Unraveling Uncertainties in Climate Change Mitigation and Poverty Alleviation through Model Intercomparison

Tatsuki Ozawa, Shinichiro Fujimori, Tomoko Hasegawa *, Seiya Kawaguchi, Shiya Zhao (Kyoto University)
in collaboration with Kazuaki Tsuchiya, Jun'ya Takakura, Kiyoshi Takahashi (NIES)

食料価格の不確実性を考慮した
気候変動とその緩和策による貧困への影響評価

小沢　樹輝[1]*・藤森　真一郎[2]・長谷川　知子[3,2]・高倉　潤也[5]
土屋　一彬[5]・高橋　潔[6]・川口　誠也[4]・趙　詩雅[4]

[1]非会員　京都大学大学院工学研究科（〒615-8540 京都市西京区京都大学桂Cクラスター C-1-367）
*E-mail: ozawa.tatsuki.56n@st.kyoto-u.ac.jp (Corresponding Author)
[2]正会員　京都大学大学院工学研究科（〒615-8540 京都市西京区京都大学桂Cクラスター C-1-362）
[3]正会員　立命館大学総合科学技術研究機構（〒525-8577 滋賀県草津市野路東1-1-1）
[4]非会員　京都大学大学院工学研究科（〒615-8540 京都市西京区京都大学桂Cクラスター C-1-367）
[5]非会員　国立環境研究所社会システム領域（〒305-8506 茨城県つくば市小野川16-2）
[6]正会員　国立環境研究所社会システム領域（〒305-8506 茨城県つくば市小野川16-2）

Email: zhao.shiya.3a@kyoto-u.ac.jp
Graduate School of Engineering, Kyoto University

* Primary affiliation: Ritsumeikan University

Climate policies and poverty, hunger, and inequality

- The Paris Agreement (PA) laid the foundation for enhanced ambitions of climate change mitigation to "keep global temperatures increase well below 2˚C while pursuing means to limit the increase to 1.5˚C above pre-industrial level".

- The distributional effects of achieving the PA long-term temperature targets.
  - Poverty population: increase by 50 million globally in 2050 in a 1.5 ˚C target scenario without countermeasures to poverty, but revenue redistribution helps poverty alleviation (Soergel et al., 2021).
  - Population at risk of hunger: increase by around 49.8 (3.5-99.4) million globally in 2050 under the 2˚C target of the PA (compared to current trend) (Fujimori et al, 2022).
  - Income inequality: the poor households are more susceptible to welfare loss caused by climate change mitigation (Fragkos et al 2021).

Uncertainties in the projection

- However, there are huge uncertainties in future socio-economic conditions and their responses to climate change as well as climate policies.
  - For example, future food prices remain largely uncertain, due to the complex responses of land use, agriculture productivies, and food demand to changes in GDP, population, climate impacts, and climate policies.
- Therefore, we performed a model intercomparison study focusing on the future food price uncertainties to
  - Reveal the common/robust findings among models
  - Quantitatively estimate the uncertainty range and identify the sources of uncertainties

Method—
AIM-PHI, the poverty projection tool

First publication using AIM-PHI

In order to better understand the relationship between poverty and climate change mitigation, a novel modelling framework that includes a module representing poverty indicators.

ENVIRONMENTAL RESEARCH
LETTERS

LETTER • OPEN ACCESS

An assessment of the potential of using carbon tax revenue to tackle poverty

Shinichiro Fujimori[1,2,3], Tomoko Hasegawa[2,4] and Ken Oshiro[1]

Published 11 November 2020 • © 2020 The Author(s). Published by IOP Publishing Ltd

Environmental Research Letters, Volume 15, Number 11

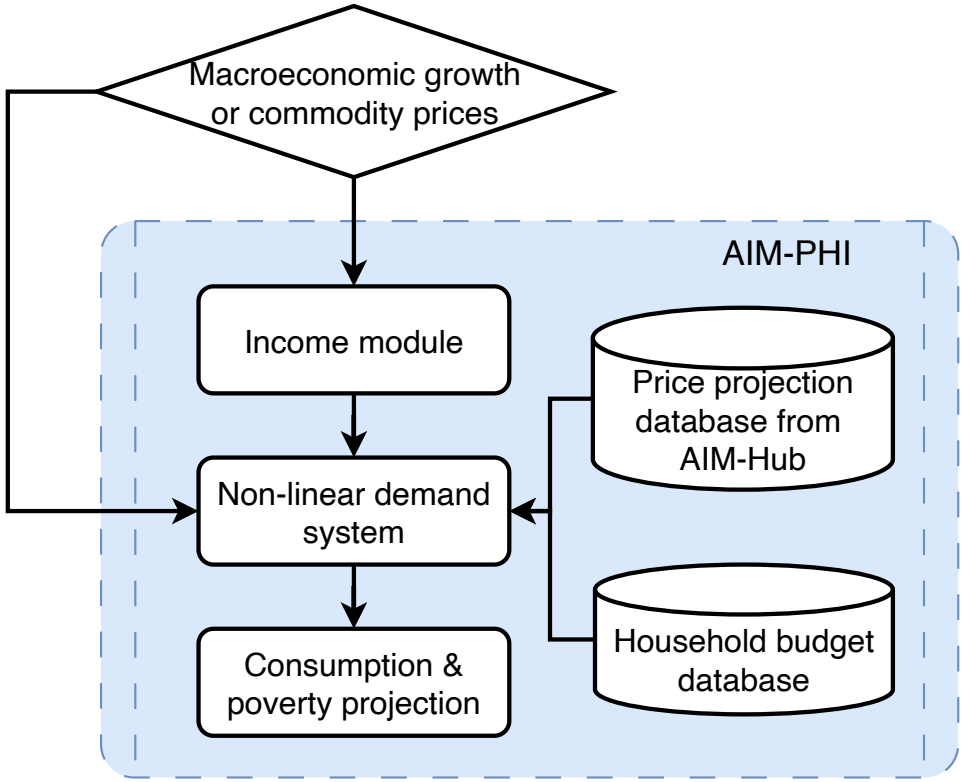
Citation Shinichiro Fujimori *et al* 2020 *Environ. Res. Lett.* **15** 114063

