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Climate Change Impacts on Agriculture in 2050 under a Range of Socioeconomic and Emissions Scenarios

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On behalf of the AgMIP global economic modeling team

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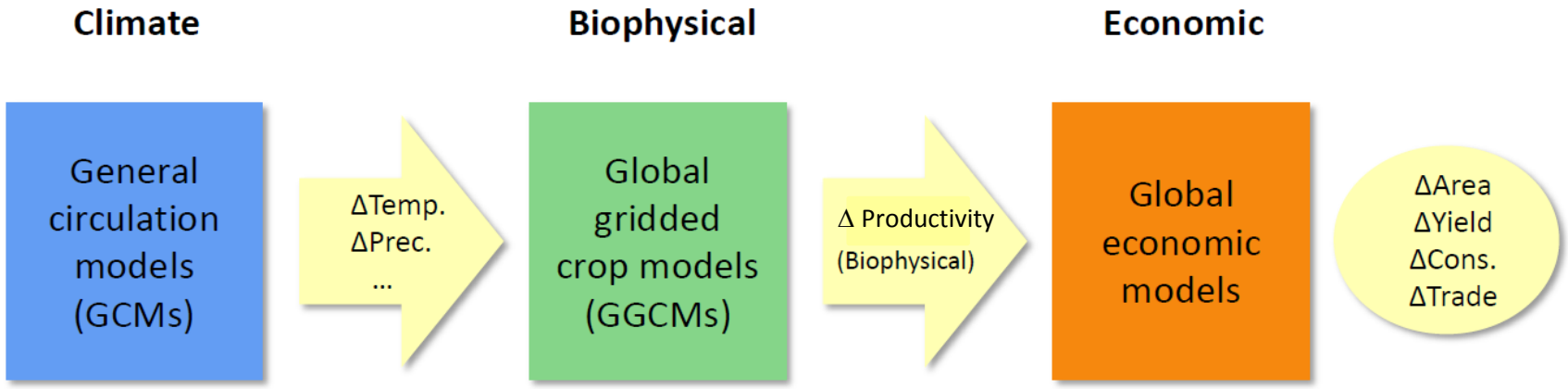
The views expressed are those of the authors and should not be attributed to the Economic Research Service or USDA

Overview

- Motivation for study
  - Funded by USDA to provide international context for forthcoming report *Global Climate Change, Food Security, and the U.S. Food System*
- Five participating global economic modeling teams
  - Partial equilibrium
    - IMPACT (International Food Policy Research Institute)
    - MAgPIE (Potsdam Institute for Climate Impact Research)
  - Computable general equilibrium (CGE)
    - ENVISAGE (Purdue University)
    - FARM (USDA Economic Research Service)
    - MAGNET (Wageningen University & Research centre, The Netherlands)
- Scenarios
  - SSP 1 and RCP 4.5
  - SSP 2 and RCP 6.0
  - SSP 3 and RCP 8.5

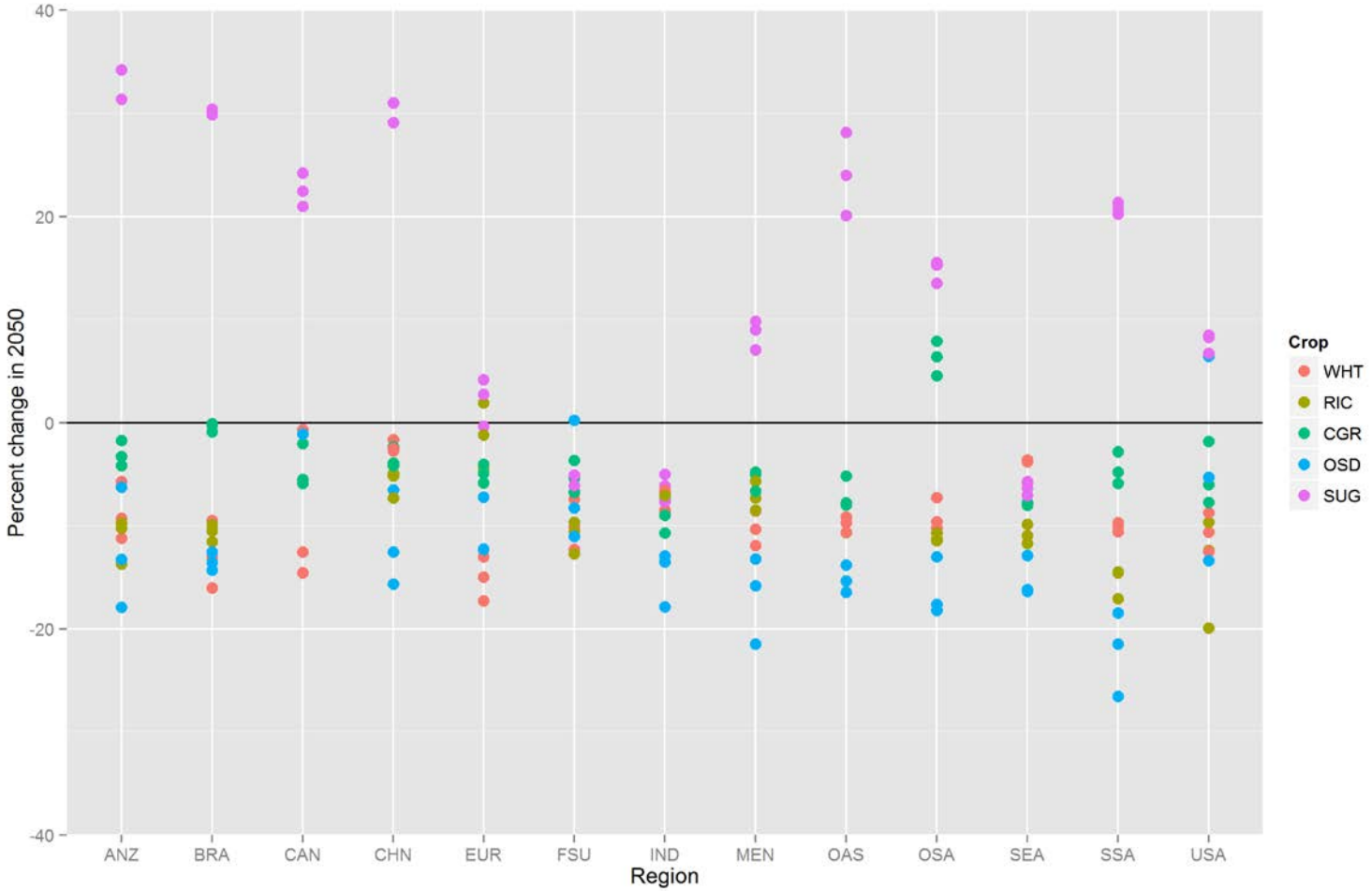
The climate modeling chain: From biophysical to socioeconomic



