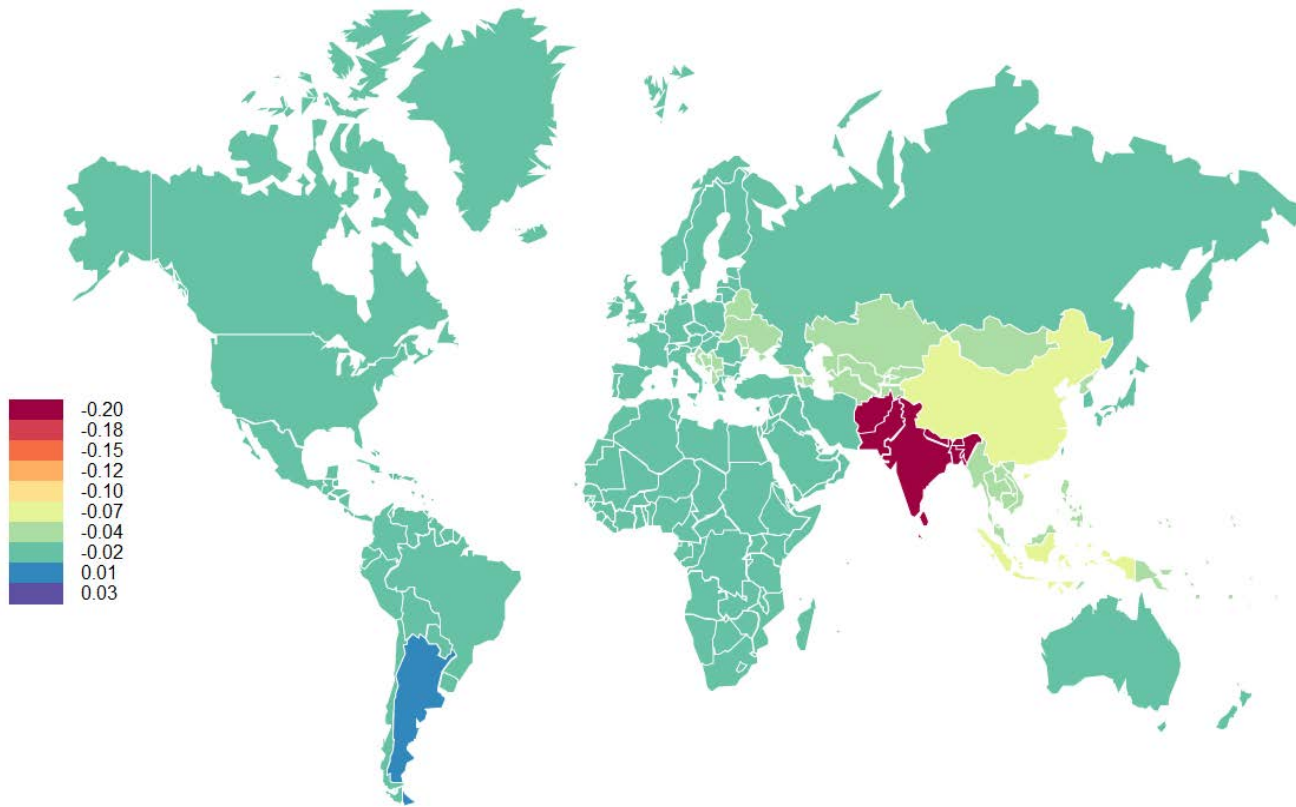
Climate change shocks represent impacts of the increase in temperature on *changes in the agricultural productivity/yields* (with respect to the baseline case with no climate impacts).

