Economic impacts of climate-induced crop yield changes: Evidence from agri-food industries in six countries

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Supplementary Material

Paper	Country	Crop	Crop Model (Type)	Climate Scenario	Time Period	CO2 effects	Projected Impact
Costa et al. (2009)	Brazil	Bean, Maize	Statistical	HadCM3 with A2	2050, 2080	with and without	For bean crops, without CO2 effects, a reduction of up to 30% is projected. When CO2 effects are included, increases of up to 30% (for the 2020s and 2050s) and 45% (for the 2080s) are projected. Reductions in maize yields of up to 30% without CO2 effects and around 15% with CO2 effects included.
Margulis and Dubeux (2010)	Brazil	Maize, Bean, Rice	Unknown	Unknown GCM, A2 and B2	2040-2070, 2070-2100	Unknown	Reductions of 20 to 30%
Marin et al. (2009)	Brazil	Sugarcane	DSSAT (Process-based)	Unknown	2040	Unknown	Increases of up to 6% in São Paulo state toward 2040
Silva et al. (2010)	Brazil	Cowpea	SARRA	Unknown	SWLs: 1.5, 3.0 and 5.0C	Unknown	Reduction in the agricultural area planted with cowpea bean in northeastern Brazil
Chen et al. (2013)	China	Multiple crops	Ricardian	3 GCMs (Hadley, CCSR, MRI)	2050s, 2080s	Unknown	General increase in yields and associated net revenue
Erda et al. (2005)	China	Rice, maize and wheat	CERES models (Process-based)	PRECIS RCM with A2 and B2	2020s, 2050s, 2080s	without	Reduction in rice, maize and wheat yields by up to 37% in the next 20–80 years
Geng et al. (2019)	China	Wheat	Cobb–Douglas production function (multifactor analysis model) (statistical)	5 GCMs from ISI-MIP with 4 RCPs	2021–2050	with	Increase by 1.47% under RCP4.5 and 2.16% under RCP8.5 for the Jing-Jin-Ji region, Shanxi, Shaanxi, Shandong, and Henan provinces.

Tao and Zhang (2013)	China	Rice, Wheat	MCWLA-Rice, MCWLA-Wheat (Process-based)	5 GCMs, with A1FI and B1	2020s, 2050s, 2080s	with and without	Rice yield increased for 2020s, 2050s, 2080s on average by 10.6%, 7.1%, and 0.7% (with CO2). Rice yield decreased for 2020s, 2050s, 2080s on average by 4.9%, 18.6%, and 29.4% (without CO2). Wheat yields could increase by up to 26.7%, 53.0% and 75.6% during 2020s, 2050s, and 2080s (with CO2). Wheat yields could increase by up to 8.8%, 17.7%, and 24.7% during 2020s, 2050s, and 2080s (without CO2).
Thomson et al. (2006)	China	Wheat	EPIC (Process-based)	HadCM3, A2 and B2	2015–2045 and 2070–2099	with	Increases in dryland winter wheat yields in the Huang-Hai Plain (China's most productive wheat growing region)
Xiao et al. (2018)	China	Wheat	APSIM model	28 GCMs	2031–2060 and 2071–2100	with and without	Increase in wheat yields with CO_2 effects Decrease in wheat yields without CO_2 effects
Xiong et al. (2007)	China	Maize	CERES-Maize (Process-based)	RCMs with A2 and B2	2080s	with	Increase in rainfed maize yield in the North China Plain by up to 50% during 2080s without adaptation
Abera et al. (2018)	Ethiopia	Maize	DSSAT - CERES-Maize (Process-based)	19 CMIP5 GCMs	2010–2039, 2040–2069 and 2070–2099	Unknown	Decrease by up to 43 and 24% by the end of the century at Bako and Melkassa stations, respectively, while simulated maize yields in Hawassa show an increase of 51%
Araya et al. (2015)	Ethiopia	Maize	DSSAT & APSIM (Process-based)	20 GCMs	2010–2039, 2040–2069, 2070–2099	with	Slight increases in the median yield for the near future (1.7%–2.9% across models and RCPs). Mixed pattern later in the century, with some areas projected to see increases in yield (around 4%) and some decreases (around 6%).

