Towards sustainable food system in China: transformation options and their connections to the food-land-climate nexus

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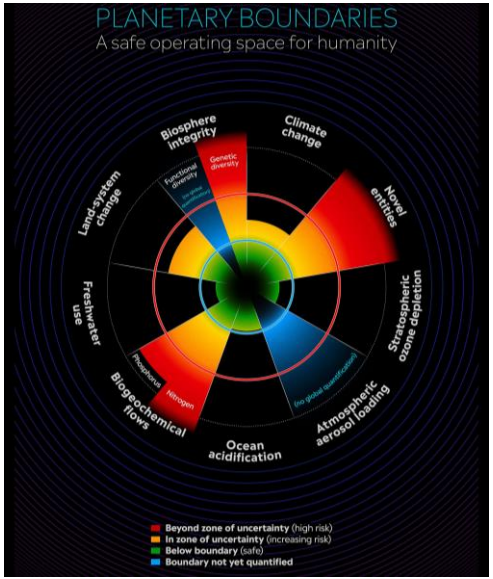
Food system transformation is critical for respecting PBs and achieving SDGs

Planetary boundaries (PBs)



Sustainable Development Goals (SDGs)

(Richardson et al., 2023; UN, 2015; Doelman et al., 2022)

Problem statement

- Food, land, and climate have, in the past, often been treated as individual and disconnected sectors (Johnson et al., 2019).
- Pathways and measures to achieve one or more specific PBs/SDGs may cause trade-offs or unexpected changes for other PBs/SDGs and/or for other sectors/regions in our society.
- It remains unclear how solutions to one PB/SDG affect other PBs/SDGs in the food-land-climate nexus.

Gaps in studies on food system transformation

What has been studied for food system transformation?

- Environmental benefits of food system transformation (e.g. Newbold et al., 2015, Doelman et al., 2022).

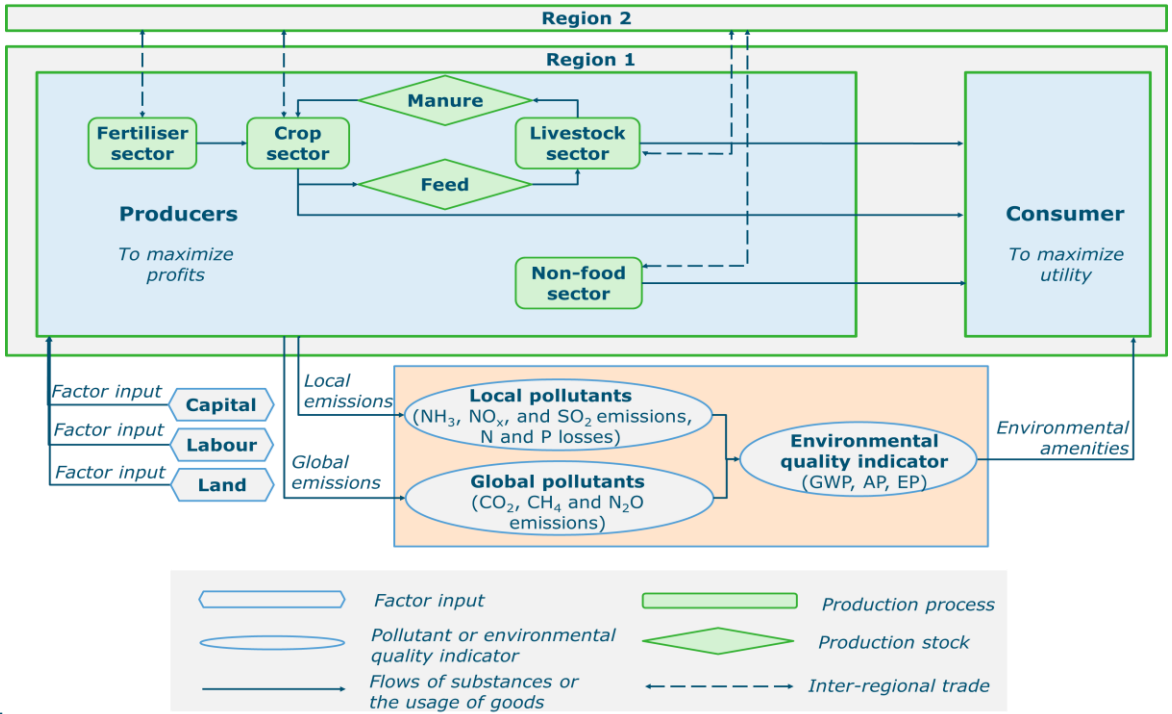
What is missing in studies on food system transformation?

