Integrated environmental-economic modelling of sustainable food systems in China

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Jul, 2023

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Environmental impacts of food production

Global warming potential (GWP)

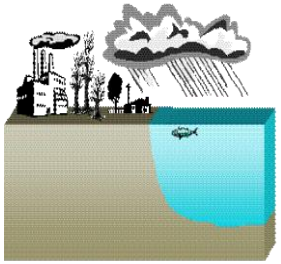
26%

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)

Acidification potential (AP)

80% (NH_3)

- Ammonia (NH_3)
- Sulphur dioxide (SO_2)
- Nitrogen oxides (NO_x)



Eutrophication potential (EP)

78%

- Nitrogen (N)
- Phosphorus (P)
- Ammonia (NH_3)

Land use

- Deforestation
- Landscape
- Biodiversity

Soil quality

- Erosion
- Pollution
- Salinisation

Food production

Water use

- Green water
- Blue water

(Herrero, M. et al., 2016, NCC; Uwizeye, A. et al., 2020, NF; Steinfeld, H., et al., 2006, FAO)

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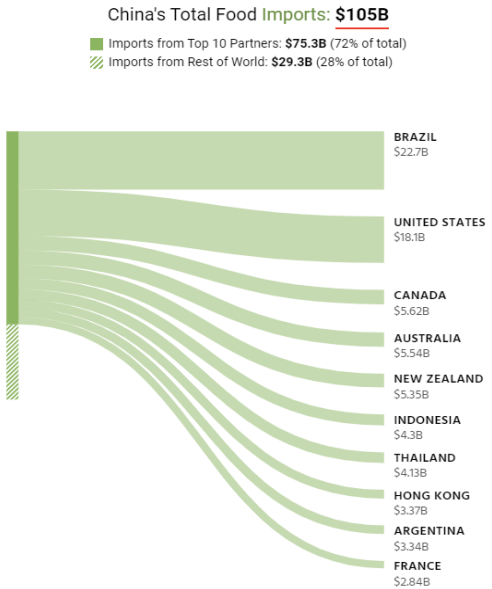
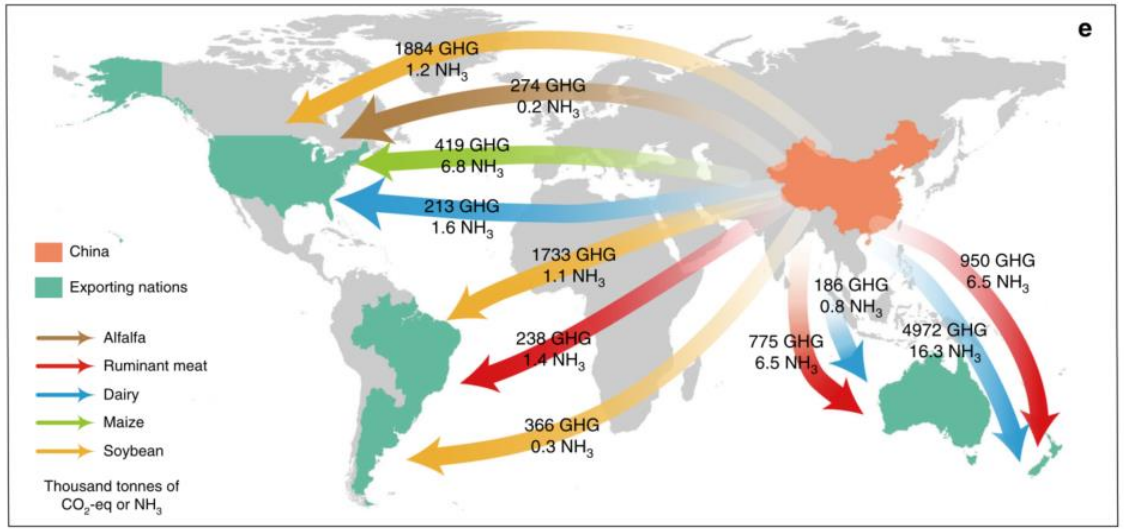
The global impacts of imported ruminant meat and milk to China



(Observatory of Economic Complexity, 2017)



(Du, Y., et al., NC, 2017)

Emission mitigation options

Dietary structure changes

- More plant-based food
- Less food waste

Production technology improvements

- Less emission-intensive production technology

Policy instruments

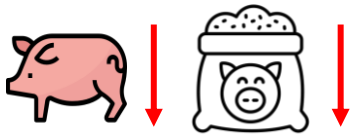
- Meat tax
- Manure subsidy
- Emission restriction

(Frank, S. et al., 2018, NC; Bai, Z. et al., 2014, EST; Hou, Y. et al., 2017, EST)

Research gap

Emission mitigation options

A certain country/sector/ emission



Capital

Labour

Land

Other countries/sectors/ emissions

- Interactions and trade-offs between countries, sectors, and emissions

Objective and research questions

- **Objective:**

- To analyse the impacts of emission mitigation measures and policy on food production, consumption, trade, and emissions for China and its main food and feed trading partners.

- **Research questions:**

- What are the environmental and economic impacts of various options for adjustments in the food system in China?
- What are the 'spillover impacts' on China's trading partners under the adjustments?