Regional aggregation

Code	Region name	Comments
USA	United States of America	
CAN	Canada	
BRA	Brazil	
OSA	Other South America, Central America & Caribbean	
EUR	Europe	Excl. Turkey
FSU	Former Soviet Union	European and Asian
MEN	Middle-East North Africa	Incl. Turkey
SSA	Sub-Saharan Africa	
CHN	China	
IND	India	
SEA	South-East Asia	Incl. Japan
OAS	Other Asia	Incl. Other Oceania
ANZ	Australia/New Zealand	

Exogenous impacts of climate change on crop yields under SSP 2 and RCP 6.0 (percent change relative to SSP 2 baseline in 2050 without climate change)

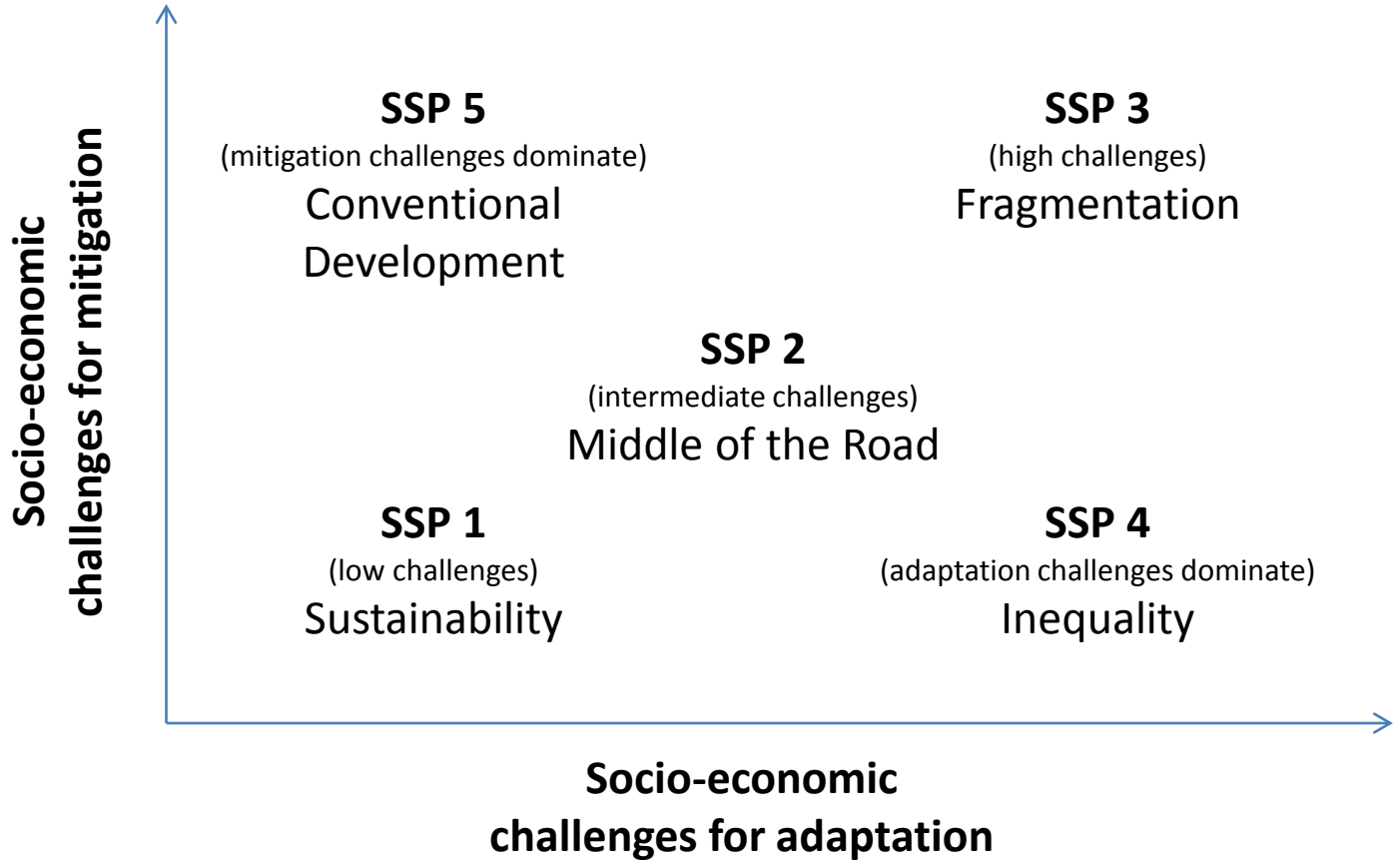


Based on three GCMs and one crop model (LPJmL). Each dot depicts the result for one crop and one GCM.

Scenarios

Radiative forcing	SSP 1	SSP 2	SSP 3	SSP 4	SSP 5
RCP 8.5		AgMIP Phase 1	HadGEM IPSL MIROC		
RCP 6.0		HadGEM IPSL MIROC			
RCP 4.5	HadGEM IPSL MIROC				
RCP 2.6					
No climate change	Reference	Reference AgMIP Phase 1	Reference AgMIP Phase 1		

Shared Socio-economic Pathways (SSPs)