- Impact of adjustments in crop and/or livestock sectors on other sectors both within and outside of the food system
- Economy-wide emissions of greenhouse gases (GHGs in CO_2-eq), acidification pollutants (in NH_3-eq), and eutrophication pollutants (in N-eq)
- Food security (i.e., average food price, food affordability, population at risk of hunger, and food availability)

Central research questions

- What are the environmental and economic impacts of food transformation options?
- How will these options cause trade-offs and synergies in the food-land-water-climate nexus?

An integrated environmental-economic framework based on applied general equilibrium (AGE) models



(Long et al., 2024, Sustainable Production and Consumption)

Economic and environmental database

- **Database:**

1) GTAP version 10 database (2014 as the base year)

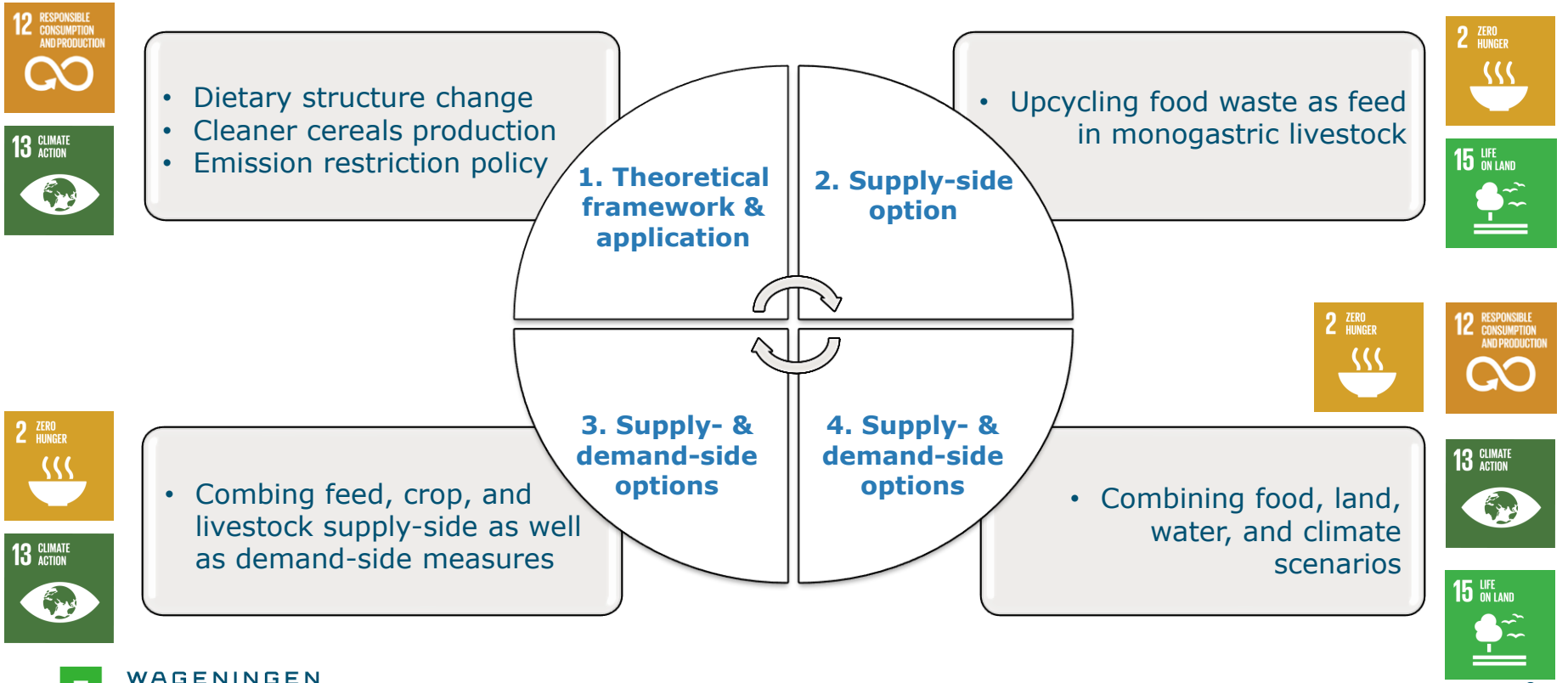
2) Region- and sector-specific environmental impact database