No	Climate	Focus	SSP1 'Sustainability'	SSP2 'Middle of the Road'	SSP3 'Fragmentation'
			Adaptation challenge: low	Adaptation challenge: medium	Adaptation challenge: high
A	NoCC	No climate change	SSP1_NoCC	SSP2_NoCC	SSP3_NoCC
B	RCP6.0	Climate change impacts	SSP1_CC6	SSP2_CC6	SSP3_CC6
C	NoCC	Mitigation measures for 2°C stabilization <u>without</u> residual climate change impacts	SSP1_NoCC_m	SSP2_NoCC_m	SSP3_NoCC_m
D	RCP2.6	Mitigation measures for 2°C stabilization + residual climate change impacts	SSP1_CC26_m	SSP2_CC26_m	SSP3_CC26_m

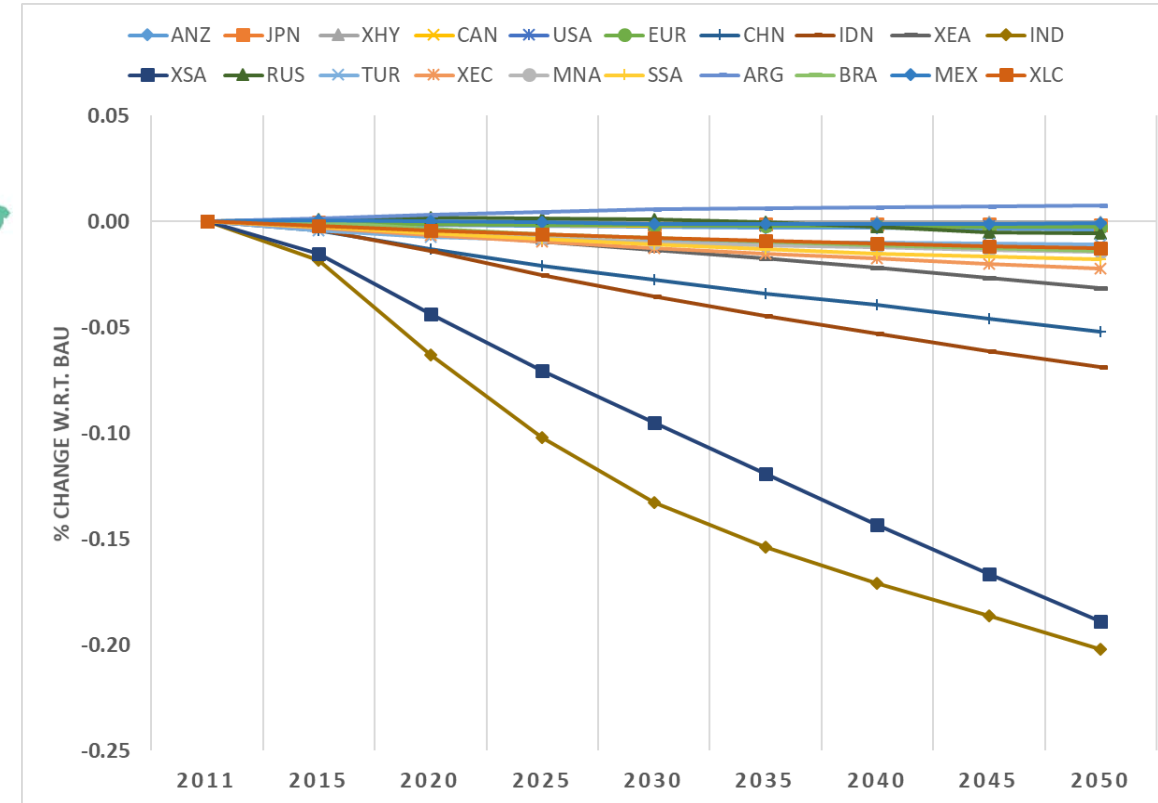
Source: Agricultural Model Intercomparison and Improvement Program (AgMIP) protocols.

Note: RCP stands for Representative concentration pathways. RCP6.0 corresponds to the +6.0 W/m² change in radiative forcing in the year 2100 relative to pre-industrial levels.