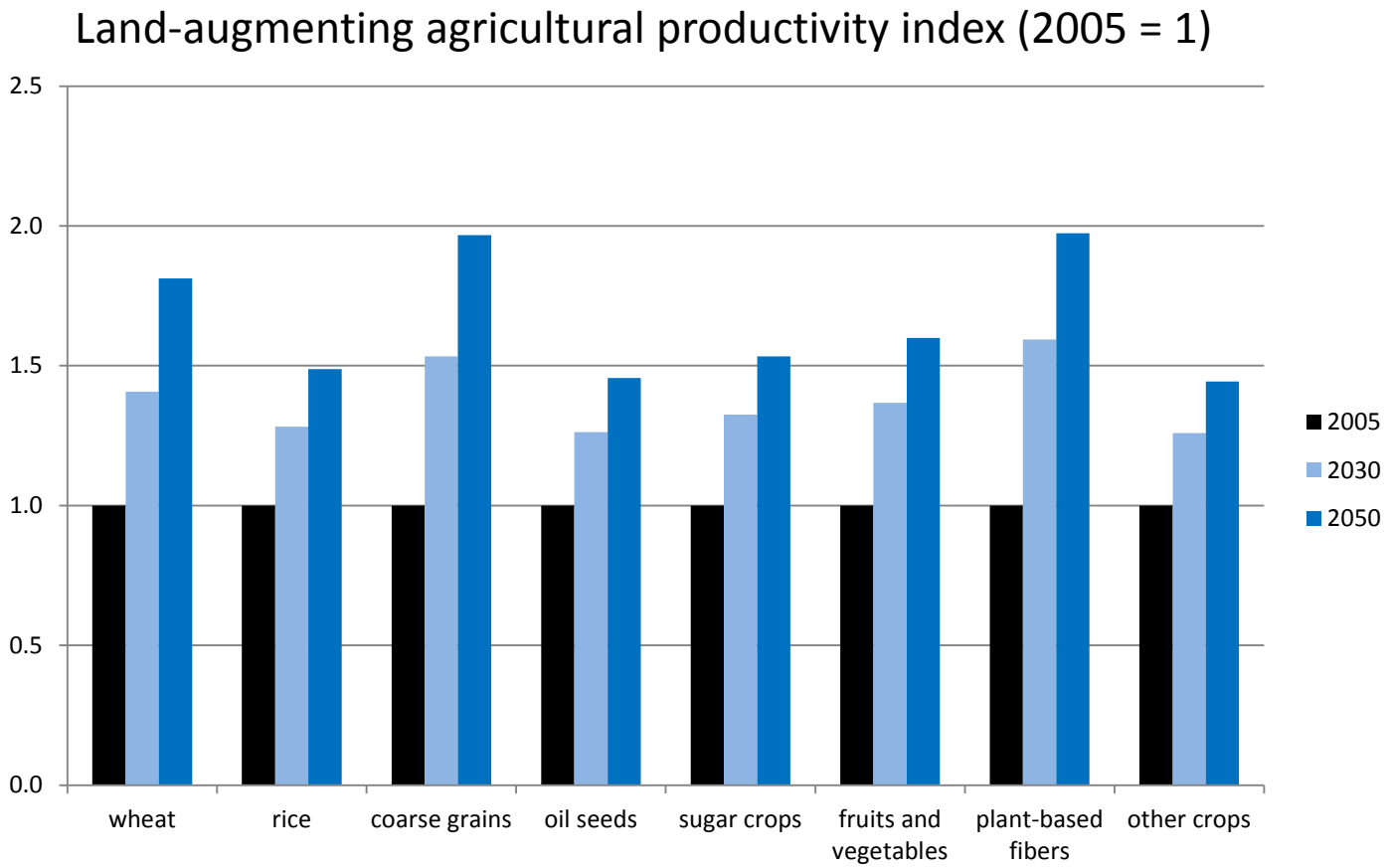


Source: O'Neill, B.C., E. Kriegler, K. Riahi, K. Ebi, S. Hallegatte, T.R. Carter, R. Mathur, D.P. van Vuuren. February 2014. "A New Scenario Framework for Climate Change Research: The Concept of Shared Socio-Economic Pathways," Special Issue on "A Framework for the Development of New Socioeconomic Scenarios for Climate Change Research," *Climatic Change* 122(3): 387-400.

Economic variables

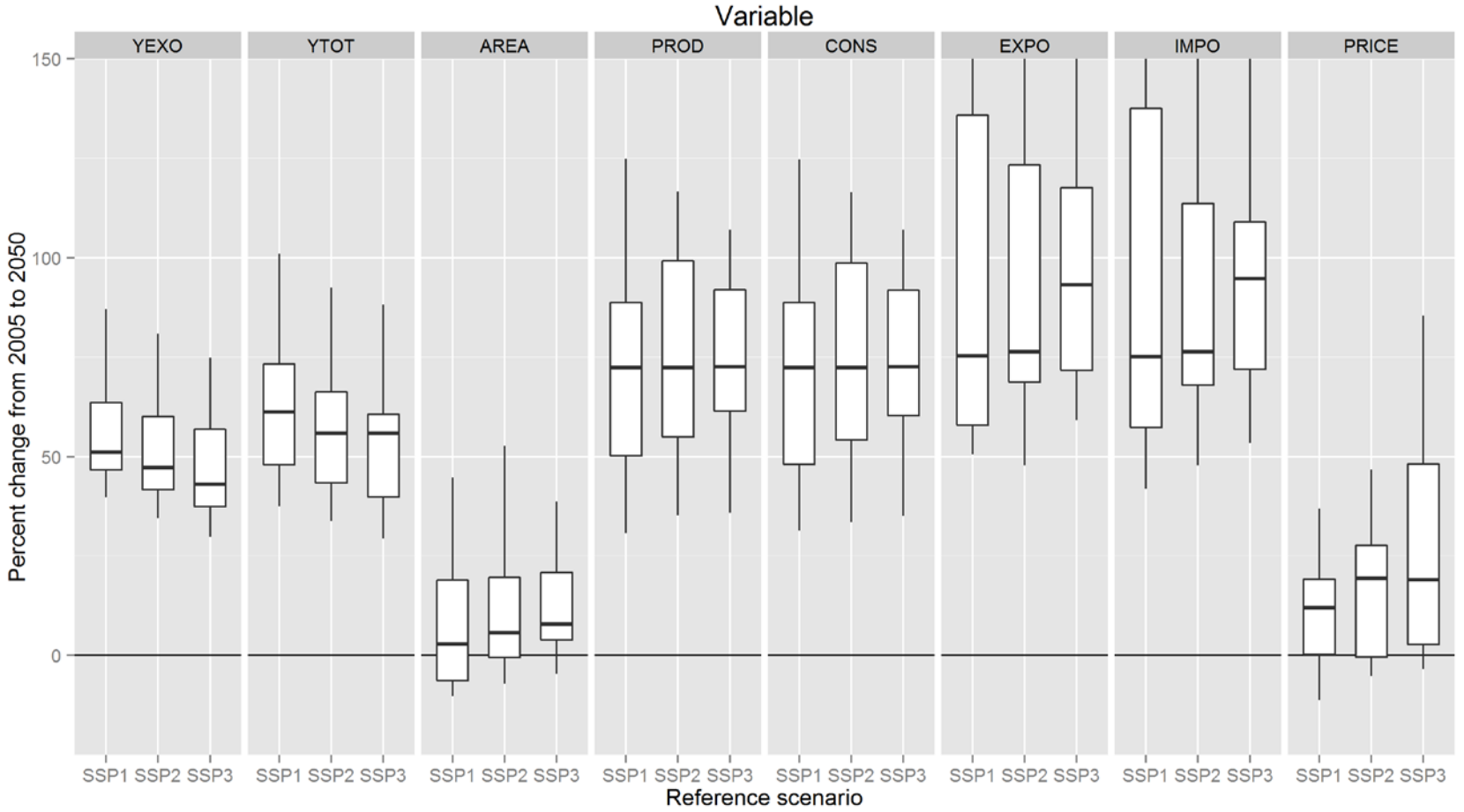
Code	Variable	Comments
YEXO	Exogenous yield shocks	Expressed as either: • Percent change over time, from 2005 through 2050 or • Percent change at a point in time (2050), relative to reference scenario
YTOT	Realized yield after management adaptation	
AREA	Agricultural area in production	
PROD	Total production	
CONS	Total consumption	
EXPO	Exports	
IMPO	Imports	
PRICE	Price	