GTAP V10 database:
65 sectors (agriculture, industries, and services), 141 regions

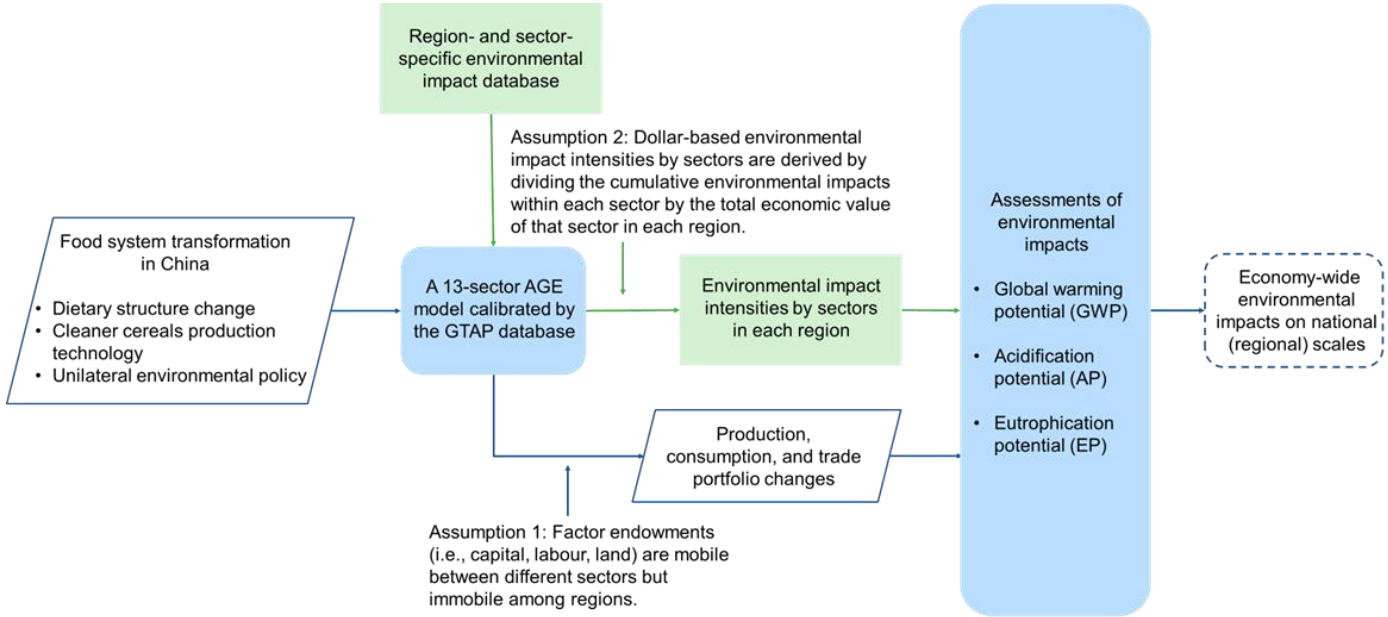
- **Regions:** China and its main food and feed trading partners (MTP, including Brazil, the United States, and Canada)
- **Sectors:** Detailed food-related sectors and aggregated non-food sector

(Hertel, T.W., 1997; https://www.gtap.agecon.purdue.edu/)

PhD research outline



Paper 1: Exploring sustainable food system transformation options in China: An integrated environmental-economic modelling approach based on the applied general equilibrium framework



(Long et al., 2024, Sustainable Production and Consumption)

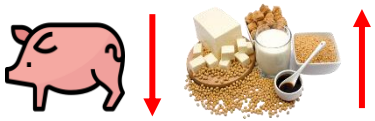
Scenarios of paper 1

Baseline (S0) → **Scenario 1 (S1)**

- **Differences in environmental concerns**

Scenario 2 (S2)

- **A partial shift from pork to soy-based food**

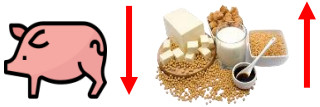


Scenario 3 (S3)

- **Cleaner cereals production technology**

Scenario 4 (S4)

- **Combination of dietary shift and cleaner cereals production**



Scenario 5 (S5)