4.7. Impacts on GDP

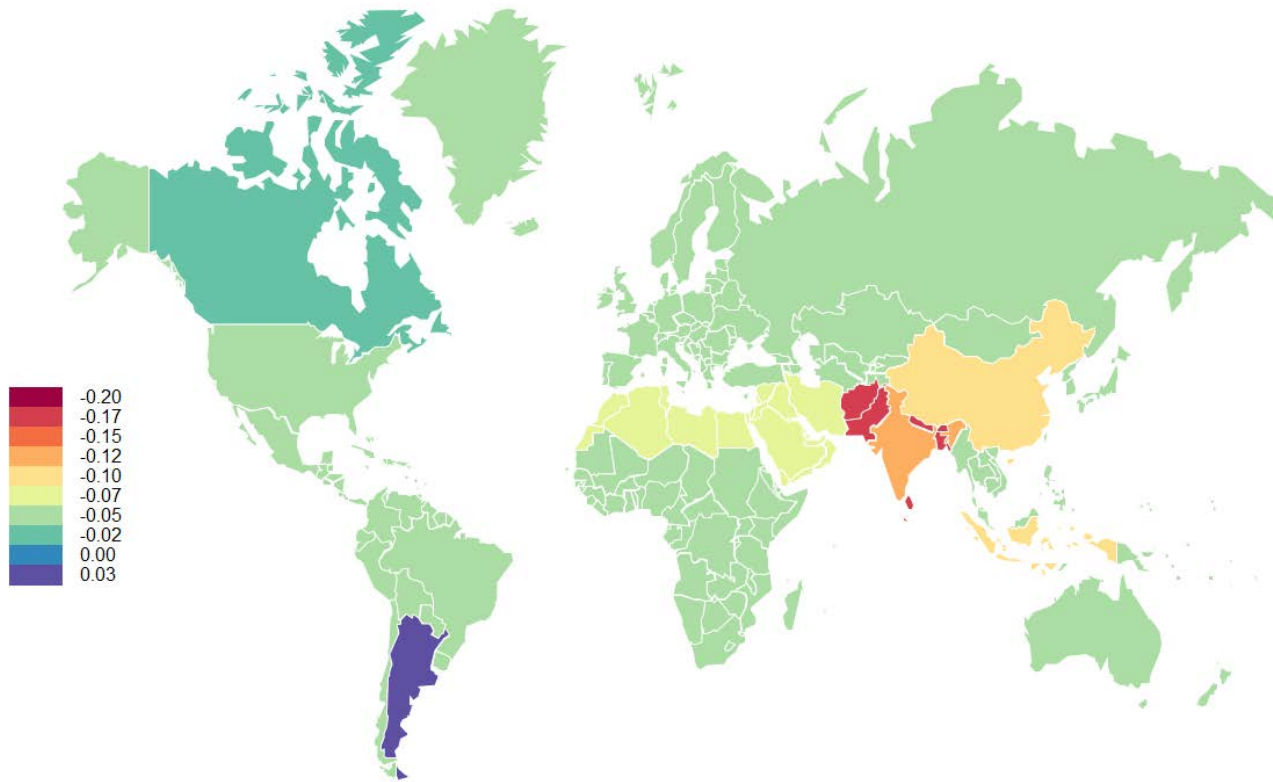


Deviation of regional GDP from baseline due to climate change impacts on agriculture in 2050, %