Kassie et al. (2015)	Ethiopia	Maize	CERES-maize model (Process-based)	3 GCMs (CanESM2, CSIRO-MK3-6-0 and HadGEM2-ES)	2050	with and without	Decrease in maize yield on average by 20% in 2050s
Sagoe (2006)	Ghana	Cassava, Cocoyam	DSSATv4 (Process-based)	Unknown	2020, 2050, 2080s	Unknown	Decrease in yields of cassava and cocoyam
Byjesh et al. (2010)	India	Maize	InfoCrop (Process-based)	HadCM3 with A2a	2020, 2050, 2080s	with	Generally, projections show reductions in yields of monsoon and winter maize
Challinor et al. (2006)	India	Groundnut	GLAM (Process-based)	PRECIS RCM with A2	2071–2100	without	General reduction in yield
Gangadhar Rao et al. (1995)	India	Sorghum	CERES-sorghum (Process-based)	3 GCMs	Unknown	with and without	Decrease in yield under all scenarios
Koehler et al. (2013)	India	Wheat	GLAM (Process-based)	17 GCMs with A1B	2030–2049, 2050–2069, and 2070–2089	without	General reduction in yield projected across northern India

Table S1: Summary of published crop yield studies focused on the study countries

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Authors	Country	Model	Variables	GCMs	Time Period	Projected Impact
Mideksa (2010)	Ethiopia	General equilibrium model	GDP	CLINE, CGCM2, PCM	Unknown	Changes to agricultural production and output in the sectors linked to the agricultural sector are likely to reduce Ethiopia's GDP by about 10%
Deressa and Hassan (2009)	Ethiopia	Ricardian method	Crop net revenue	CGM2, HaDCM3 and PCM	2050, 2100	Reduction in crop net revenue per hectare is projected by the years 2050 and 2100
Yates and Strzepek (1998)	Egypt	Statically coupled economic models	GDP agriculture, crop price index, food price index, harvested area	GFDL, UKMO, GISS	2060	GDP agriculture: % change from baseline: 96% (optimistic scenario), 135% (pessimistic scenario). Crop price index: % change from baseline: -22% (optimistic scenario), -22% (pessimistic scenario). Food price index: % change from baseline: 6.9% (optimistic), -3.4% (pessimistic). Harvested area: % change from baseline: 30% (optimistic and pessimistic)
Arndt et al. (2015)	Ghana	CGE	GDP	NCAR-PCM1	2050	Decline in agricultural GDP by 1.9% by 2050. Some of the largest economic losses occur within the important export crop sector, especially cocoa.
Issahaku and Maharjan (2014)	Ghana	Ricardian method	Revenue	Unknown	Unknown	Positive impact on revenues of sorghum and yam, reduction of expected revenue from cassava and maize.

Table S2: Summary of published economic studies of crop yield impacts focused on the study countries

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	Rice	**Wheat**
Avg. Temperature	1.810 (2.039)	-15.653*** (2.585)
Avg. Temperature^2	-5.080 *** (1.293)	-4.580** (1.450)
Avg. Precipitation	-0.227 (0.976)	2.292* (0.890)
Avg. Precipitation^2	-0.154 (0.531)	-2.377*** (2.920)

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: Table reports regression coefficients for each crop yield response function as well as standard errors in brackets. All regressions include quadratic time trends (year and year^2).