- **Emission restriction policy**

3% reduction

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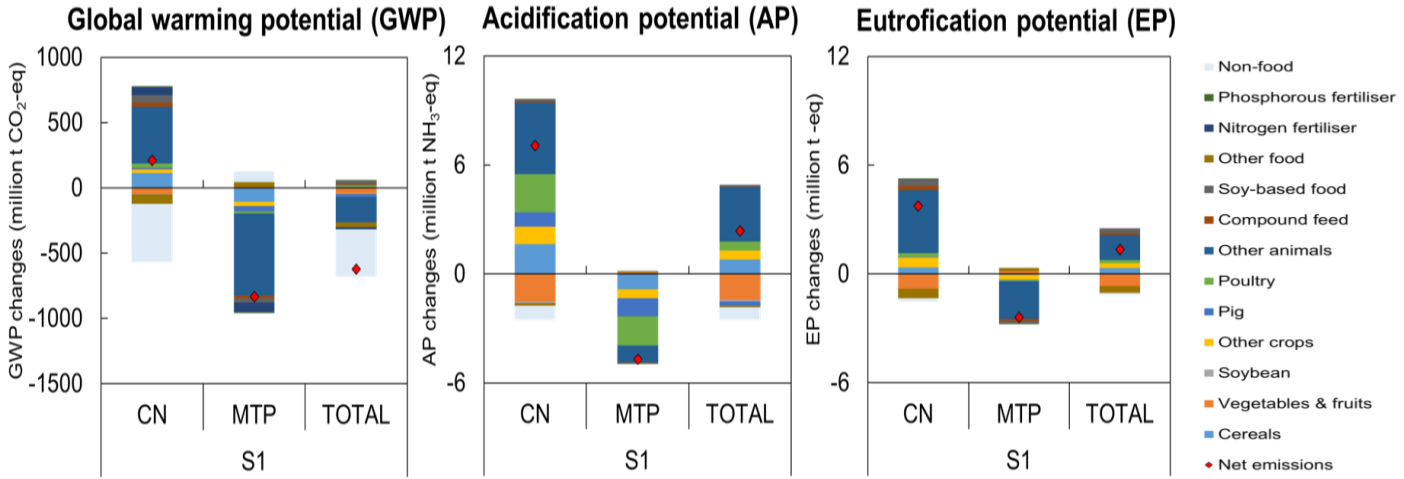
(Long et al., 2024, Sustainable Production and Consumption)

Differences in environmental concerns of consumers led to cross-border pollution spillover effects through international trade

Emissions will leak from trading partners with higher environmental concerns to China, causing negative environmental spillover effects.



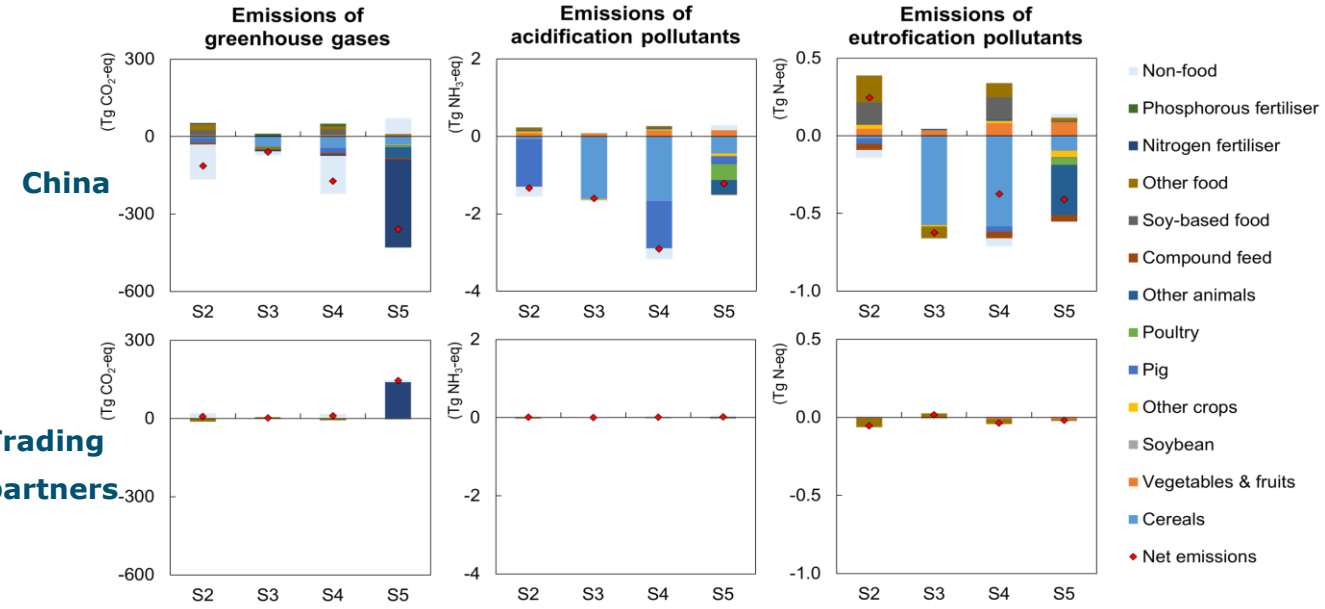
(Long et al., 2024, Sustainable Production and Consumption)