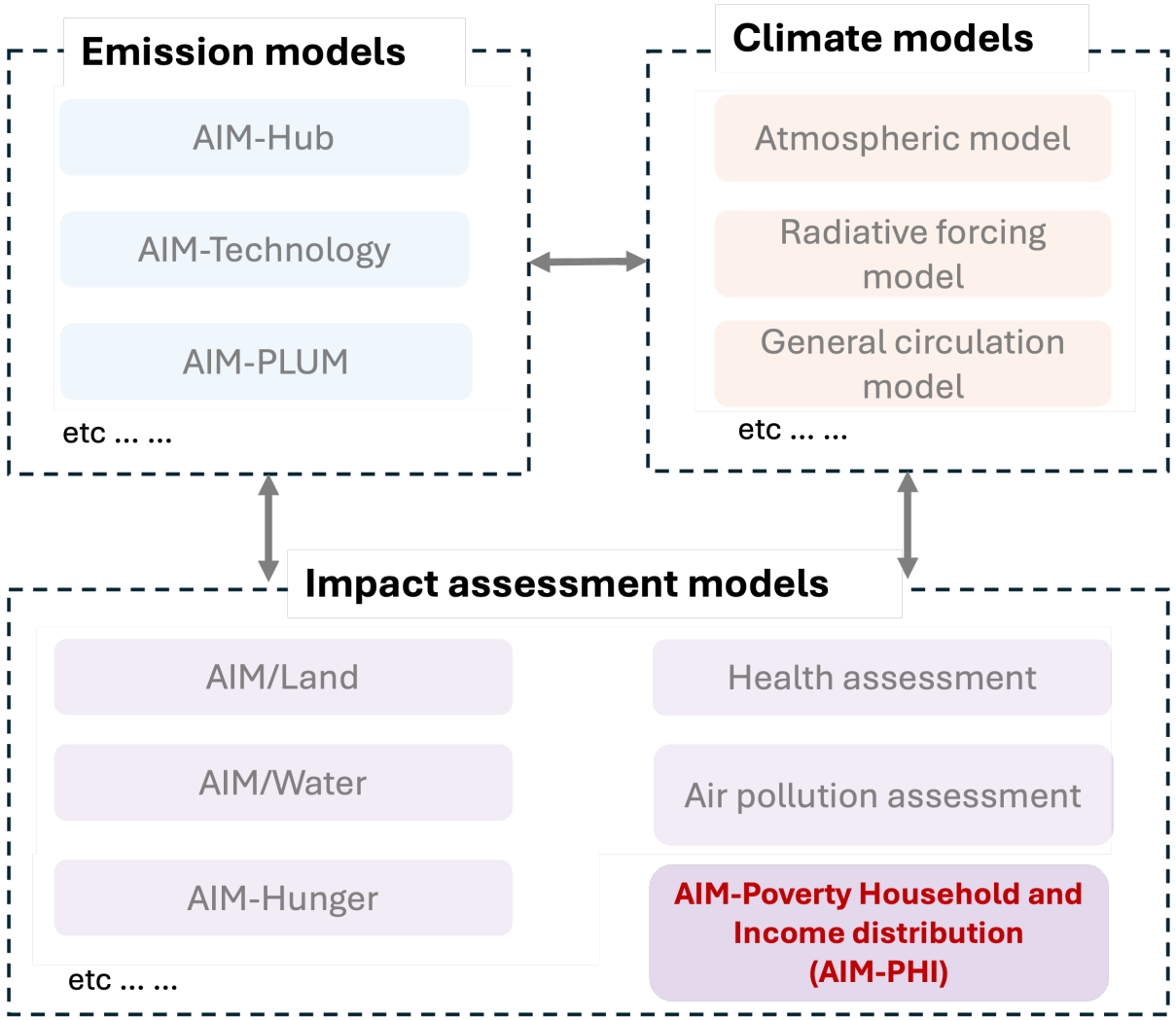
DOI 10.1088/1748-9326/abb55d

An assessment of the potential of using carbon tax revenue to tackle poverty - IOPscience

AIM-PHI model

Asian-Pacific **I**ntegrated **M**odel-**P**overty, **H**ousehold, **I**ncome inequality distribution model