Modelling framework

Modelling framework

- **Model type:** Welfare format of static applied general equilibrium (AGE) model of the global economy

- **Data source:**
  - Global Trade Analysis Project (GTAP) database version 10
  - Region- and sector-specific environmental impact database

- **Base year:** 2014

Regions and sectors

- **Regions:** China and its main food and feed trading partners (MTP, including Brazil, the United States, and Canada)

- **Sectors:**

- 4 crop sectors (cereals, vegetables & fruits, soybean, other crops)
- 3 animal sectors (pig, poultry, other animals)
- 1 feed sector (compound feed)
- 5 other sectors (soy-based food (SBF), other food, nitrogen fertiliser, phosphorous fertiliser, non-food)

The welfare format of applied general equilibrium (AGE) model

➢ **Social welfare** is the "collective utility" of all consumers.

(Pollak, R. et al., 1979, QJE)

NON FOOD

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Scenarios

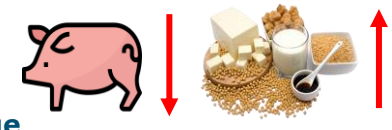
Baseline (S0)

Scenario 1 (S1)

- **Country-specific differences in environmental concerns**

Scenario 2 (S2)

- **Dietary structure change**

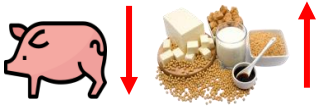


Scenario 3 (S3)

- **Cleaner cereals production technology**

Scenario 4 (S4)

- **Dietary structure change + Cleaner cereals production technology**



Scenario 5 (S5)

- **Emission restriction policy**

3% reduction

Results part 1 based on S1:
Impacts of country-specific differences in environmental concerns

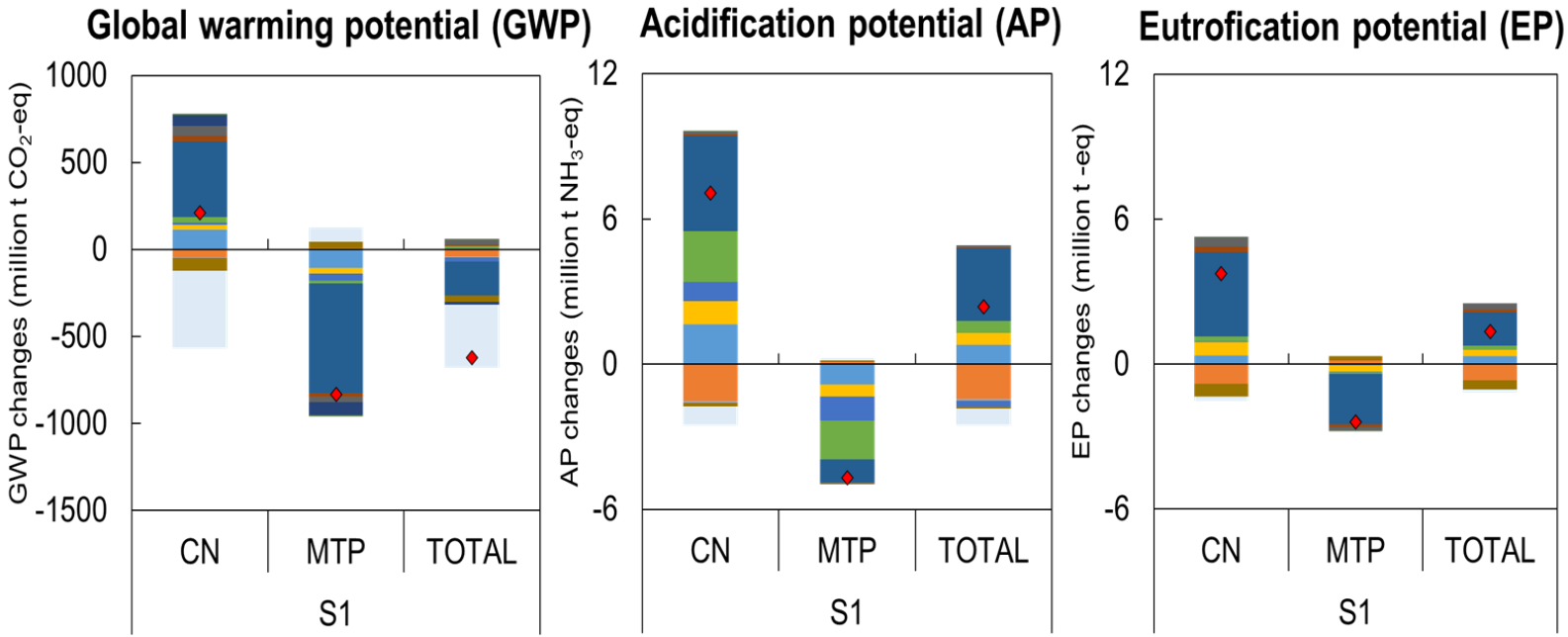
MTP with higher environmental concerns has higher environmental quality