Policy implications

- **Indirect environmental impacts** are crucial to consider when analysing the economy-wide consequences of food system transformations, as these indirect impacts may inadvertently affect other regions and/or economic sectors that were not initially targeted.

- S1: Differences in environmental concerns of consumers

- S2: Dietary structure change
- S3: Cleaner cereals production technology
- S4: Combination of dietary structure change and cleaner cereals production technology
- S5: Emission restriction policy



(Long et al., 2024, Sustainable Production and Consumption)

Paper 2: Rebound effects may undermine benefits of upcycling low-opportunity-cost feed as animal feed in China

Global food waste drive greenhouse gas (GHG) emissions

- Around 1.3 billion tonnes of food waste are produced in the world, which are mainly disposed in landfills and incinerators, and are a significant source of greenhouse gas (GHG) emissions (Gustavsson et al., 2011).

Environmental benefits of feeding animals with food waste

- Feeding animals with food waste can possibly reduce GHG emissions, mitigate land pressures, and alleviate food-feed competition (Van Zanten et al., 2018; Van Hal et al., 2019; Fang et al., 2023).

Contribution to Sustainable Development Goals (SDGs)

- It may to achieving Sustainable Development Goals (SDGs), including SDG 2 (zero hunger), SDG 6 (clean water and sanitation), SDG 12 (responsible consumption and production), SDG 13 (climate action), and SDG 15 (life on land) (UN, 2025).

Indirect and spillover effects not covered in previous studies

- **Rebound effect:** Lower feed costs may expand livestock production and increase emissions.
- **Knock-on effects:** It may exacerbate emissions further.
- **Food security:** Addressing rebound effects while ensuring food security remains unclear.

Why China?

46% of global pork production

34% of global egg production

13% of global poultry meat production

27% of food produced is wasted

(Long et al., 2024, Unpublished)

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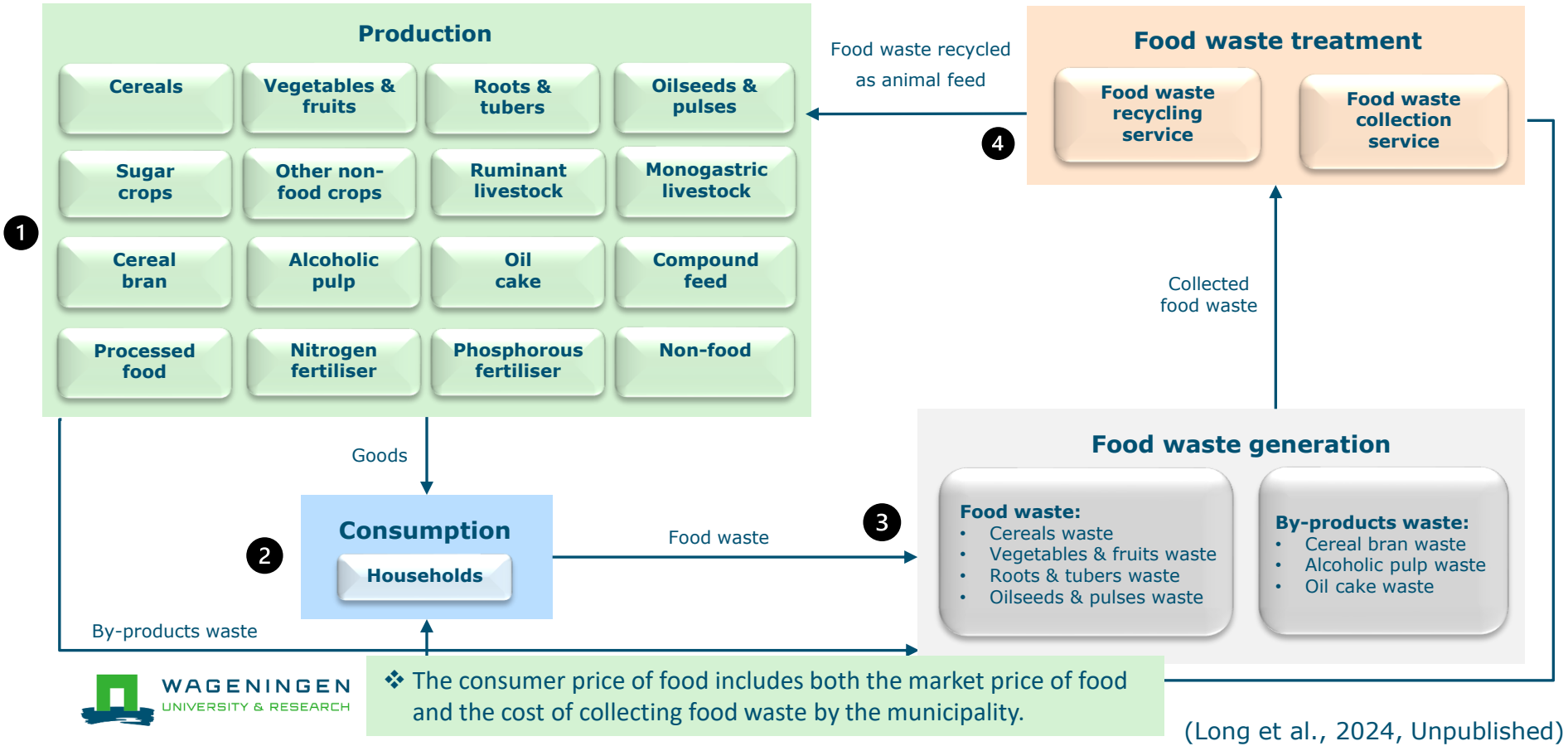
Applied general equilibrium models with food waste