Model intercomparison studies

8 models of 4 theoretical approaches

nature climate change

Article

https://doi.org/10.1038/s41558-024-02151-7

A multi-model assessment of inequality and climate change

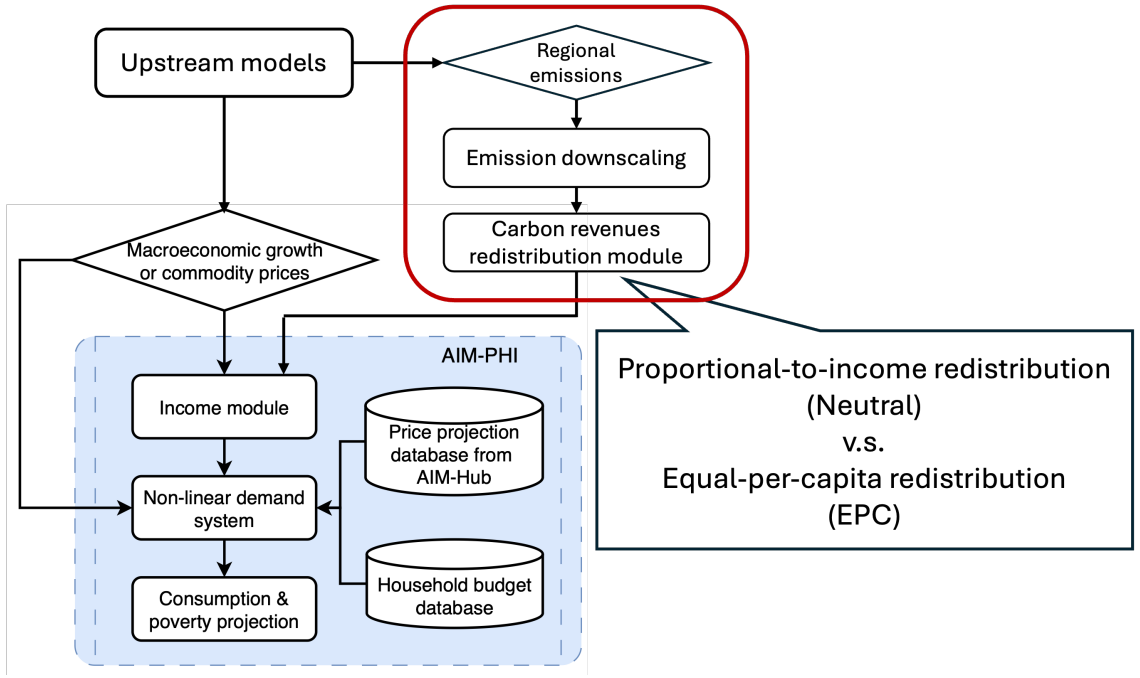
Received: 16 January 2024

Accepted: 4 September 2024

Published online: 4 October 2024

Check for updates

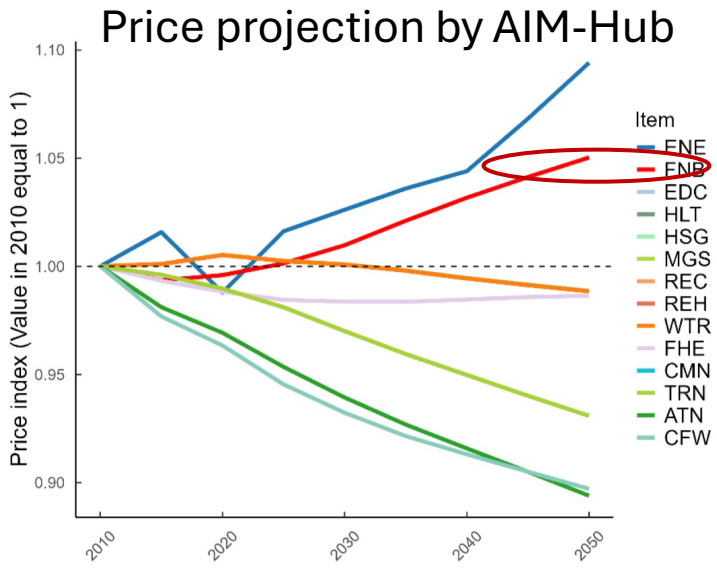
Johannes Emmerling[1,2], Pietro Andreoni[1,2,3], Ioannis Charalampidis[4], Shouro Dasgupta[5,6,7], Francis Dennig[8], Simon Feindt[9,10,11], Dimitris Fragkiadakis[4], Panagiotis Fragkos[4], Shinichiro Fujimori[12], Martino Gilli[2,13], Carolina Grottera[14], Celine Guivarch[15,16], Ulrike Kornek[9,11,17], Elmar Kriegler[11,18], Daniele Malerba[19], Giacomo Marangoni[2,20], Aurélie Méjean[15,21], Femke Nijsse[22], Franziska Piontek[11], Yeliz Simsek[22,23], Bjoern Soergel[11], Nicolas Taconet[11], Toon Vandyck[24], Marie Young-Brun[25,26], Shiya Zhao[12], Yu Zheng[27] & Massimo Tavoni[1,2,3]