Agricultural Productivity Growth



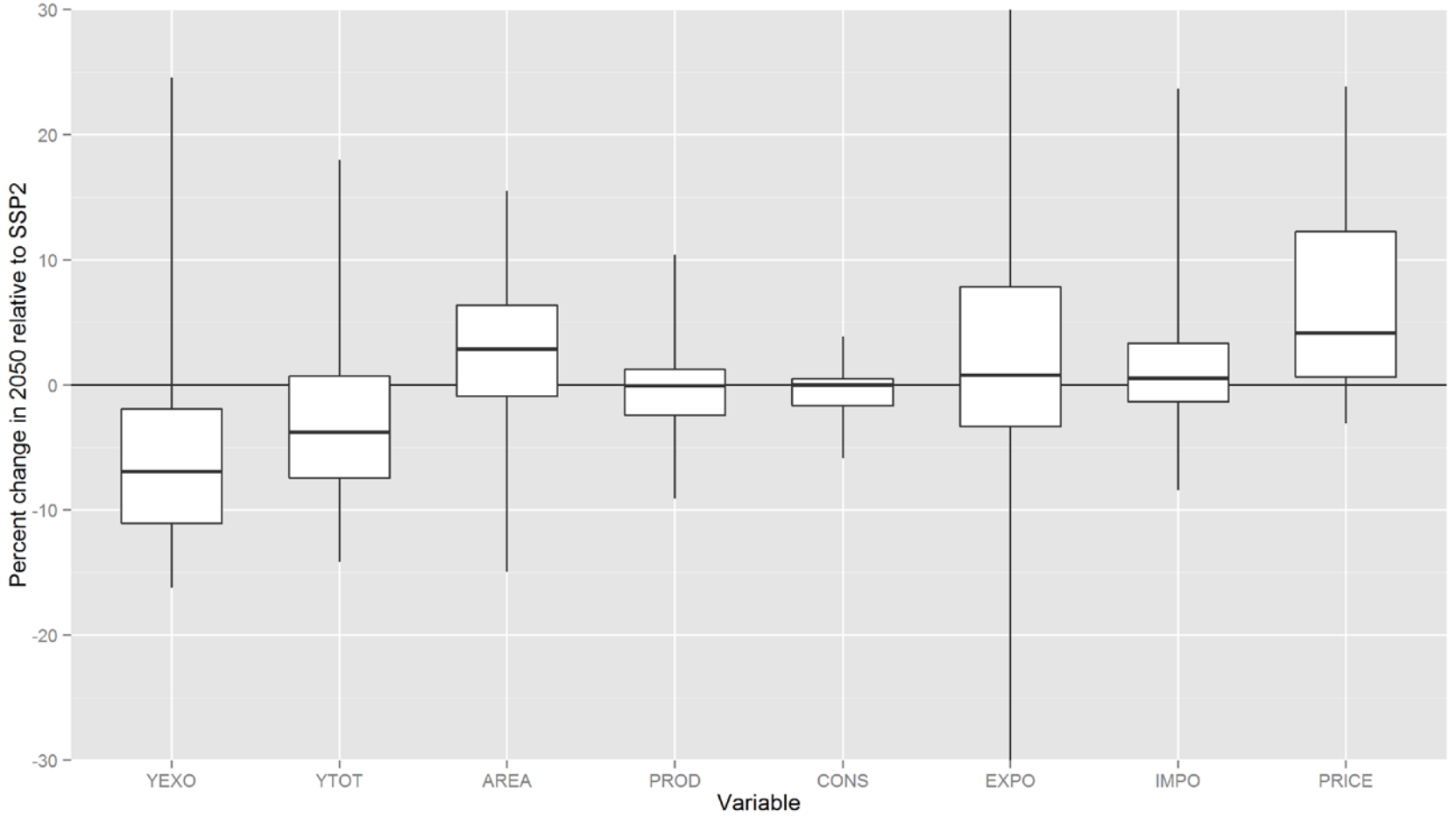
Source: IMPACT model maintained by the International Food Policy Research Institute. IMPACT values are based on expert opinion about potential biological yield gains for crops in individual countries based on historical yield gains and expectations about future private and public sector research and extension efforts.

Baseline increases in economic variables to 2050 (percent change relative to 2005)



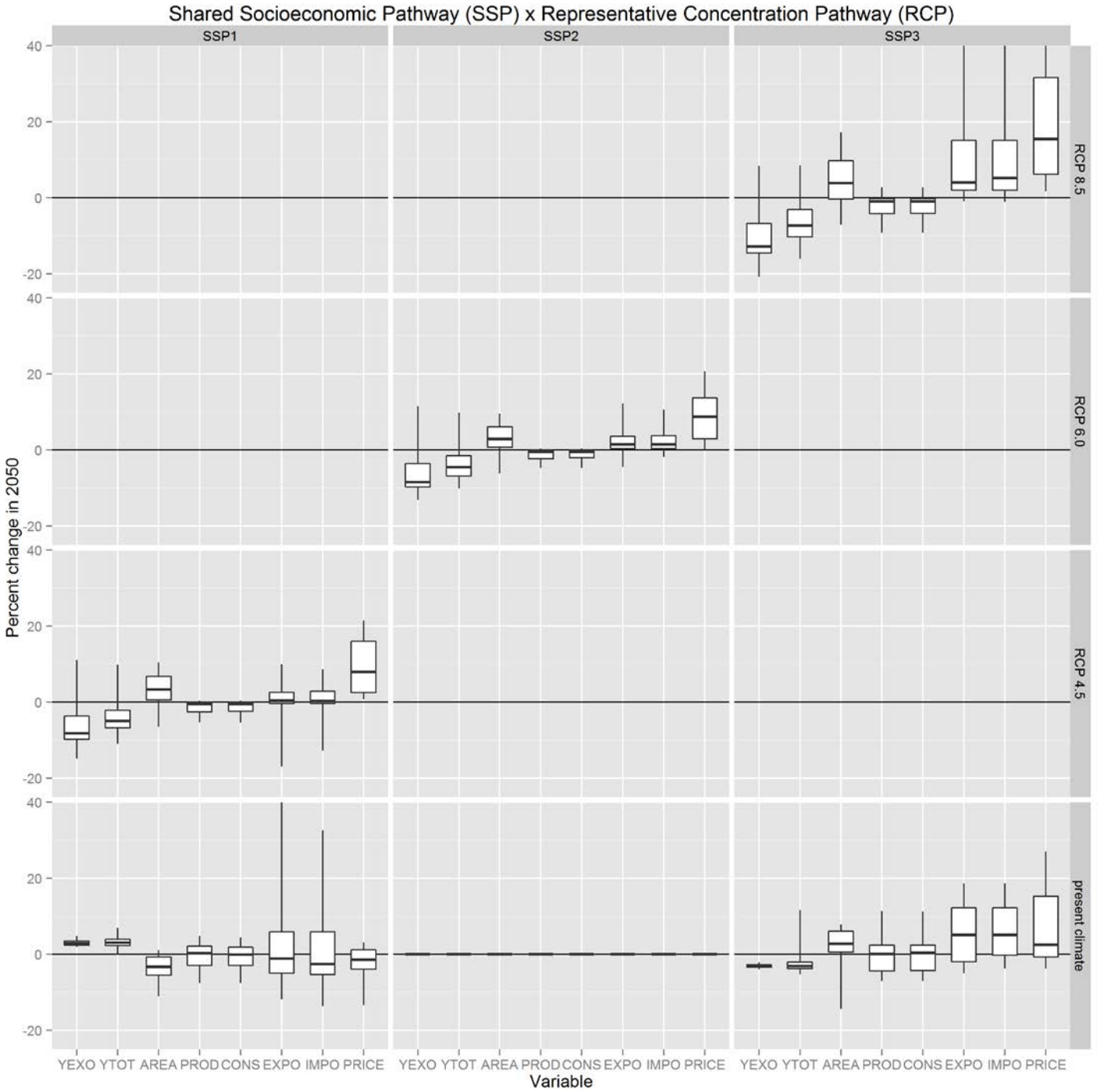
Pooled results for five commodities (rice, wheat, coarse grains, oil seeds, sugar) from five economic models (n = 25), aggregated across 13 world regions. The boxes and whiskers depict 5th, 25th, 50th, 75th, and 95th percentiles.