Table S3 Regression results

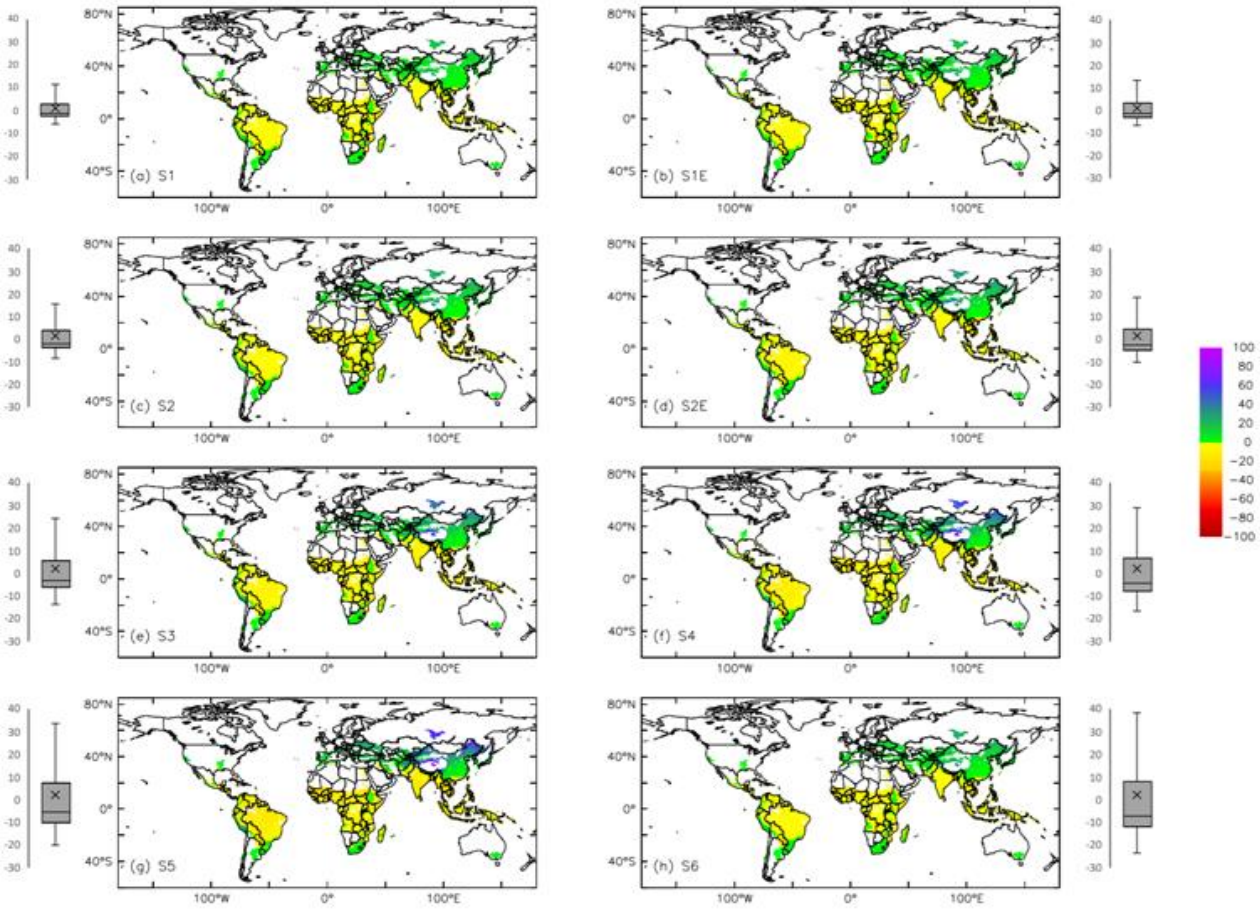

Figure S1: Gridded ensemble mean percentage change in rice yield for (a) scenario 1; (b) scenario 1E; (c) scenario 2 (d) scenario 2E; (e) scenario 3; (f) scenario 4; (g) scenario 5; (h) scenario 6. Box-and-whisker plots reflect the underlying climate model uncertainty.