Environmental quality > 100 → Lower emissions than S0

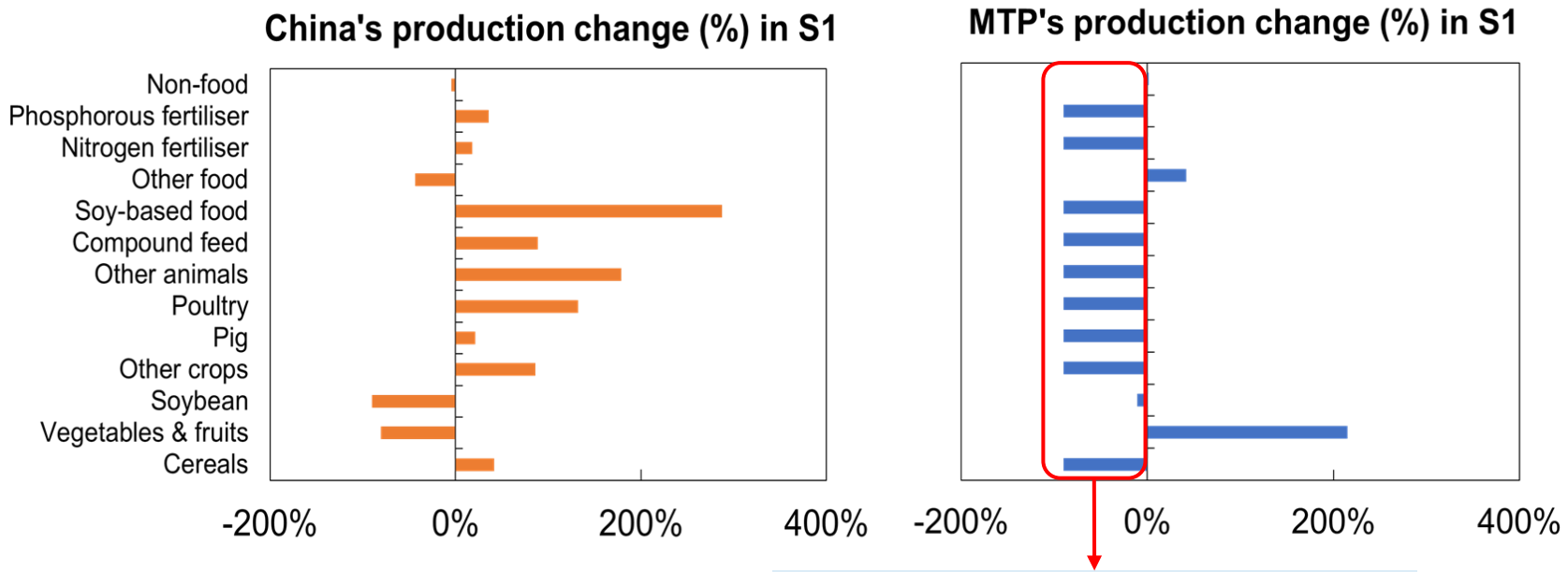
Environmental quality < 100 → Higher emissions than S0

		GWP	AP	EP
S0	China	100	100	100
	MTP	100	100	100
S1	China (1% of budget)	98 ☹	79 ☹	62 ☹
	MTP (2% of budget)	110 ☺	134 ☺	143 ☺

Emissions will leak from the MTP with higher environmental concerns to the China with lower environmental concerns



The production of goods with high emission intensities will take place in China with lower environmental concerns



- MTP will reduce the production of goods with high emission intensities.

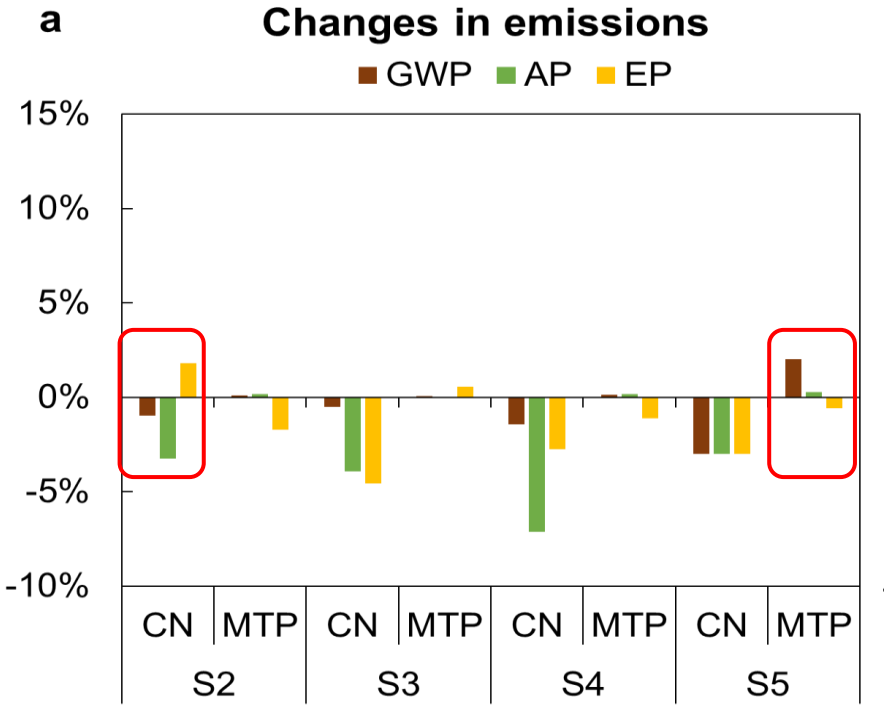
Results part 2 based on S2-S5:

Impacts of dietary structure, cleaner cereals production technology, and emission restriction policy

The environmental trade-offs caused by a dietary shift from pork to soy-based food