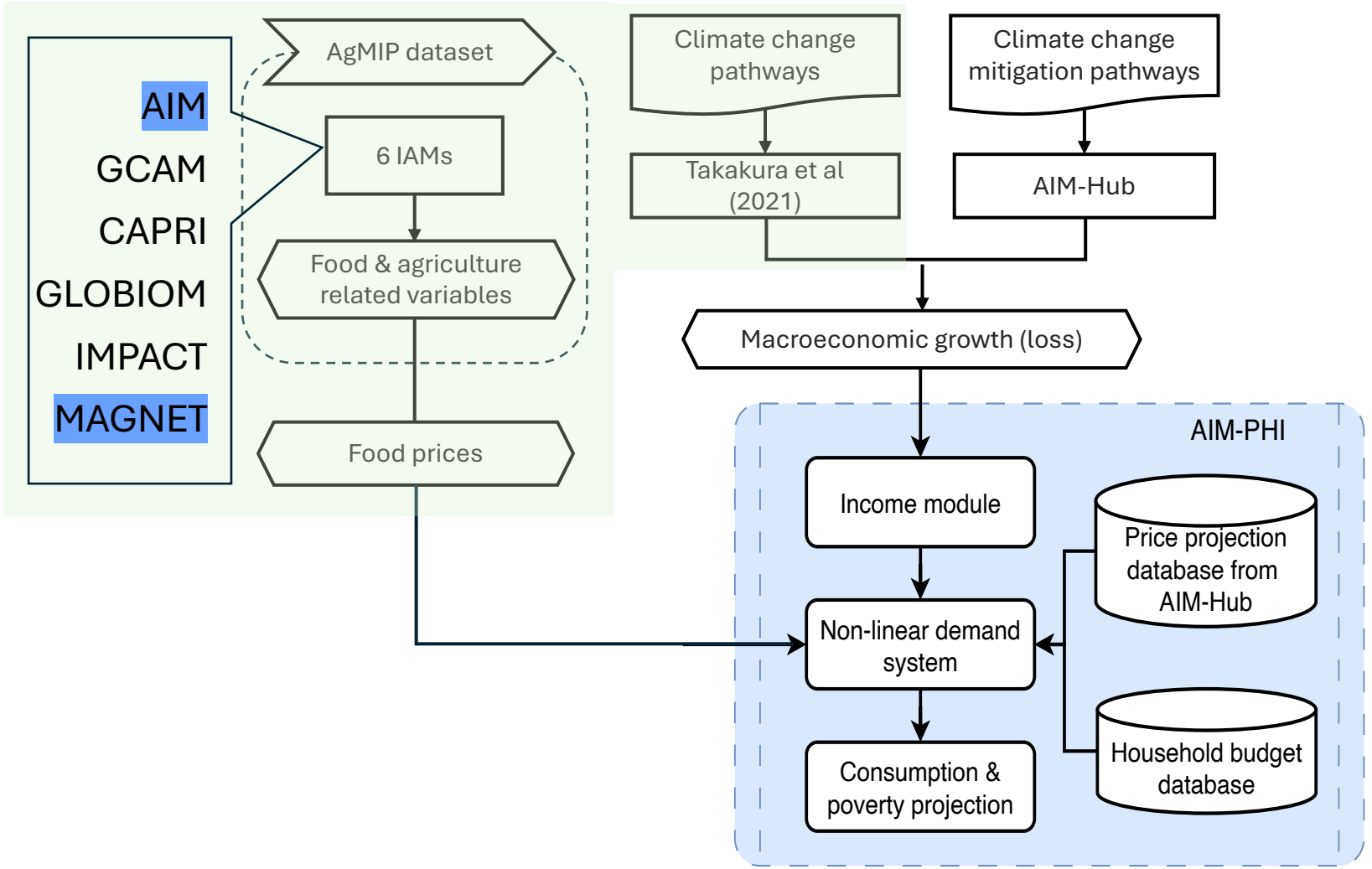


Model	*Type*	*Regional Focus*	*Sources of inequality*	*Modelling of Distribution*	*Measure of Distribution*	*Mitigation distribution*	*Impact Distribution*
AIM	DP-IAM	Global, 184 countries	Price change, Consumption patterns	soft-linked poverty, household and income distribution model	Deciles Gini index	All goods Carbon revenues	-
E3ME	Econometric	71 regions	Price changes, unemployment, structural change	Endogenous	Quintiles, employed, unemployed, self-employed (14 groups)	All goods Employment (Quintiles have been just downscaled to Deciles)	-
GEM-E3	CGE	Global 20 regions, EU country level	income, price changes, savings, consumption patterns, structural change	soft-linked inequality module with GEM-E3	Deciles	All goods Energy expenditures Carbon revenues	-
Imaclim	CGE	Global, 12 regions	Consumption shares	Exogenous module, endogenous integration	regional Gini, Deciles	Elasticity of mitigation costs (based on [1]) Carbon revenues	-
NICE	CB-IAM	Global 12 regions	Consumption shares	Regional distribution + income elasticities	Deciles	Elasticity of mitigation costs (based on [1]) Carbon revenues	Income elasticity of damage function (=1) with RICE damage function
ReMIND	DP-IAM	Global, 12 regions	energy expenditures, impacts	regional distribution	Lognormal distribution	Elasticity of energy expenditures, Carbon revenues	Aggregate GDP damage function[2] with income elasticity of 0.5
WITCH	DP-IAM	Global, 17 regions	Capital ownership Wages Energy consumption shares	soft-linked inequality model with WITCH	Deciles Gini	Energy expenditures (based on individual HH surveys) Carbon revenues	-
RICE50+	CB-IAM	Global 57 regions	Consumption shares	Regional distribution + income elasticities	Deciles	Elasticity of mitigation costs (based on [1]) Carbon revenues	Income elasticity of damage function (=0.5) and damage function[2]