❖ The consumer price of food includes both the market price of food and the cost of collecting food waste by the municipality.

(Long et al., 2024, Unpublished)

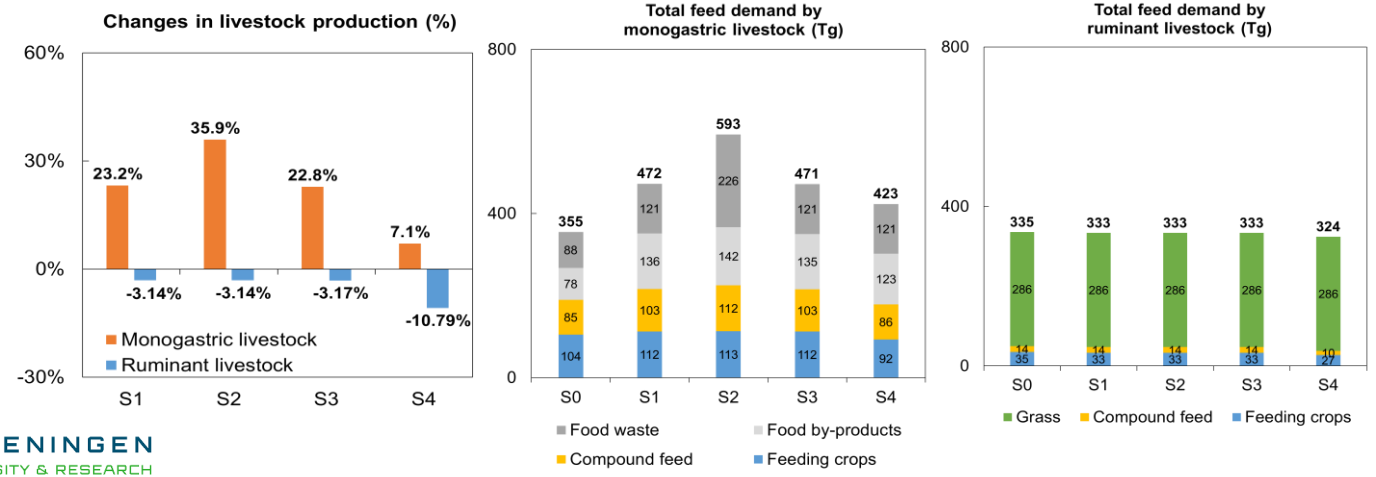
Scenarios of paper 2

Scenarios	Food waste as feed	Emission mitigation target
S1: Partial use of food waste as feed	Food waste: 54% By-products: 100%	No
S2: Full use of food waste as feed	Food waste: 100% By-products: 100%	No
S3: S1 + A modest emission mitigation target	Food waste: 54% By-products: 100%	Implementing economy-wide emission taxes to ensure that emissions of greenhouse gases, acidification pollutants, and eutrophication pollutants in both China and its trading partners do not exceed their baseline (S0) levels.
S4: S1 + An ambitious emission mitigation target	Food waste: 54% By-products: 100%	Implementing economy-wide emission taxes to meet their annual mitigation target of the Intended Nationally Determined Contributions (INDC) under the Paris Agreement and the "13th Five-Year Plan".