- S1: Country-specific differences in environmental concerns

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



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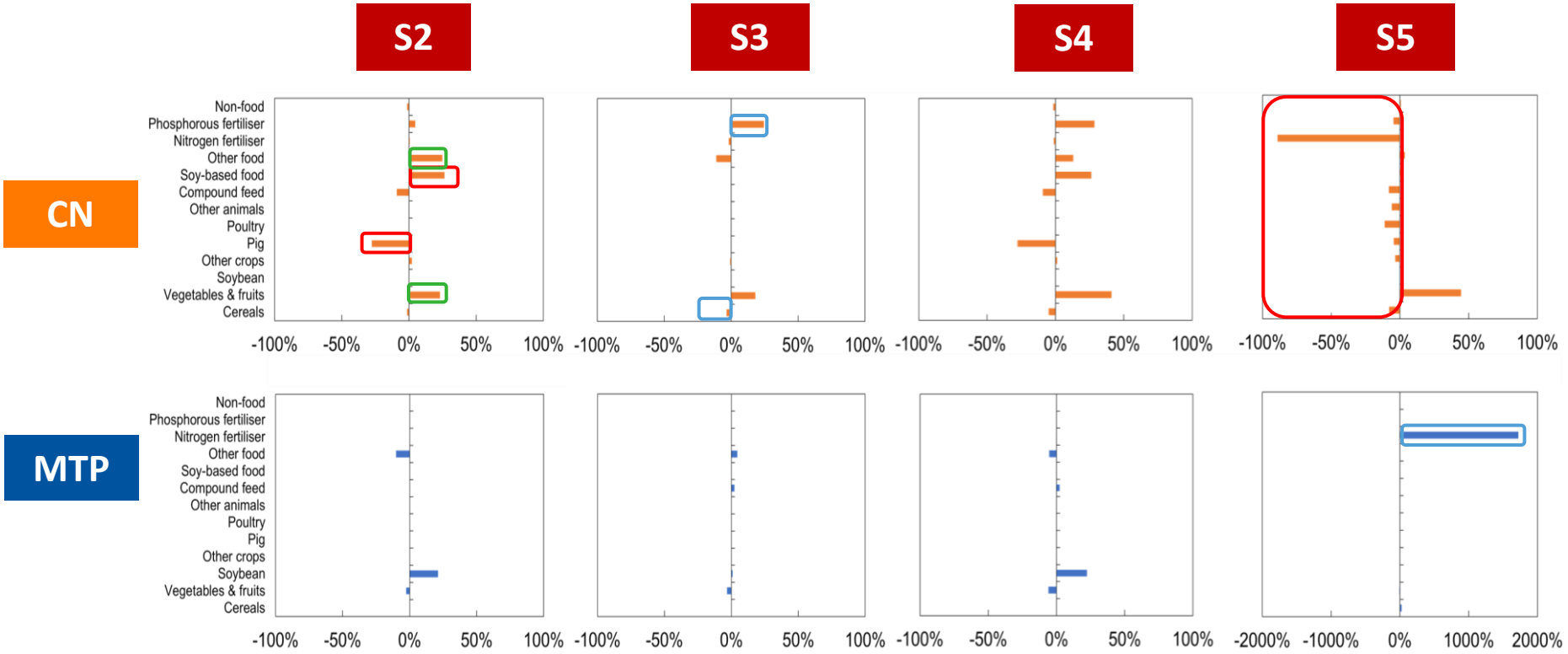
Changes in production for S2, S3, S4, and S5



- S1: Country-specific differences in environmental concerns
- S2: Dietary structure change
- S3: Cleaner cereals production technology
- S4: Combination of dietary structure change and cleaner cereals production technology
- S5: Emission restriction policy