Note: DP: detailed-process based, CB = Cost-Benefit, CGE = Computable General Equilibrium model

AgMIP-AIM-PHI linkage





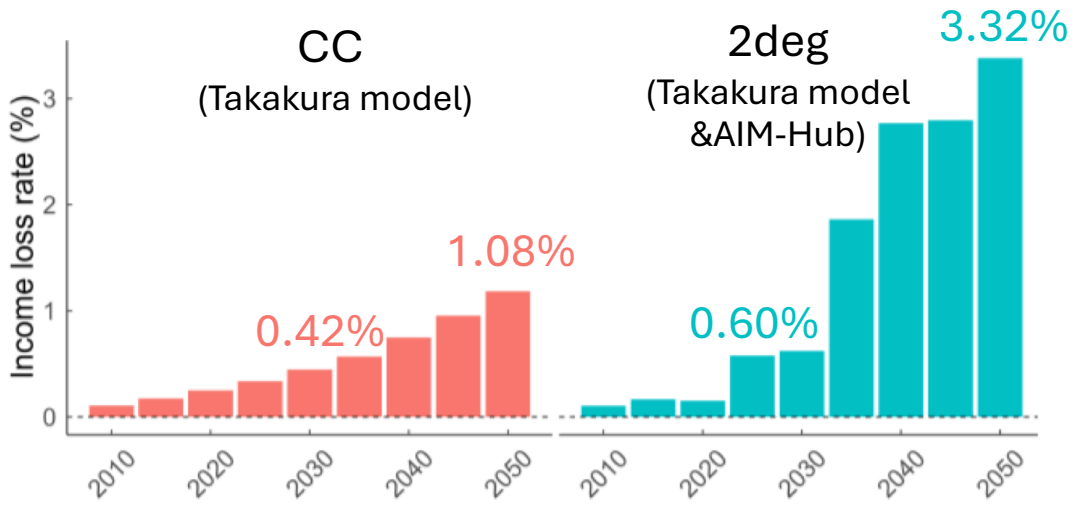
Method—
Scenarios and climate impacts

Scenario design

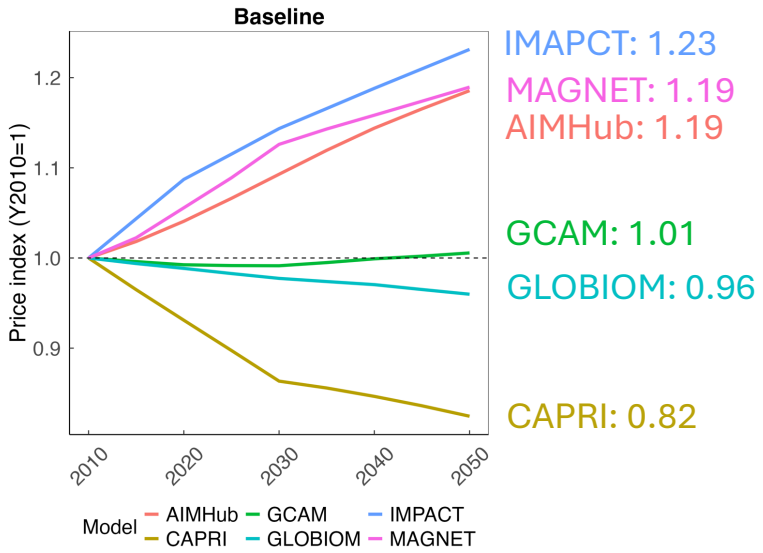
Scenario	Mitigation target	Climate change pathway	Model and data		
			Food price uncertainty	Macroeconomic loss (climate change)	Macroeconomic loss (mitigation)
Baseline	-	-	AgMIP	-	-
Climate Change (CC)	-	RCP6.0 (3~4°C)	AgMIP	Takakura et al, 2020	-
2deg	2゜C	RCP2.6 (~2°C)	AgMIP	Takakura et al, 2020	AIM-Hub