Impacts of climate change on economic variables under SSP 2 and RCP 6.0



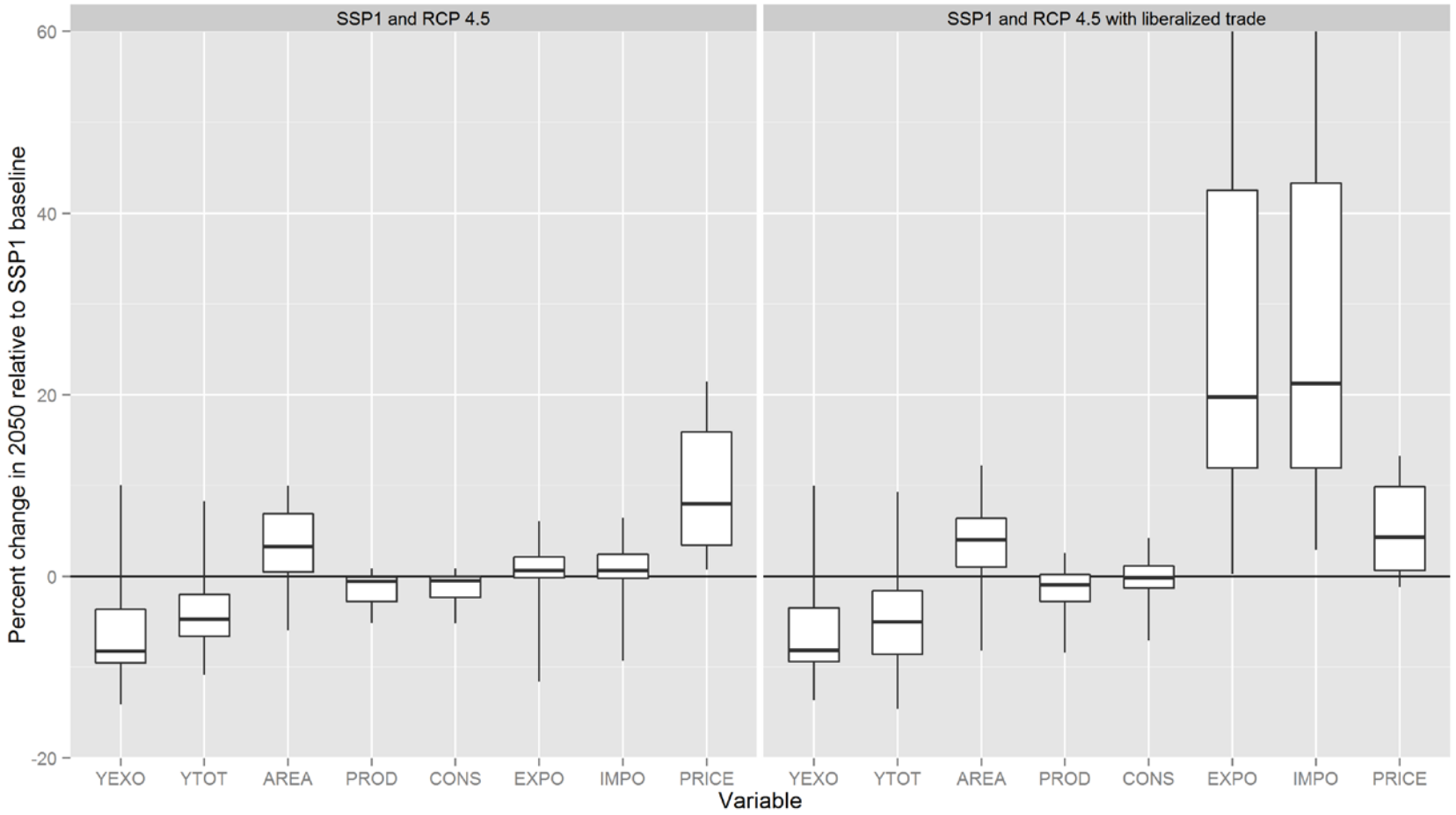
Pooled results for five commodities (rice, wheat, coarse grains, oil seeds, sugar) in 13 world regions from three GCMs and five economic models (n = 975). The boxes and whiskers depict 5th, 25th, 50th, 75th, and 95th percentiles.

Impacts of climate change under different SSP x RCP/GCM combinations (percent change relative to SSP baseline in 2050)