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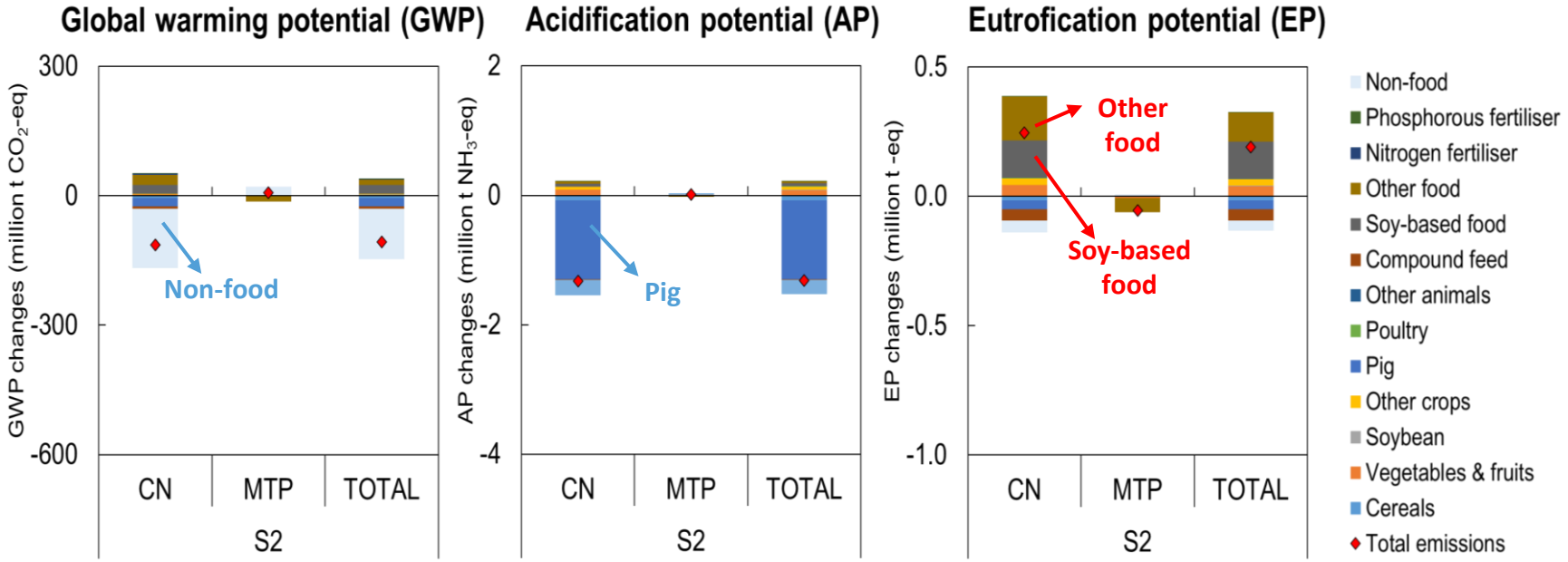
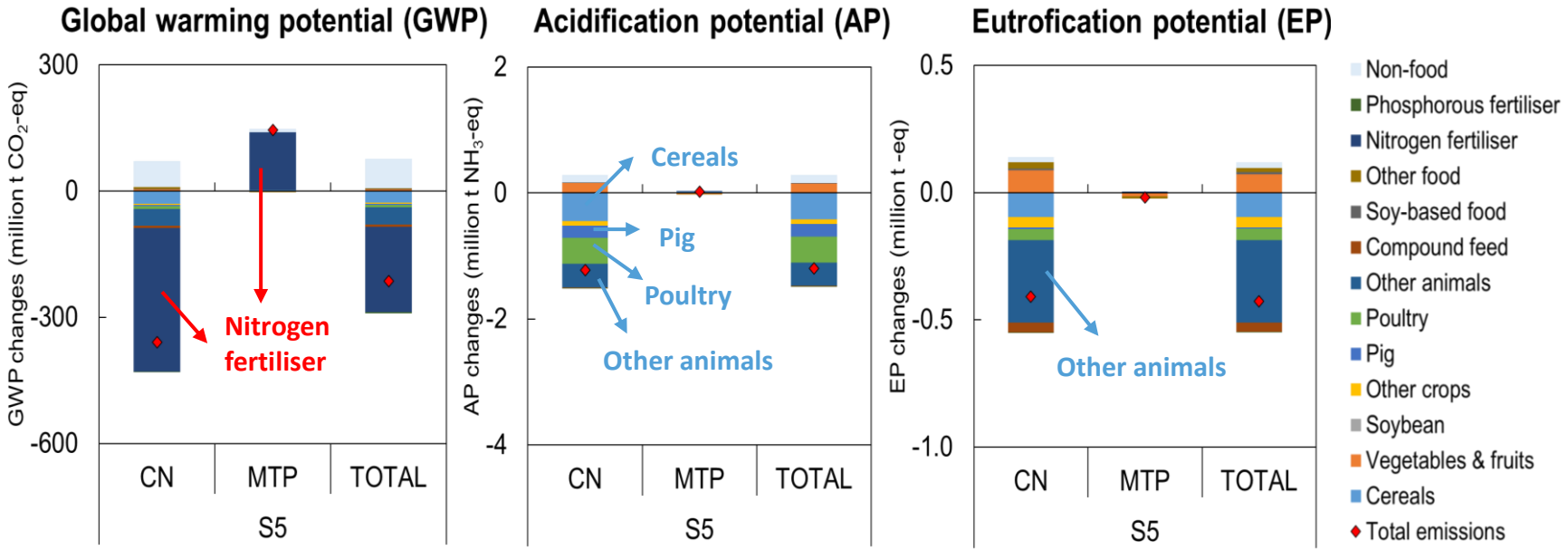
Changes in emissions for S2 (Dietary structure change)



Changes in emissions for S5 (Emission restriction policy)



Conclusions

- Only shifting the diet from pork to SBF is insufficient to reduce multiple environmental impacts (GWP: -1%; AP: -3%; EP: +2%).
- Combining a dietary shift with a cleaner production technology will decrease all types of emissions (GWP: -1%; AP: -7%; EP: -3%).
- Emission restrictions in China by 3% will decrease total emissions in China but cause emission leakages to its trading partners (GWP: +2%).
- Using a social welfare perspective enables the identification of trade-offs between environmental and economic objectives.

Thank you!

Questions?