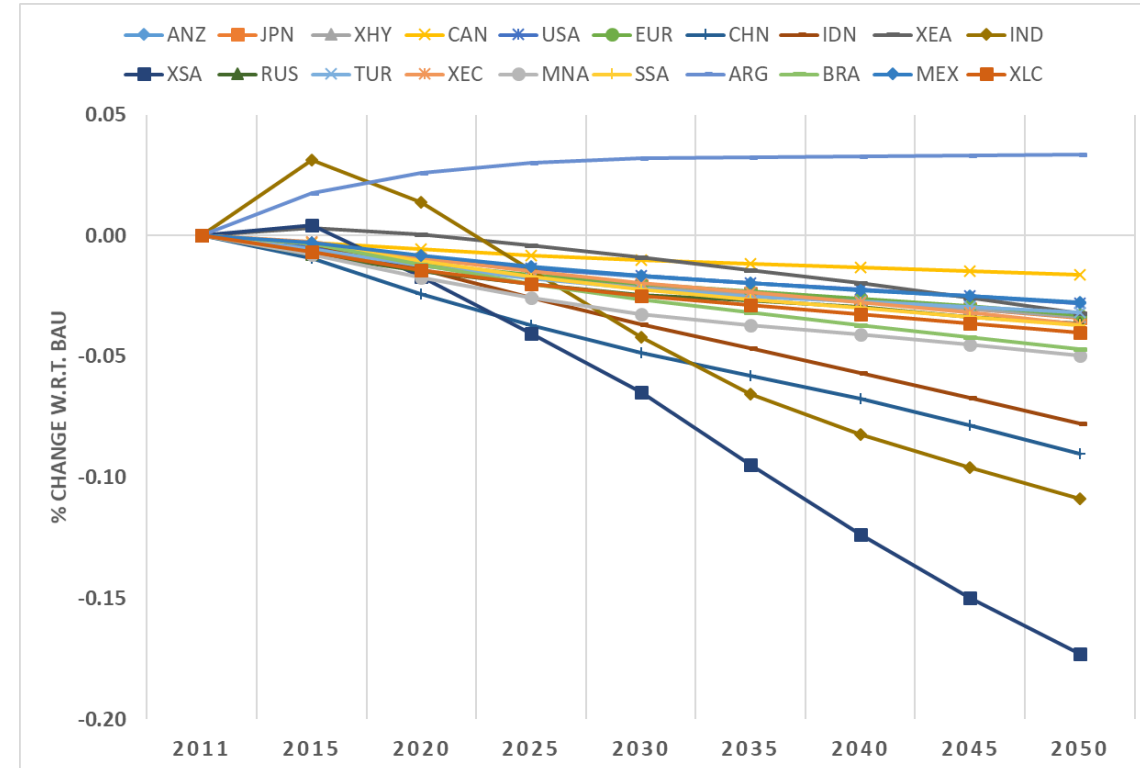


Deviation of regional GDP from baseline due to climate change impacts on agriculture, %