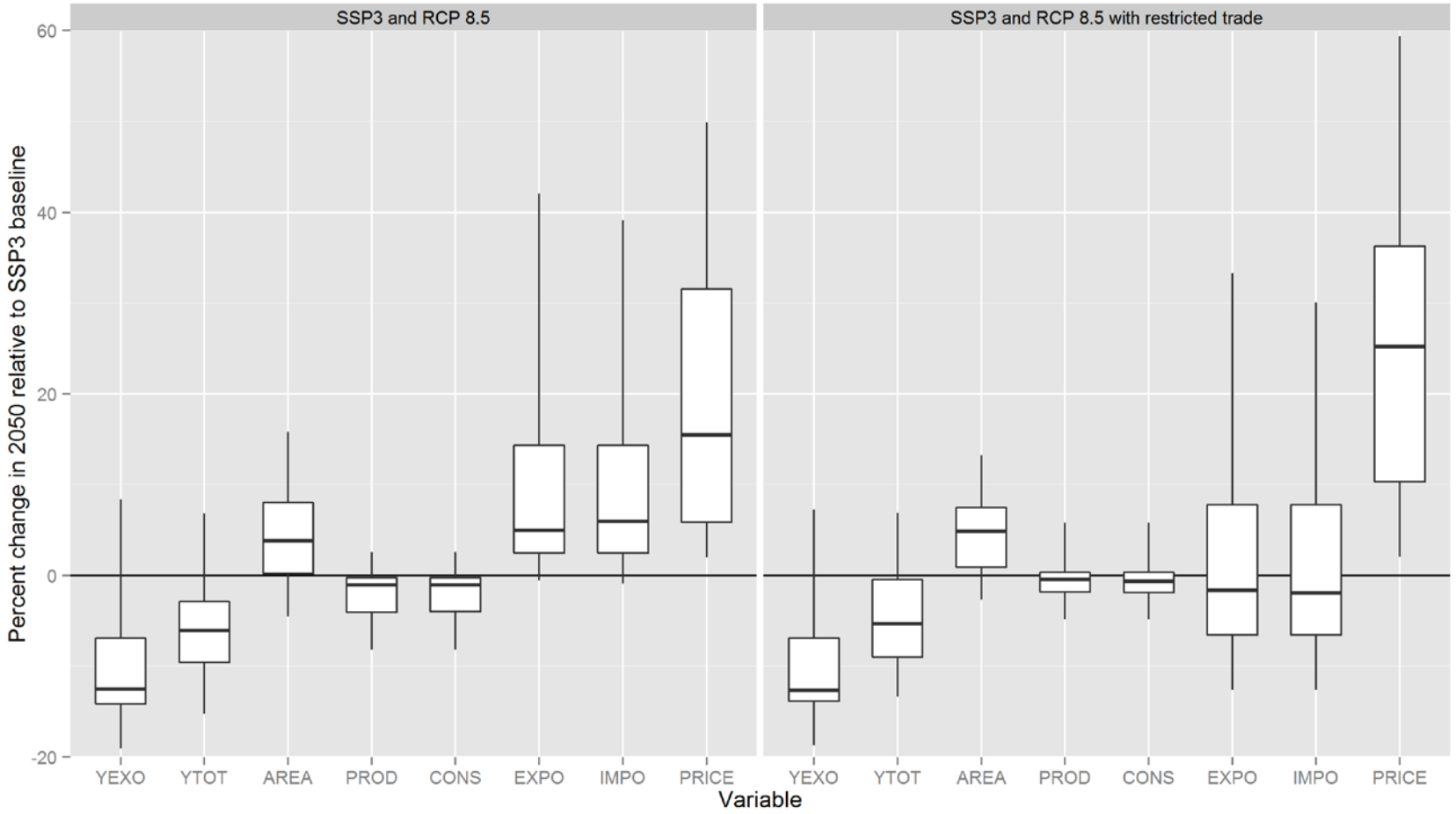
Pooled results for five commodities (rice, wheat, coarse grains, oil seeds, sugar) from three GCMs and five economic models (n = 75), aggregated across 13 world regions. The boxes and whiskers depict 5th, 25th, 50th, 75th, and 95th percentiles.

Impacts of climate change without (left) and with (right) trade liberalization



Pooled results for five commodities (rice, wheat, coarse grains, oil seeds, sugar) and one GCM (HadGEM2-ES) and four economic models (n = 20), aggregated across 13 world regions.

Impacts of climate change without (left) and with (right) restricted international trade



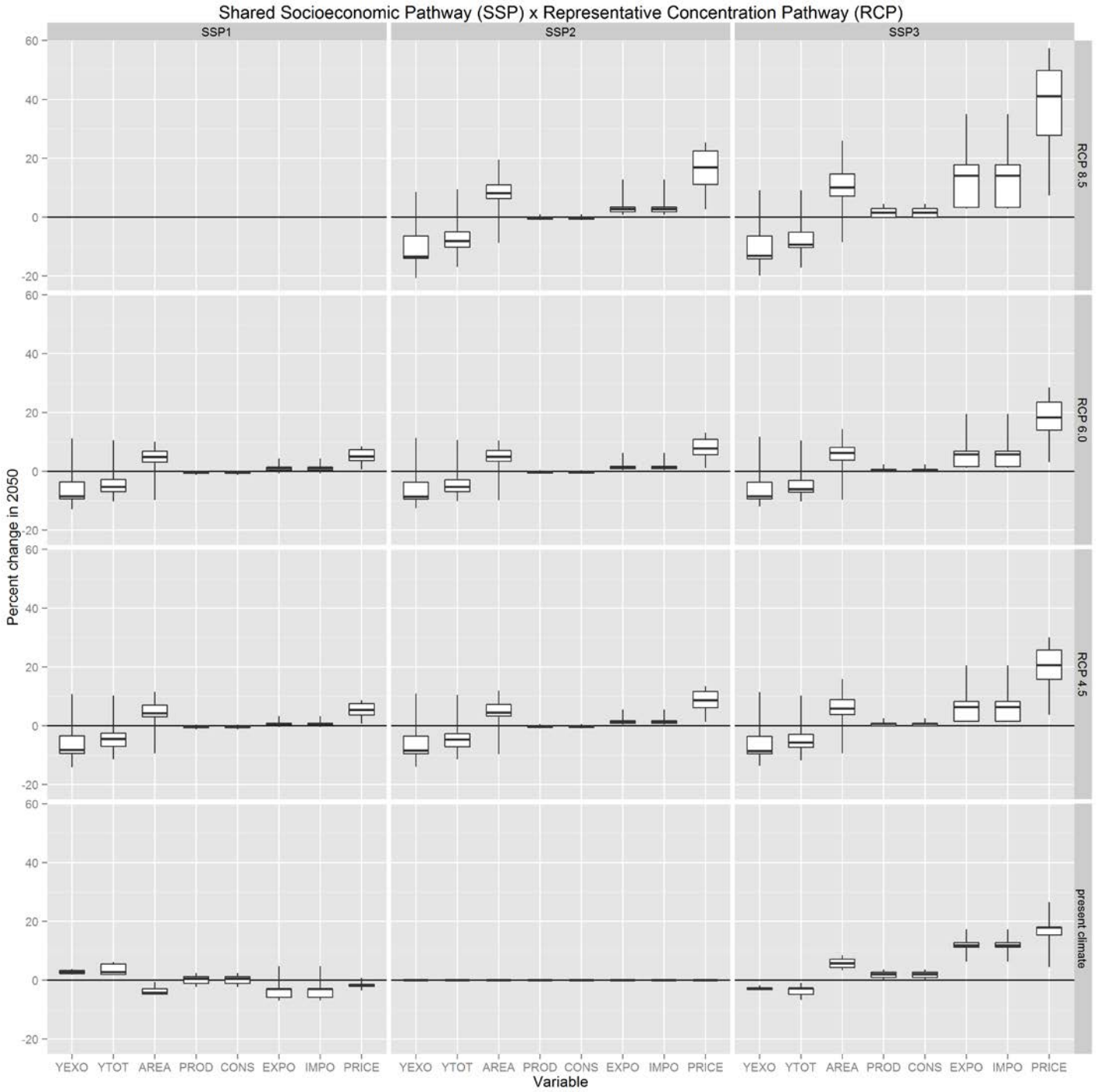
Pooled results for five commodities (rice, wheat, coarse grains, oil seeds, sugar), one GCM (HadGEM2-ES) and four economic models (n = 20), aggregated across 13 world regions.