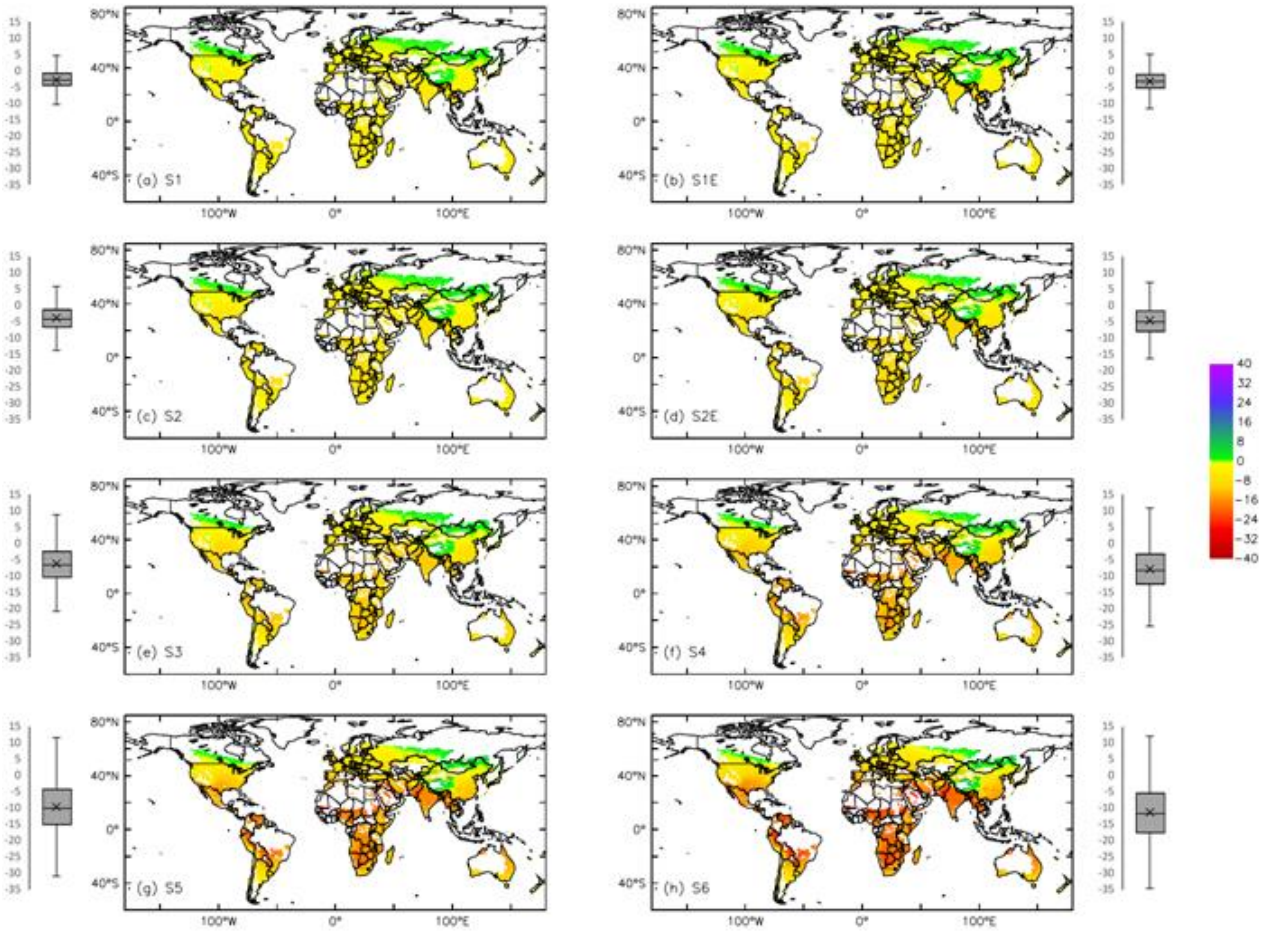

Figure S2: Gridded ensemble mean percentage change in wheat yield for (a) scenario 1; (b) scenario 1E; (c) scenario 2 (d) scenario 2E; (e) scenario 3; (f) scenario 4; (g) scenario 5; (h) scenario 6. Box-and-whisker plots reflect the underlying climate model uncertainty.