Scenarios

Loss in income compared with baseline



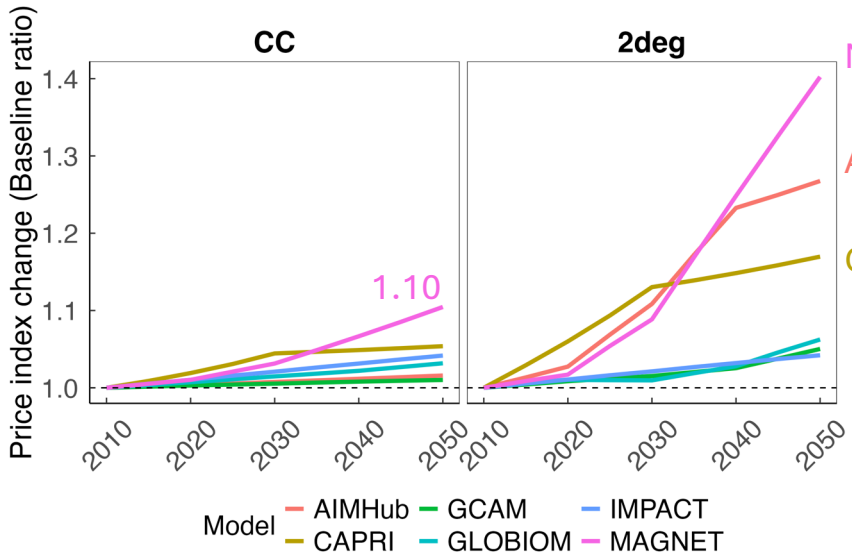
Food prices



IMAPCT: 1.23
MAGNET: 1.19
AIMHub: 1.19

GCAM: 1.01
GLOBIOM: 0.96

CAPRI: 0.82



MAGNET: 1.40

AIMHub: 1.27

CAPRI: 1.17

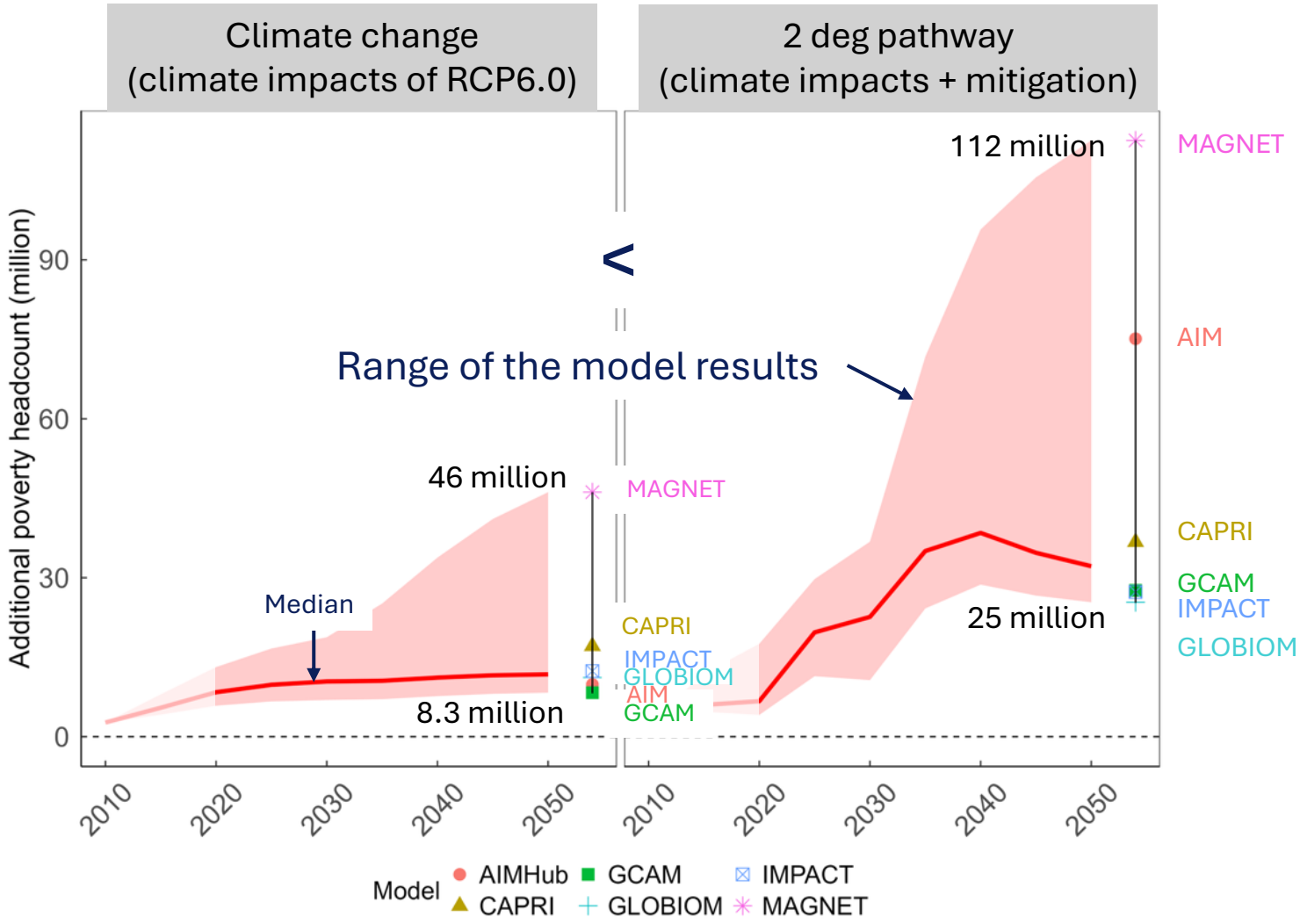
Modeling of climate impacts

- AgMIP (price changes)
  - GCM calculating the changes in temperature (ΔT) and precipitation (ΔP)
  - Global gridded crop models calculating the yield changes ($\Delta yield$) according to ΔT and ΔP,
  - Economic models calculating the changes in crop area, crop consumption, production, food trade, and food prices.