Outstanding Issues

- How to apply output from crop process models to global economic models
- Response of food consumption to increasing per-capita income
- Income distribution within world regions
- Variation across world regions
- CO_2 fertilization
- Extreme events such as multi-year drought
- Link to analysis at sub-national level

Extra Slides

Impacts of climate change under different SSP x RCP/GCM combinations using the FARM model (percent change relative to SSP baseline in 2050)



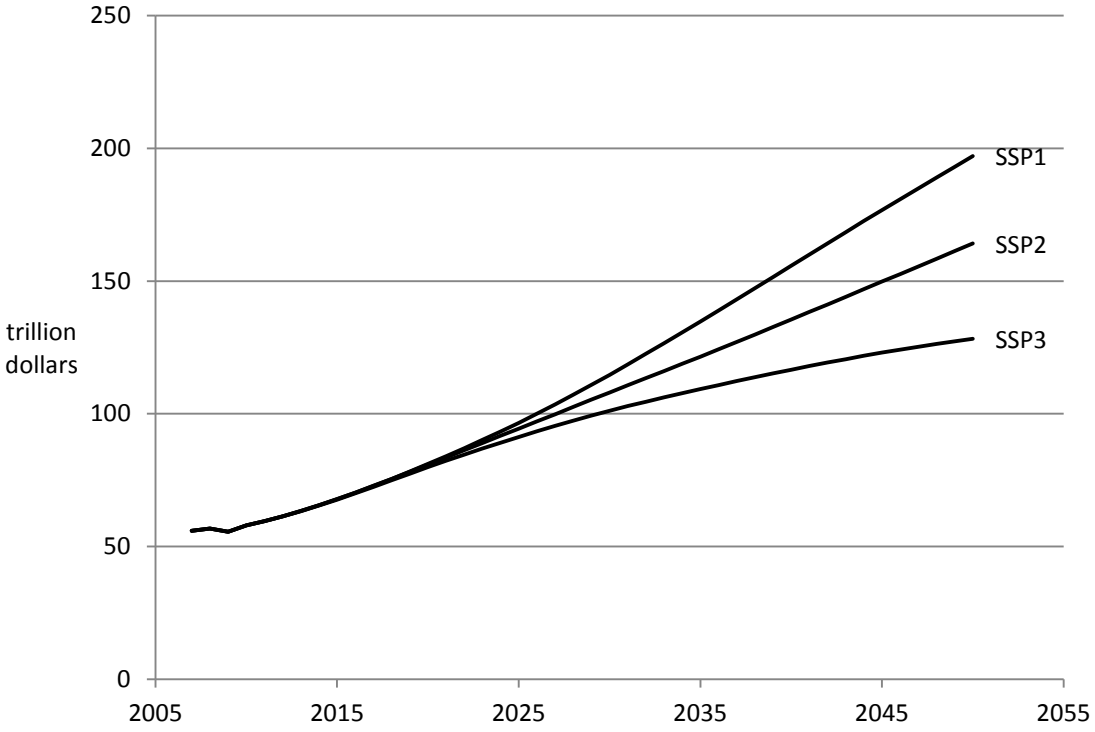
Pooled results for five commodities (rice, wheat, coarse grains, oil seeds, sugar) from three GCMs and one economic model (n = 15), aggregated across 13 world regions. The boxes and whiskers depict 5th, 25th, 50th, 75th, and 95th percentiles.

Key characteristics of participating economic models

Model	Institution	Type	Economy coverage	Agr. sectors*	Regions**	Base year	Agr. Policies	Bioenergy	Global numeraire	Agric. supply	Final demand	Trade
AIM	NIES, Japan	**CGE**	Full economy	8 / 1	89 / 17	2005	Implicitly assumed unchanged	Endogenous 1st and 2nd generation	US CPI	Nested CES	LES utility	Non-spatial; Armington gross-trade
ENVISAGE	FAO/World Bank/ Purdue	**CGE**	Full economy	10 / 5	11 / 9***		Price wedges (based on GTAP)	None explicitly represented	Price index high-inc. manuf'ed exports	Nested CES	LES utility (with dynamic shifters)	Armington spatial equilibrium
FARM	USDA, USA	**CGE**	Full economy	12 / 8	5 / 8***	2004 & 2007	Price wedges (based on GTAP)	Little for electricity and heating	Price Index of European Service Sector	Nested CES	LES utility	Armington spatial equilibrium
GTEM	ABARE, Australia	**CGE**	Full economy	7 / 7	5 / 8***	2004	Implicitly assumed unchanged	Endogenous 1st generation	Average price of capital goods	Nested Leontief and CES	CDE utility	Armington spatial equilibrium
MAGNET	LEI-WUR, The Nether-lands	**CGE**	Full economy	10 / 9	29 / 16	2004 & 2007	Price wedges (adjusted from GTAP); milk quotas	Biofuel targets w/ endogenous allocation	World GDP Deflator	Nested CES	CDE private demand and Cobb-Douglas utility	Armington spatial equilibrium
GCAM	PNNL, USA	**PE**	Agriculture, Energy	18 / 0	7 / 9***	2005	Implicitly assumed unchanged	Endogenous 1st and 2nd generation	n.a.	Leontief	Demand elasticities adjusted over time	Heckscher-Ohlin non-spatial, net-trade
GLOBIOM	IIASA, Austria	**PE**	Agriculture, forestry, Bioenergy	31 / 6	10 / 20	2000	Implicitly assumed unchanged	Exogenous demand	n.a.	Leontief	Demand elasticities adjusted over time	Enke-Samuelson-Takayama-Judge spatial equilibrium
IMPACT	IFPRI, USA	**PE**	Agriculture	32 / 14	101 / 14	2000	Price wedges (based on PSE/CSE)	Exogenous demand for feedstock crops	n.a.	Supply elasticities adjusted over time	Demand elasticities adjusted over time	Heckscher-Ohlin non-spatial, net-trade
MAgPIE	PIK, Germany	**PE**	Agriculture	21 / 0	0 / 10	1995	Implicitly assumed unchanged	Exogenous Bioenergy demand	n.a.	Leontief	exogenous	Based on historical self-sufficiency rates