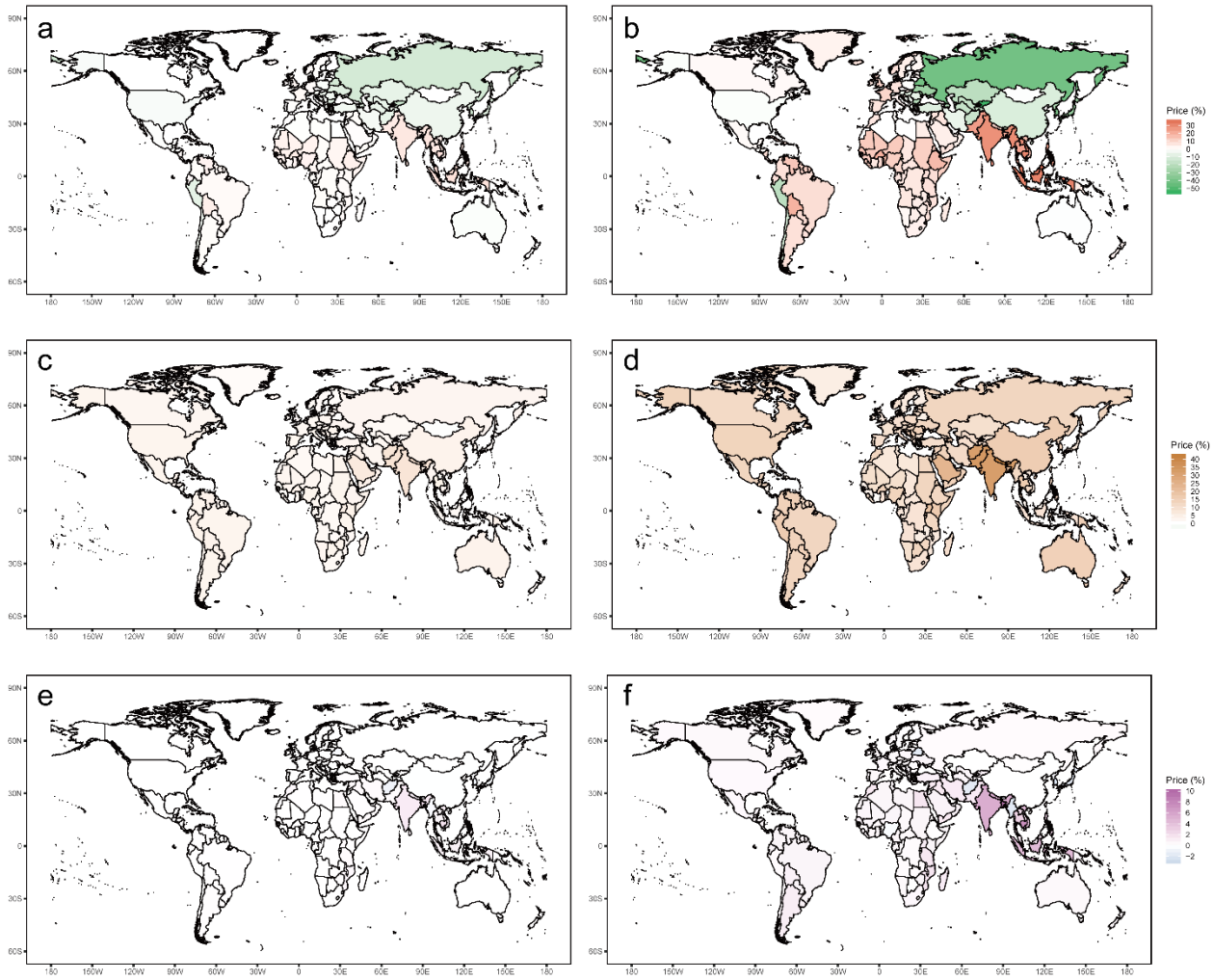

Figure S3: Aggregate export price index of rice, wheat and food manufacturing products for (a) change of price of rice in S1; (b) change of price of rice in S6; (c) change of price of wheat in S1; (d) change of price of wheat in S6; (e) change of price of food manufacturing products in S1; (f) change of price of food manufacturing products in S6.