(Long et al., 2024, Unpublished)

Expanded monogastric livestock production will reverse the substitution of human-edible feed crops for per animal output

- **Expand Livestock production:** Upcycling food waste as feed reduced feed costs and increased profits, driving a 25-36% rise in monogastric livestock production.
- **Feed Demand Increase:** This expansion caused a 17-34% surge in total demand for human-edible feed crops as feed for livestock production.



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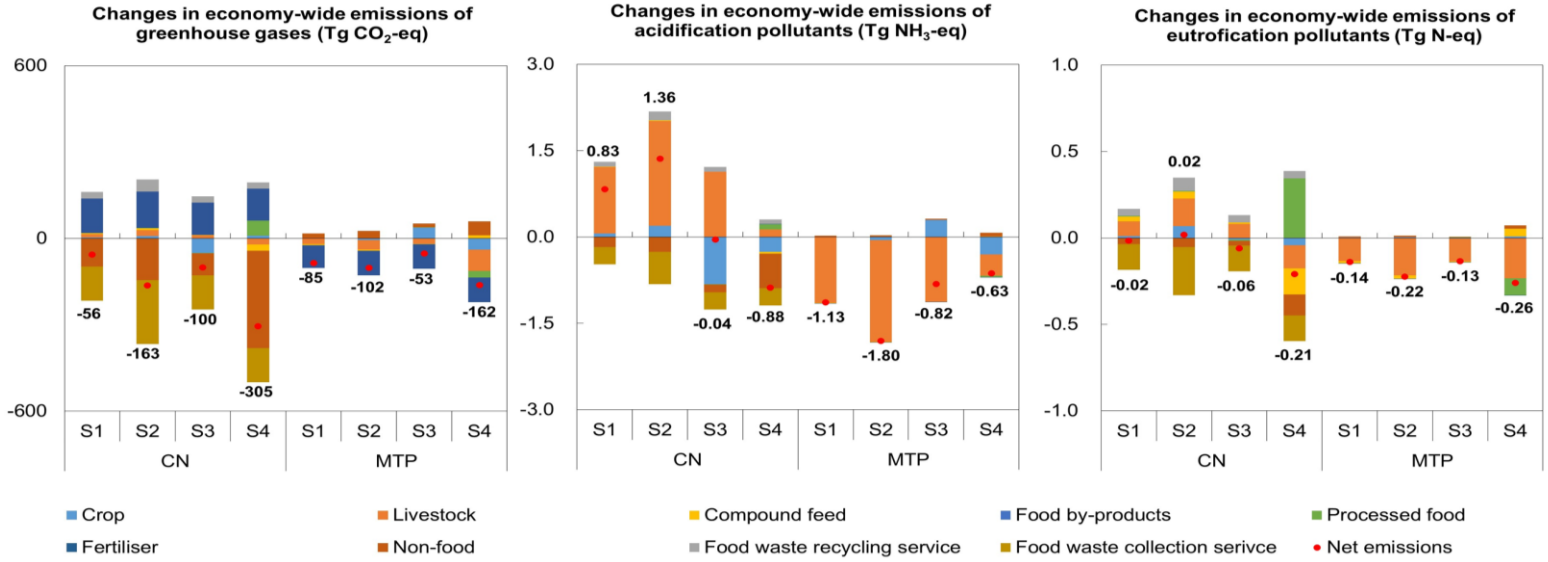
(Long et al., 2024, Unpublished)