4.8. Impacts on households' income

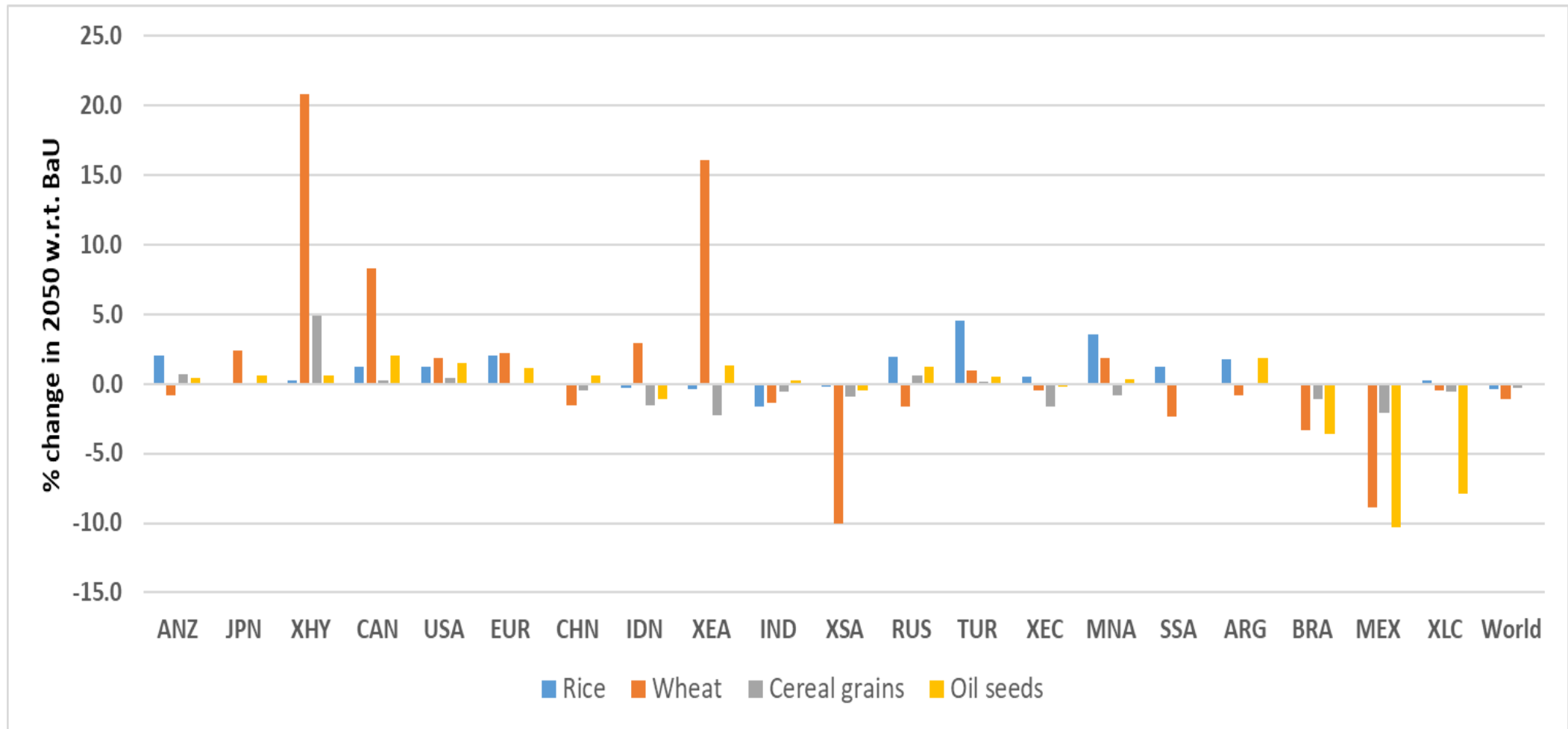


Deviation of households income from baseline due to climate change impacts on agriculture in 2050, %



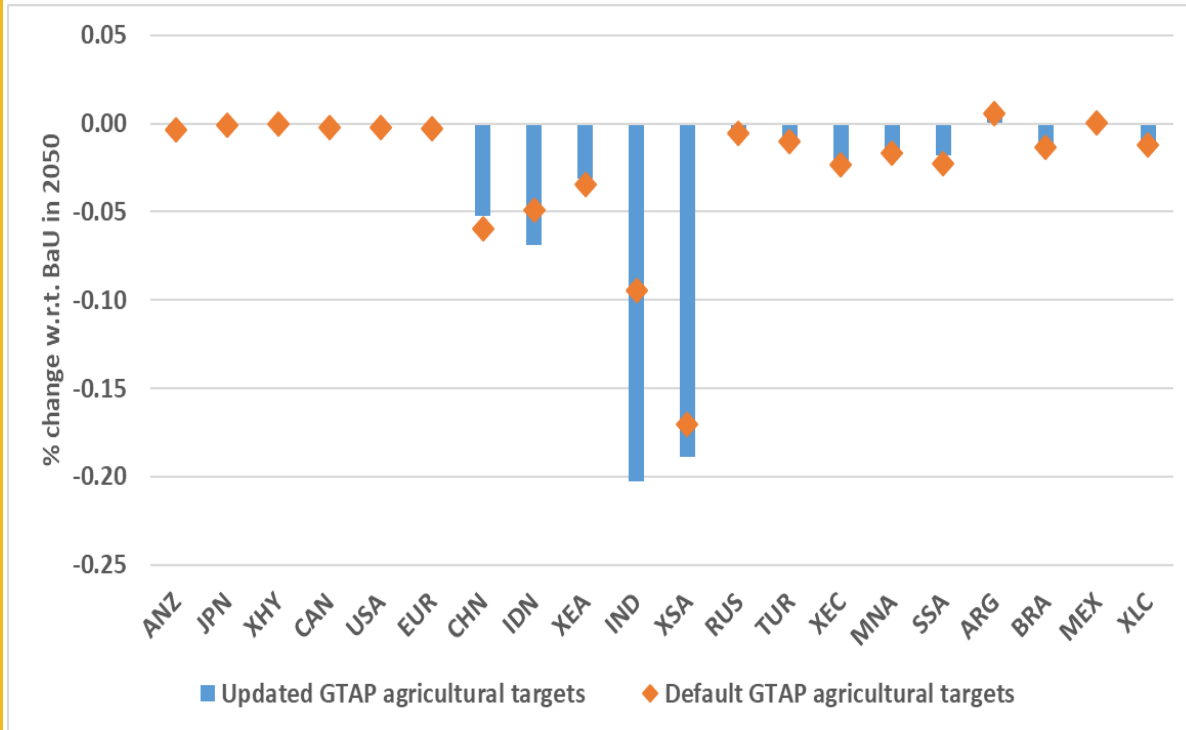
Deviation of households income from baseline due to climate change impacts on agriculture, %