	China		India		Brazil		Egypt		Ghana		Ethiopia	
	S1	S6	S1	S6	S1	S6	S1	S6	S1	S6	S1	S6
pdr	-4.83	-10.43	5.74	27.72	1.39	8.08	0.26	4.22	2.04	9.05	3.15	17.03
wht	3.55	15.64	8.18	32.13	3.08	12.63	3.12	12.85	1.98	8.52	2.97	12.34
ocr	-0.04	0.63	0.40	1.93	0.18	1.16	0.30	1.75	0.21	1.21	0.22	1.24
lsf	0.01	0.57	0.09	0.46	0.15	0.90	-0.06	-0.12	0.01	0.15	0.04	0.38
mng	-0.01	-0.12	-0.03	-0.15	-0.02	-0.12	-0.02	-0.14	-0.01	-0.07	-0.07	-0.27
fdm	-0.15	-0.01	1.23	5.34	0.12	0.66	0.28	1.47	0.08	0.48	0.01	0.15
omf	0.01	-0.07	-0.11	-0.50	-0.01	-0.02	-0.10	-0.48	-0.01	-0.03	-0.08	-0.26
cns	0.02	-0.07	-0.19	-0.81	-0.01	-0.04	-0.17	-0.76	-0.01	-0.01	-0.06	-0.16
trd	0.01	-0.04	-0.07	-0.31	-0.01	0.00	-0.21	-0.95	-0.01	-0.02	-0.09	-0.31
tps	0.01	-0.10	-0.14	-0.64	-0.01	-0.04	-0.12	-0.52	-0.01	-0.02	-0.06	-0.21
sev	0.03	-0.08	-0.18	-0.77	-0.01	-0.03	-0.16	-0.71	0.00	0.03	-0.04	-0.09

Table S4: Change in price (%) to households of domestic commodities in the six selected countries. Results are shown for Scenario 1 and scenario 6.

	China		India		Brazil		Egypt		Ghana		Ethiopia	
	S1	S6	S1	S6	S1	S6	S1	S6	S1	S6	S1	S6
pdr	2.42	14.17	-0.16	3.05	0.84	6.66	1.09	8.61	0.46	5.22	4.19	21.79
wht	3.02	12.60	3.01	12.20	2.97	12.26	2.71	11.66	2.43	10.44	2.82	12.21
ocr	0.18	1.12	0.21	1.24	0.19	1.21	0.22	1.28	0.14	0.90	0.23	1.32
lsf	0.11	0.65	-0.34	-1.44	0.11	0.74	0.18	0.93	0.18	0.98	0.15	0.74
mng	-0.02	-0.12	-0.02	-0.12	-0.02	-0.13	-0.02	-0.12	-0.02	-0.13	-0.02	-0.13
fdm	0.20	1.00	0.52	2.48	0.15	0.79	0.24	1.16	0.23	1.15	0.21	1.01
omf	-0.01	-0.08	-0.01	-0.09	-0.01	-0.07	-0.02	-0.11	-0.01	-0.10	-0.02	-0.14
cns	0.00	-0.05	0.00	-0.07	-0.01	-0.10	0.00	-0.07	-0.02	-0.11	0.00	-0.07
trd	-0.01	-0.06	0.00	-0.05	-0.01	-0.05	-0.01	-0.05	-0.01	-0.06	-0.01	-0.05
tps	-0.02	-0.13	-0.02	-0.10	-0.02	-0.11	-0.02	-0.11	-0.02	-0.11	-0.01	-0.09
sev	-0.02	-0.13	-0.01	-0.07	-0.02	-0.10	-0.02	-0.10	-0.02	-0.10	-0.02	-0.10

Table S5: Change in price (%) to households of imported commodities in the six selected countries. Results are shown for Scenario 1 and scenario 6.

	China		India		Brazil		Egypt		Ghana		Ethiopia	
	S1	S6	S1	S6	S1	S6	S1	S6	S1	S6	S1	S6
Land	-1.89	0.90	4.30	18.97	2.20	12.75	8.85	46.13	3.08	15.41	4.94	21.69
Agriculture and unskilled labour	0.06	-0.05	-0.45	-1.95	-0.02	-0.07	-0.41	-1.82	-0.03	0.09	-0.26	-0.79
Unskilled labour	0.05	-0.08	-0.21	-0.91	-0.01	-0.03	-0.25	-1.11	0.00	-0.01	-0.10	-0.34
Skilled labour	0.04	-0.08	-0.16	-0.72	-0.01	-0.04	-0.25	-1.13	0.00	0.01	-0.09	-0.31
Capital	0.04	-0.08	-0.21	-0.90	-0.01	-0.04	-0.23	-1.05	-0.01	-0.02	-0.10	-0.36
Natural Resources	0.45	0.29	-2.07	-9.12	-0.08	-0.76	0.14	0.38	-0.34	-1.67	-0.98	-3.77

Table S6: Percentage change in the market price of primary factors in the 6 selected countries for scenarios 1 and 6