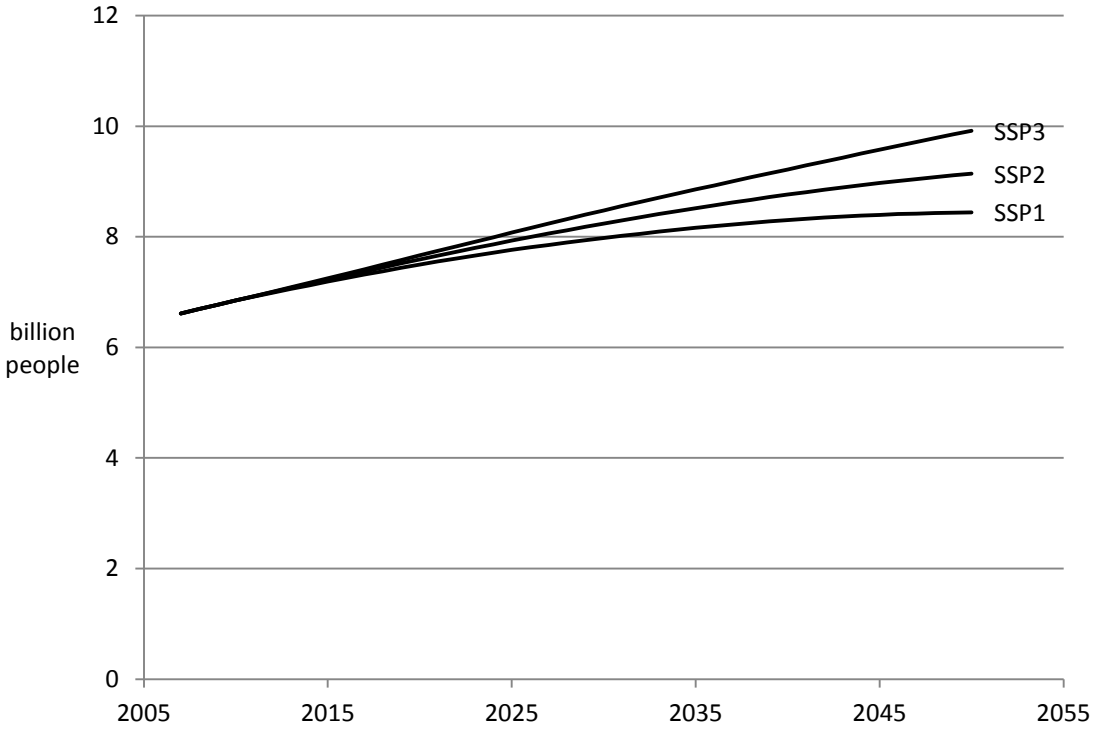
* Figures indicate the number of raw and processed agricultural products represented, respectively.
** Figures indicate the number of individual countries and multi-country aggregates represented, respectively.
*** Regional breakout specific for this application.

World Projections of Total GDP



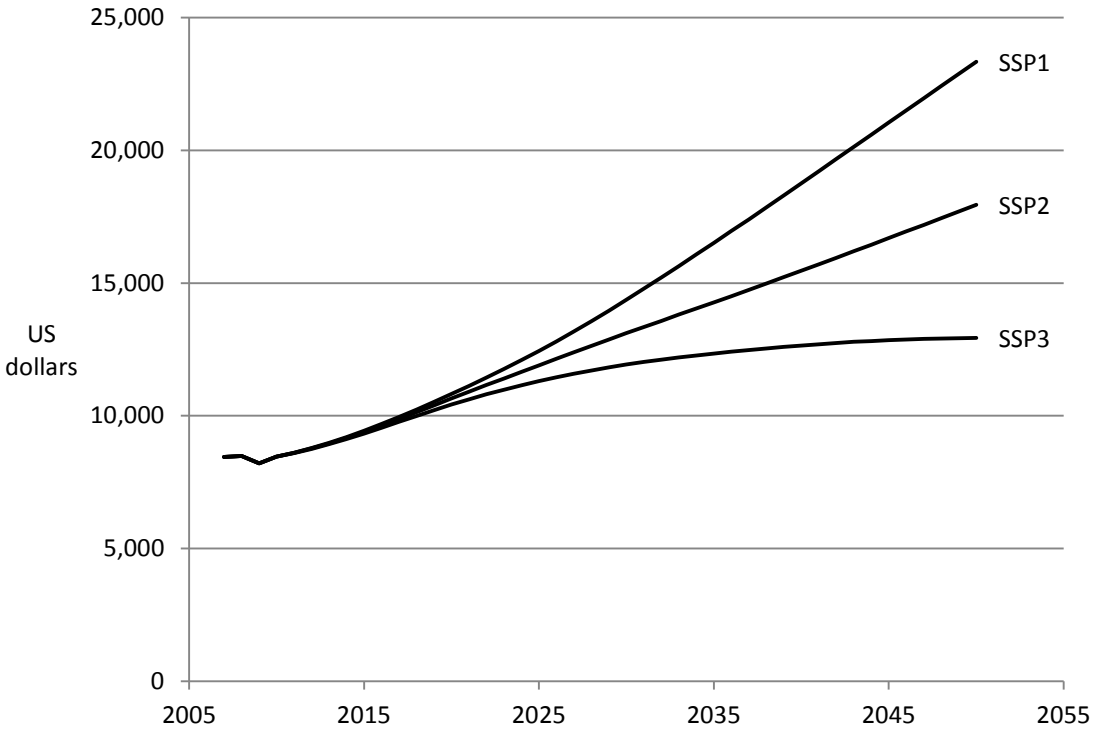
Source: OECD

World Population Projections



Source: OECD

World Projections of Average GDP Per Capita



Source: OECD

Further Reading

- **Special issue** of *Agricultural Economics* on AgMIP global economic scenarios (January 2014)
- Nelson, G.C., H. Valin, R.D. Sands, P. Havlik, H. Ahammad, D. Deryng, J. Elliott, S. Fujimori, T. Hasegawa, E. Heyhoe, P. Kyle, M. von Lampe, H. Lotze-Campen, D. Mason d'Croz, H. van Meijl, D. van der Mensbrugghe, C. Müller, A. Popp, R. Robertson, S. Robinson, E. Schmid, C. Schmitz, A. Tabeau, and D. Willenbockel, 4 March 2014, "Climate change effects on agriculture: Economic responses to biophysical shocks," *Proceedings of the National Academy of Sciences* (**special feature**) **111**(9): 3274-3279.
- Wiebe, K., H. Lotze-Campen, R.D. Sands, A. Tabeau, D. van der Mensbrugghe, A. Biewald, B. Bodirsky, S. Islam, A. Kavallari, D. Mason-D'Croz; C. Mueller, A. Popp, R. Robertson, S. Robinson, H. van Meijl and D. Willenbockel, 2015, "Climate change impacts on agriculture in 2050 under a range of plausible socioeconomic and emissions scenarios," *Environmental Research Letters* **10** 085010.