4.9. Sectoral impacts

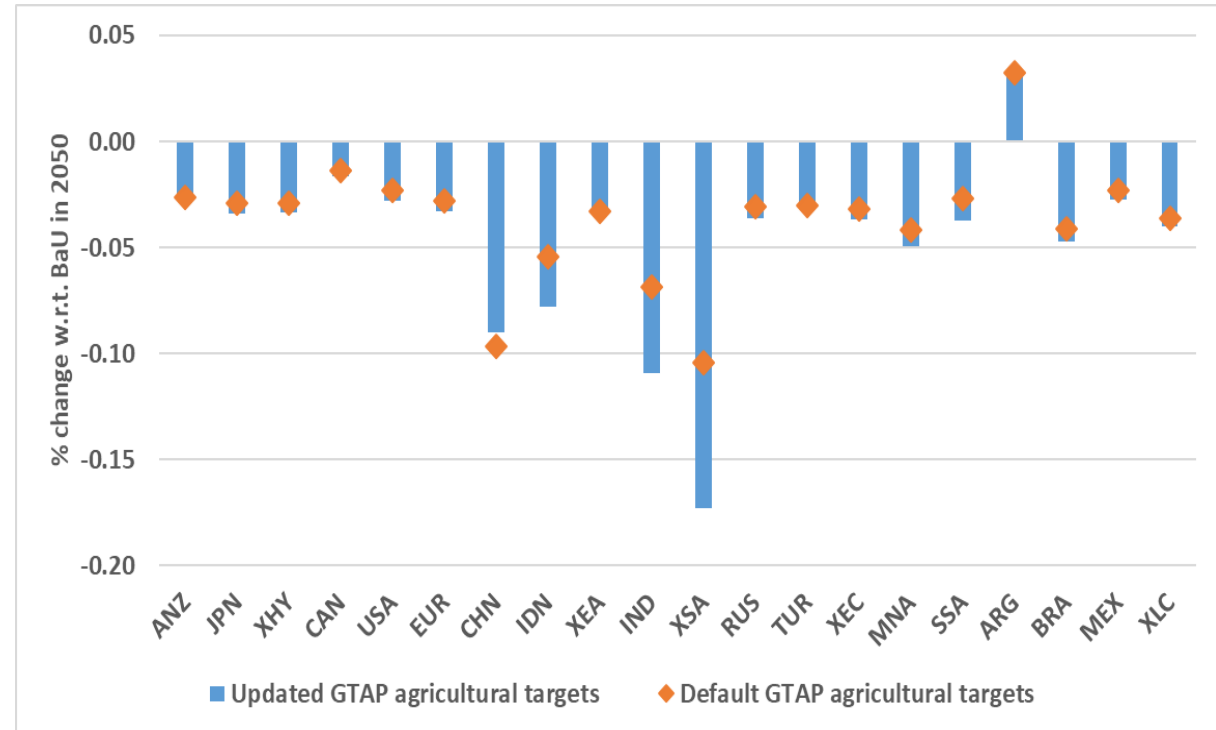


Deviation of agricultural output by sectors in 2050 from baseline due to climate change impacts, %