- Takakura model (macroeconomic loss)
  - Process-based impact assessment for nine sectors, including agricultural productivity, and aggregating the monetized costs
    - agricultural productivity, undernourishment, heat-related excess mortality, cooling/heating demand, occupational-health cost, hydroelectric power generation capacity, thermal power generation capacity, fluvial flooding and coastal inundation,
  - Enhanced adaptation (due to improvements in socioeconomic conditions) is considered

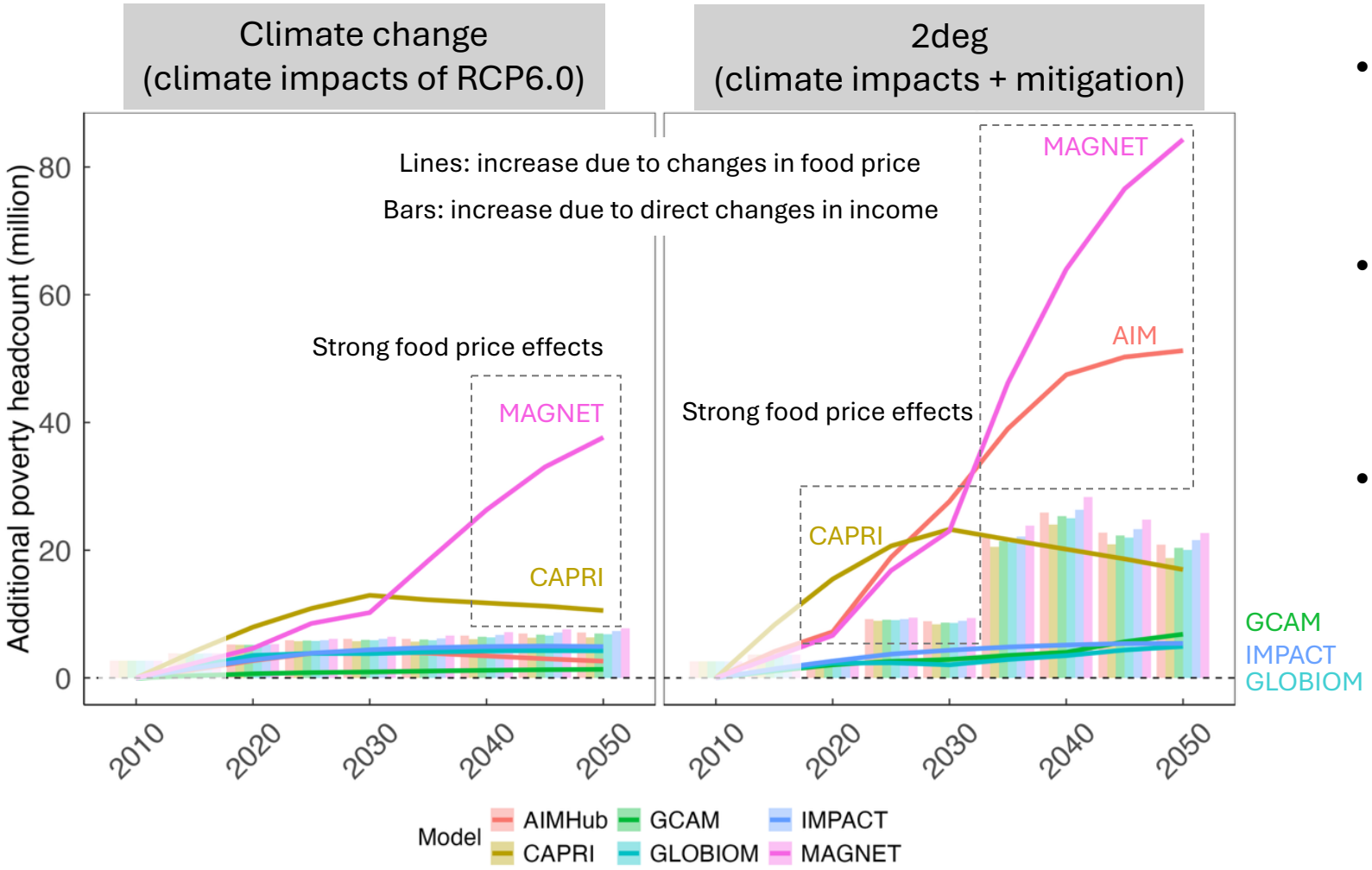
Results

Effects on poverty headcount



- If no stringent climate policy is adopted, global poverty headcount increase by ~8.3 to 46 million.
- The pathway achieving the 2°C target, 25 to 112 million people would live under the $2.15/capita/day poverty line.
- MAGNET has the largest poverty projection for both scenarios.
- AIM is low in the climate change scenario but high in the 2 degree scenario.