Contact me via
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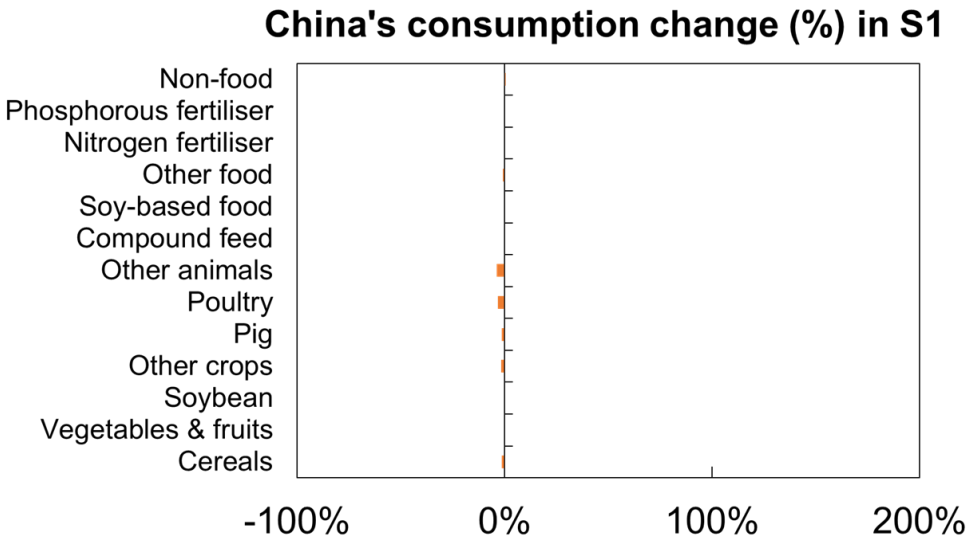
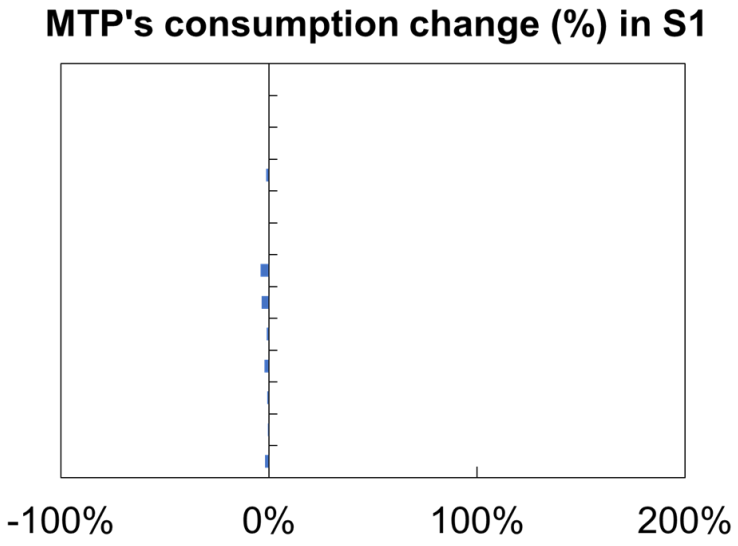
Changes in consumption for S1





Changes in consumption for S2, S3, S4, and S5

- S1: Country-specific differences in environmental concerns
- S2: Dietary structure change
- S3: Cleaner cereals production technology
- S4: Combination of dietary structure change and cleaner cereals production technology
- S5: Emission restriction policy