4.10. Results comparison: macro impacts

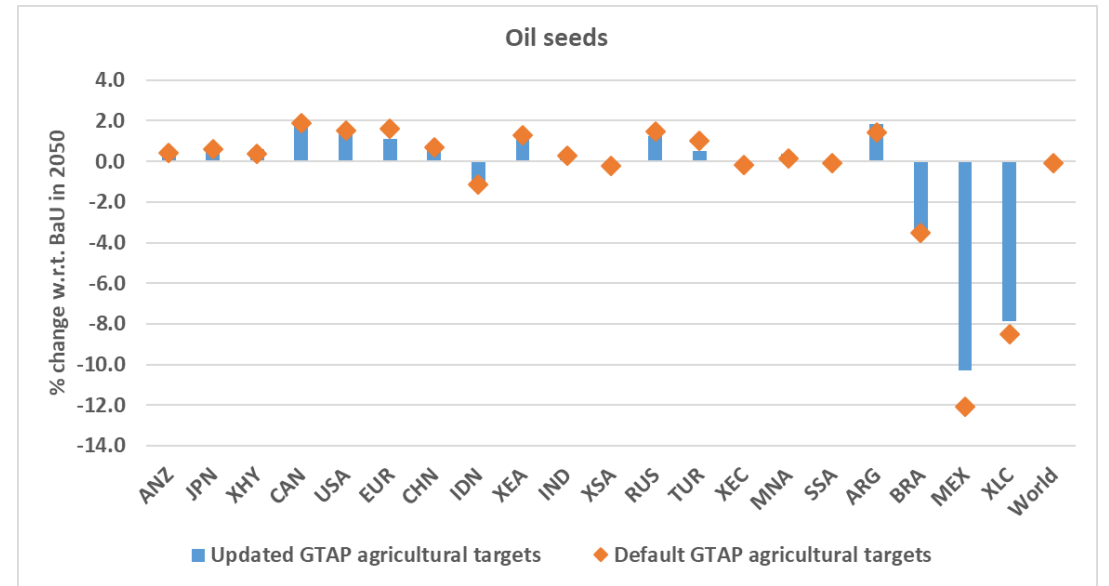
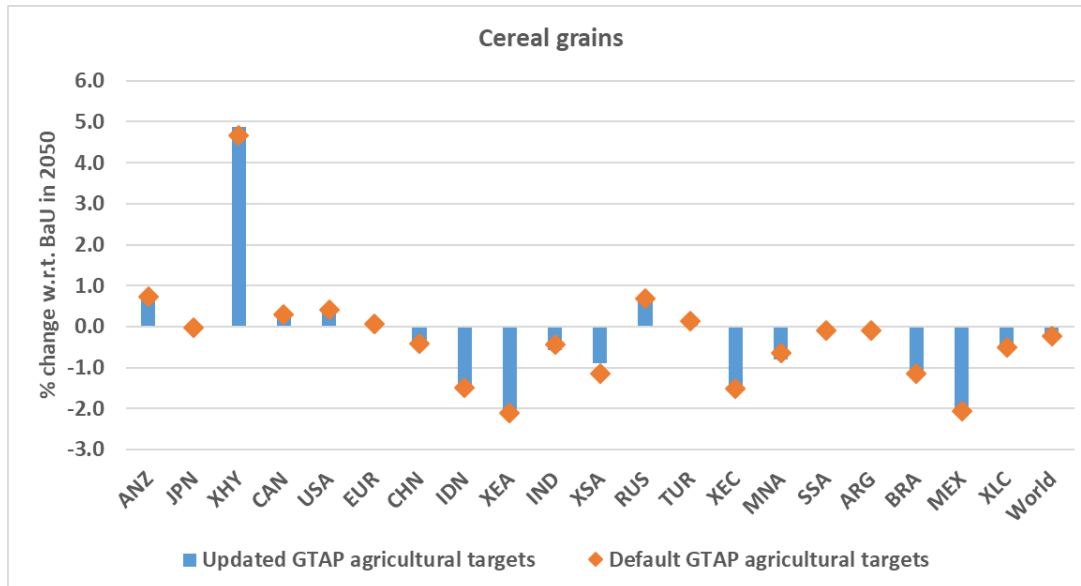
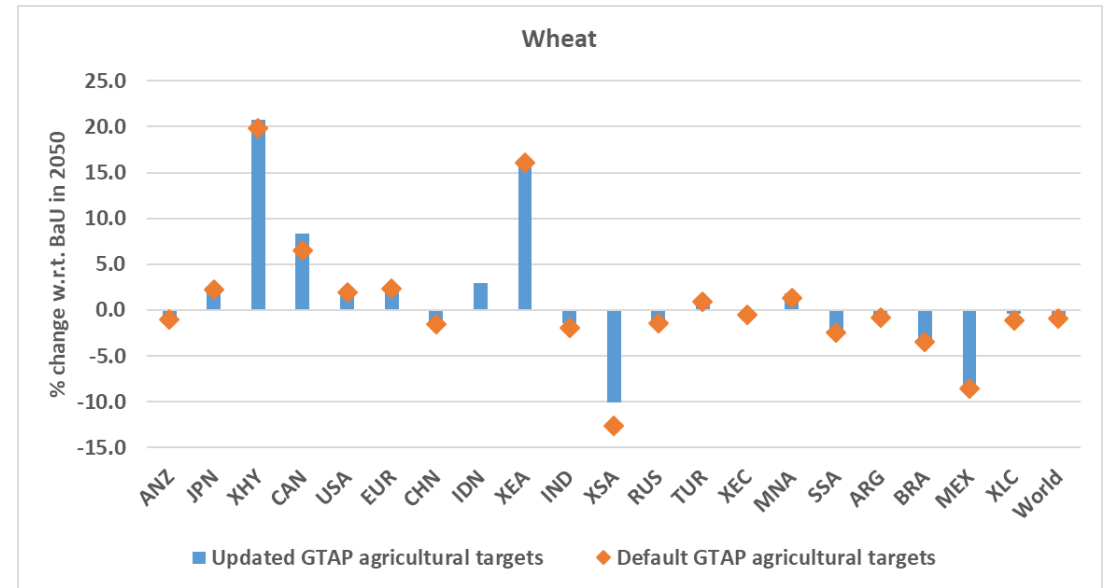
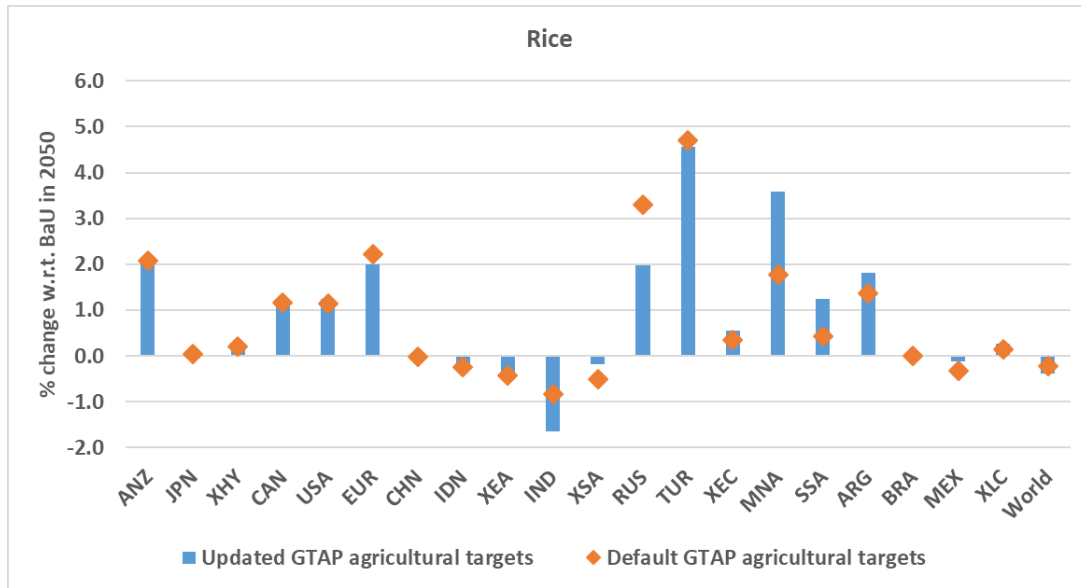


Deviation of regional GDP from baseline due to climate change impacts on agriculture in 2050, %



Deviation of households income from baseline due to climate change impacts on agriculture, %

4.11. Results comparison: sectoral impacts



Concluding remarks

Updated APT approach:

- Uses FAO data and fully covers 133 GTAP regions and 286 commodities.
- In most country/commodity cases is closer to national data/international reports compared to current GTAP APT values (sourced from OECD/Eurostat).
- Simplifies further incorporation of food balance sheets.
- Needs further verification in some country cases (e.g. China).

Climate change impacts on agriculture:

- The most severely impacted regions (China, Indonesia, India and South Asia) decrease their GDP by utmost 0.2% in 2050. Positive impacts for Argentina.
- More severe impacts to be expected in the long run and with inclusion of other climate change-related impact channels (e.g. labor productivity, tourism).
- The most impacted agricultural sectors include rice, wheat, cereal grains and oil seeds with wheat experiencing the largest negative impacts (1% globally) – *regional reallocation*.
- Updated APT values show more negative outcomes compared to the current GTAP values.



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Questions/Comments?