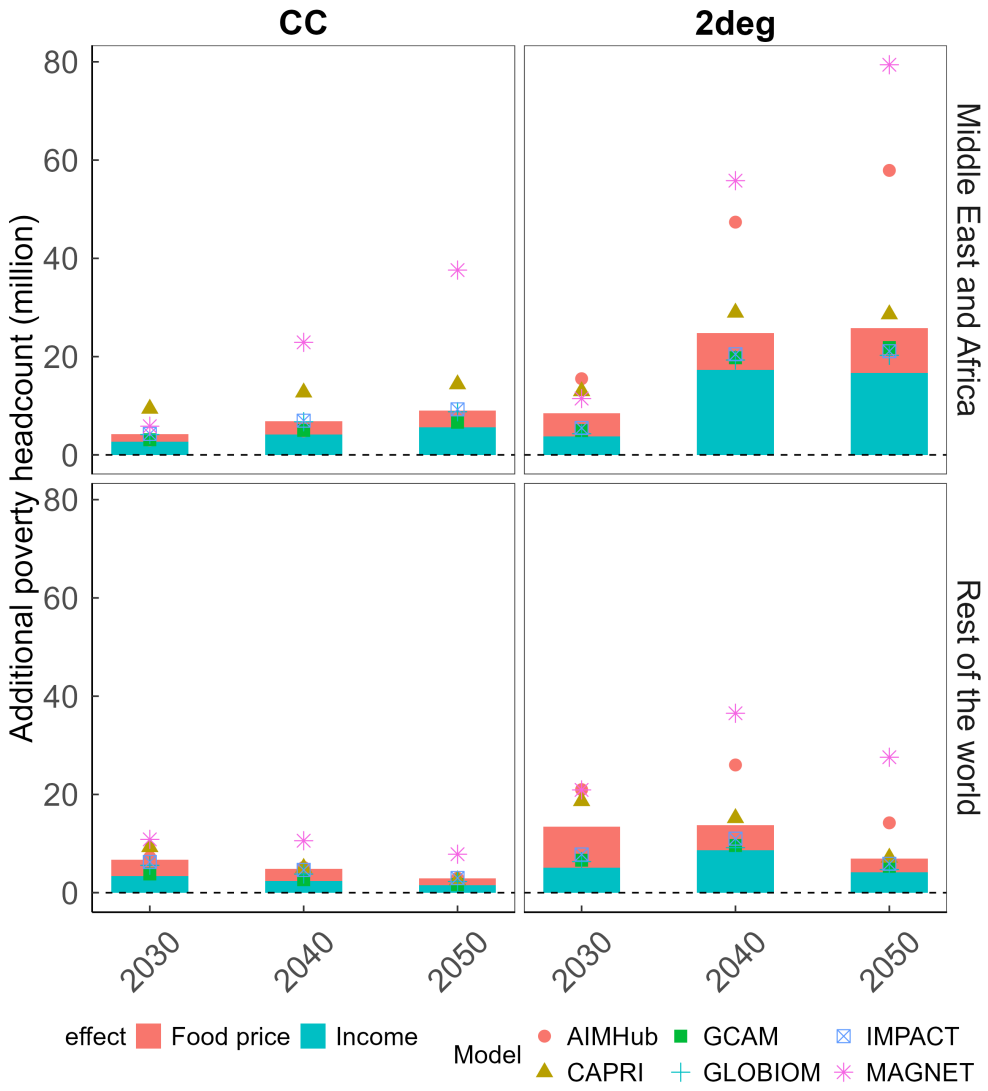
Decomposition



- CAPRI gives high projection by 2030 while MAGNET projection is high after 2030.
- Variation in the impacts of food price changes is huge among models, esp. in the 2 degree scenario.
- Similar to previous hunger risk study (Hasegawa et al, 2018), we found that
  Most of the increase in the 2deg scenario is caused by the implementation of climate mitigation policies, not the climate change impacts.

Focusing on Middle East and Africa

- Large uncertainty range in Middle East and Africa countries, esp. in 2˚C scenario
- Additional poverty headcount due to impacts from both climate change and mitigation increases from 2030 to 2050 in Middle East and Africa



Discussion and conclusions

Limitations

- Data sources
  - Still poor coverage of lower income countries (Global Consumption Database (World Bank), EUROSTAT Household Budget Survey, National Household Budget Survey in Japan, US, China, Australia, Canada)
- Channels considered
  - Climate change impacts on food prices: temperature, precipitation => grid-based yield change => food prices
  - Macroeconomic loss due to climate change impacts: 9 sectors
  - Climate change mitigation: changes in average disposable income, commodity (esp. food changes)
- Adaptation policies and short-term extreme weather events are not considered.

Conclusions

This study, among other previous work, highlights

- The distributional effects of climate change mitigation cannot be ignored before and during policymaking.
- Future food price is an important factor driving the changes in poverty both under climate change and mitigation.
- However, there are huge uncertainties in models' key output such as food prices.
- Therefore, It is important to understand model-specific features and tendencies.

Outlook

- Model
  - Better considerations of climate change impacts and its adaptation
  - Better representation of the physical energy and food demand
  - Improving the assessment of the lowest and highest tails of the income distribution
  - Enriching the household features profiles

- Policy representation and scenario
  - Representation of broader mitigation policies
  - Poverty alleviation policies and relevant scenarios analysis
  - Place our study in the broader just transition/equity discussions