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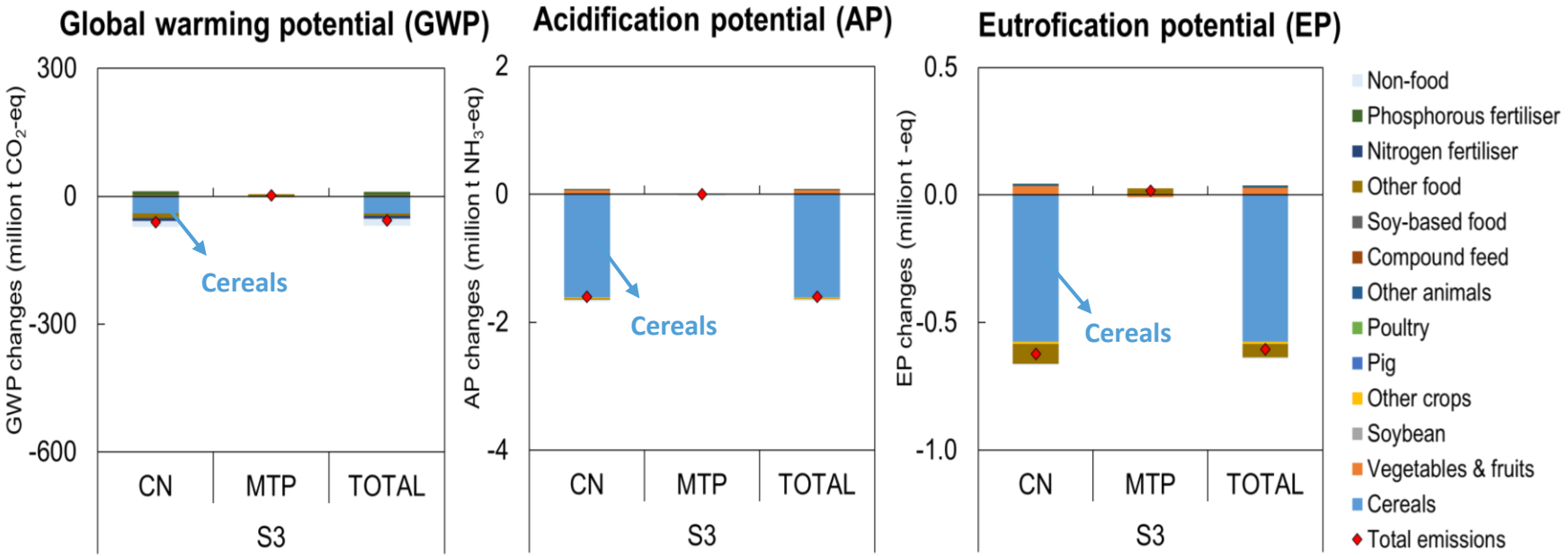
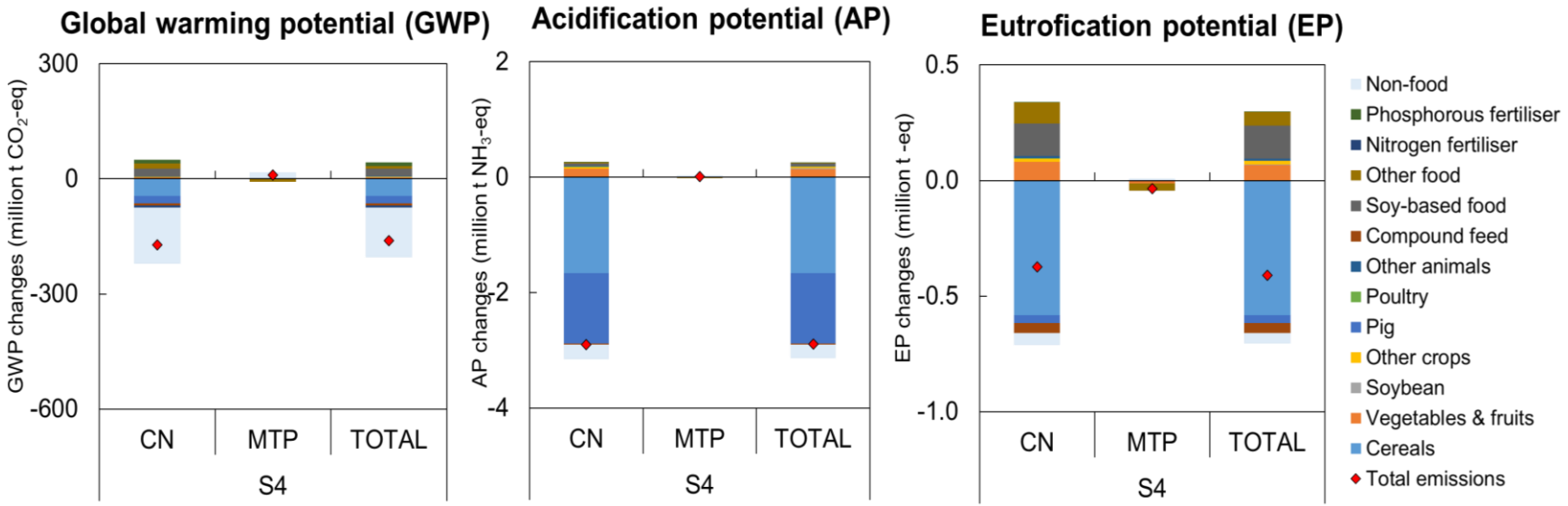
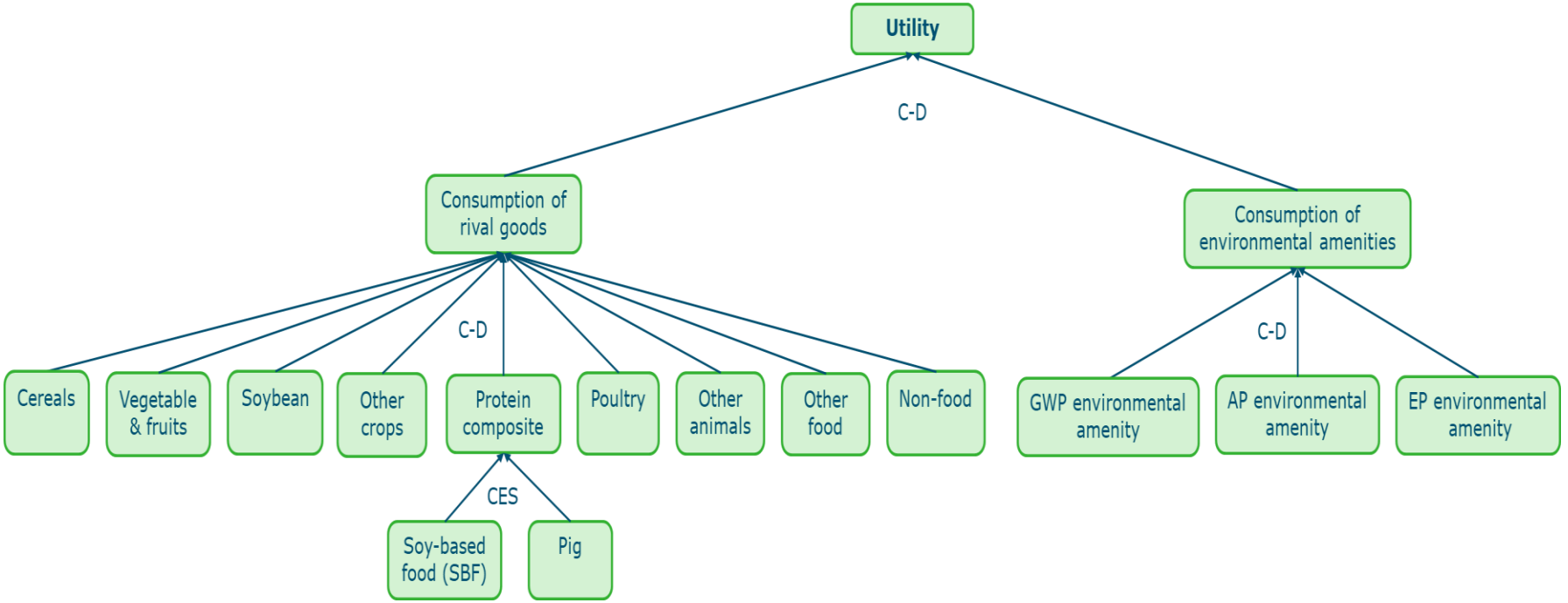
Changes in emissions for S3 (Cleaner cereals production technology)