Emission taxes could address rebound effects

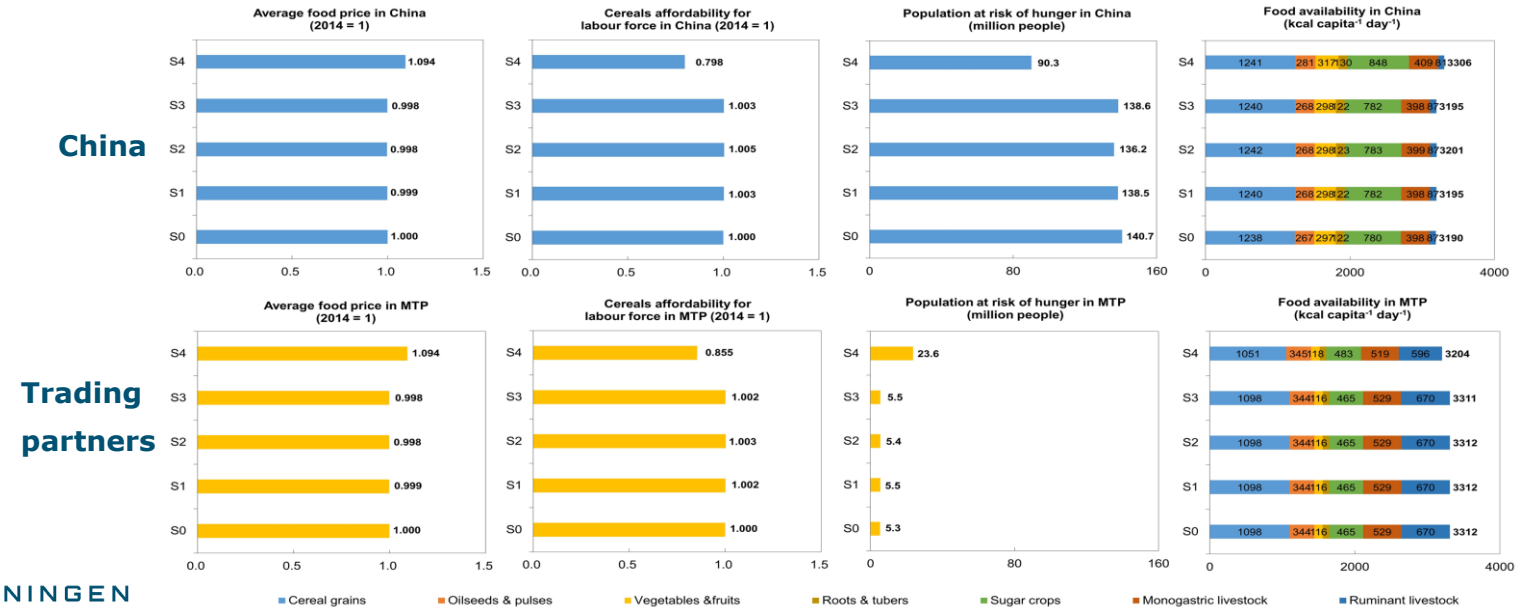
- **Implementing economy-wide emission taxes to achieve emission mitigation targets (S3-4)** could counteract the rebound effects of expanded monogastric livestock production and improve global environmental quality.



(Long et al., 2024, Unpublished)

But emission taxes may risk global food security

- **An ambitious emission mitigation target (i.e., emission taxes to meet Paris Agreement goals)** could counteract rebound effects but risk a 9.4% rise in food prices, threatening global food security.
- Conversely, **a modest emission mitigation target (i.e., emission taxes to maintain baseline levels)** provides an opportunity to address rebound effects while safeguarding global food security.



(Long et al., 2024, Unpublished)

Paper 3: Food system transformation is key to achieving food security and environmental sustainability in China

Scenarios	Descriptions
S1: Feed supply-side option	• Upcycling low-opportunity-cost feed in monogastric (food waste and food processing by-products) and ruminant (grass) livestock production.
S2: Crop supply-side option	• Closing crop yield gaps by adopting Integrated Soil-crop System Management technology (ISSM).
S3: Livestock supply-side option	• Improving monogastric and ruminant livestock production efficiency up to the level of developed countries.
S4: Demand-side option	• Shifting towards less meat-intensive diets based on the EAT-Lancet diet recommendation.
S5: S1+S2+S3+S4	• Combing feed, crop, and livestock supply-side as well as demand-side measures.

Paper 4: Exploring transformation options in the food-land-climate nexus: towards achieving multiple sustainable development goals in China

Scenarios	Descriptions
Food scenario	• Combing feed, crop, and livestock supply-side as well as demand-side measures in line with SDG 2 (zero hunger).
Land scenario	• An afforestation policy based on China's National Forest Management Plan (2016–2050) in line with SDG 15 (life on land). *→ learn GTAP-BIO-FCS model in UC Davis*
Climate scenario	• Implementing a global uniform carbon tax under the Paris Agreement in line with SDG13 (climate action).
Combined scenario	• Combining food, land, and climate scenarios.