Changes in emissions for S4 (Combination of dietary structure change and cleaner cereals production technology)



Utility function of the consumer in each region



GTAP database: sectoral aggregation

Aggregated sectors	GTAP original sectors
Cereals	"Paddy ricr (pdr)" , "Processed rice", "Wheat (wht)", and "Cereal grains nec (gro)" sectors
Vegetables & fruits	"Vegetables, fruits, nuts (v_f)" sector
Soybean	Split from "Oil Seeds (osd)" sector
Other crops	"Oil Seeds (osd)" sector after splitting out soybean; "Sugar cane, sugar beet (c_b)", "Plant-based fibers (pfb)", and "Crops nec (ocr)" sectors
Pig	Split from the original "Animal products nec (oap)" and "Meat products nec (omt)" sectors
Poultry	Split from the original "Animal products nec (oap)" and "Meat products nec (omt)" sectors
Other animals	"Animal products nec (oap)" and "Meat products nec (omt)" sectors after splitting out pig and poultry; "Cattle, sheep, goats, horses (ctl)", "Meat: cattle, sheep, goats, horses (cmt)", "Raw milk (rmk)", "Wool, silk-worm cocoons (wol)", and "Dairy products (mil)" sectors
Compound feed	Split from the original "Food products nec (ofd)"
Soy-based food	Split from the original "Food products nec (ofd)"
Other food	"Food products nec (ofd)" after splitting out compound feed and soy food; "Vegetable oils and fats (vol)", "Sugar (sgr)", and "Beverages and Tobacco products (b_t)" sectors
Nitrogen fertiliser	Split from the original "Manufacture of chemicals and chemical products (chm)" sector
Phosphorus fertiliser	Split from the original "Manufacture of chemicals and chemical products (chm)" sector
Non-food	"Manufacture of chemicals and chemical products (chm)" sector after splitting out N fertiliser and P_2O_5 fertiliser; "Forestry (frs)", "Fishing (fsh)", "Coal (coa)", "Oil (oil)", "Gas (gas)", "Minerals nec (oxt)", "Petroleum, coal products (p_c)", "Electricity (ely)", "Gas manufacture, distribution (gdt)", "Textiles (tex)", "Wearing apparel (wap)", "Leather products (lea)", "Wood products (lum)", "Paper products, publishing (ppp)", "Manufacture of pharmaceuticals, medicinal chemical and botanical products (bph)", "Manufacture of rubber and plastics products (rpp)", "Mineral products nec (nmm)", "Ferrous metal (i_s)", "Metal nec (nfm)", "Metal products (fmp)", Electronic equipment (ele)", "Manufacture of electrical equipment (eeq)", "Manufacture of machinery and equipment n.e.c. (ome)", "Motor vehicles and parts (mvh)", "Transport equipment nec (otn)", "Manufactures nec (omf)", "Water (wtr)", "Construction (cns)", "Wholesale and retail trade; repair of motor vehicles and motorcycles (trd)", "Accommodation, Food and service activities (afs)", "Land transport and transport via pipelines (otp)", "Warehousing and support activities (whs)", "Sea transport (wtp)", "Air transport (atp)", "Communication (cmn)", "Financial services nec (ofi)", "Insurance (ins)", "Real estate activities (rsa)", "Other Business Services nec (obs)", "Recreation & other services (ros)", "Other Services (Government) (osg)", "Education (edu)", "Human health and social work (hht)", "Dwellings: ownership of dwellings (imputed rents of houses occupied by owners) (dwe)" sectors

Sensitivity analysis

- **Environmental willingness to pay for improving one type of environmental quality:**
  - 1/3 for GWP, 1/3 for AP, and 1/3 for EP (current)
  - Only improving GWP/AP/EP environmental quality: 1,0,0 / 0,1,0 / 0,0,1
- **Equal environmental willingness to pay in both regions:**
  - 0.01 for China and 0.02 for MFIP (current)
  - The environmental willingness to pay in both regions are equal : 0.02 for China and MFIP
- **Substitution elasticity between pork and soy-based food:**
  - 0.5 (current) → change from 0.5 to 1.5
- **Technology replacement ratio:** 0.5 (current) → change from 0 to 1
- **Emission reduction target:**
  - 0.03 for GWP, 0.03 for AP, and 0.03 for EP (current)

  → Only reducing GWP: 0.03 for GWP, 0 for AP, and 0 for EP

  → Only reducing AP: 0 for GWP, 0.03 for AP, and 0 for EP

  → Only reducing EP: 0 for GWP, 0 for AP, and 0.03 for EP