How Trade Integration Can Mitigate the Effects of Extreme Weather Events on Agricultural Markets

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MARCEL ADENÄUER, CLARA FREZAL (OECD), AND THOMAS CHATZOPOULOS

IATRC, ANNUAL MEETING DECEMBER 11-13, 2022, CLEARWATER BEACH

INTRODUCTION

Project background

- Joint Working Party on Agriculture and Trade – Project in the current Program of Work
- Extreme weather events can disrupt agricultural markets and trade, but agricultural trade can, in turn, help address food supply and food security concerns in the wake of these events
- How important is a reliable global trade system to mitigate such extreme events?

Extreme events: definition

- Extreme event: rare and short-lived event, lasting from hours up to several months, with devastating potential

- Climate change is increasing the frequency, intensity and spatial extent of these events. **+ 83%** in the first two decades of the 21st century

- "This will have more serious consequences for food production than changes in mean climate alone" (IPCC, AR4)

→ Calls for considering both changes in mean climate and extreme events in climate change impact assessment in agriculture

Impact of extreme events on agriculture: State of the literature

- Under-researched compared to impact of climate change itself
- Some simulation studies, mainly at the regional and a few at the global level
- **How extreme events are modelled in global simulation studies?**
  - Supply-shock approach (Willenbockel, 2012)
  - Deterministic simulation with integration of yield stress indicator (Chatzopoulos et al, 2020)
  - Stochastic simulation (Chatzopoulos et al, 2021)
  - Integrated assessments (Deryng et al, 2014; Hasegawa et al, 2021)

→ Including the impact of extreme events leads to more pessimistic outcomes (on yields, food prices, food insecurity etc)

References:
Willenbockel (2012), Extreme weather events and crop price spikes in a changing climate – Illustrative global simulation scenarios
Deryng et al (2014), Global crop yield response to extreme heat stress under multiple climate change futures
Chatzopoulos et al (2020), Climate extremes and agricultural commodity markets: A global economic analysis of regionally simulated events
Chatzopoulos et al (2021), Potential impacts of concurrent and recurrent climate extremes on the global food system by 2030
Hasegawa (2021), Extreme climate events increase risk of global food insecurity and adaptation needs

The mitigation potential of trade: State of the literature

- International trade and climate change adaptation in agriculture addressed since the 90s with partial and general equilibrium models.
- (e.g. Costinot, 2016; Gouel and Laborde, 2018; Janssens et al, 2020; Guerrero et al, 2022) report that restricting trade exacerbates the negative impact of climate change, whereas liberalizing trade alleviates it
- Includes OECD study looking at impact of policy reform (including tariffs reduction) on climate change adaptation (Guerrero et al, 2022)
- Only one study looks at trade policy in the context of extreme events → Willenbockel (2012): use of export restrictions leads to further increase in export prices

References:
Willenbockel (2012), Extreme weather events and crop price spikes in a changing climate – Illustrative global simulation scenarios
Costinot (2016), Evolving Comparative Advantage and the Impact of Climate Change in Agricultural Markets: Evidence from 1.7 Million Fields around the World
Gouel and Laborde (2018), The crucial role of international trade in adaptation to climate change
Janssens et al (2020), Global hunger and climate change adaptation through international trade
Guerrero et al (2022), The impacts of agricultural trade and support policy reform on climate change adaptation and environmental performance: A model-based analysis

Main contributions and limitations

1) Contributions

   – Factors increased frequency and strength of extreme events into shock on yields

   – Explores mitigation potential of trade in the context of extreme event

2) Limitations

   – Climate change not explicitly modelled in Aglink-Cosimo

   – Extreme events defined as extreme yields. In reality extreme yields can be due to other factors (e.g. pest, economic shock)

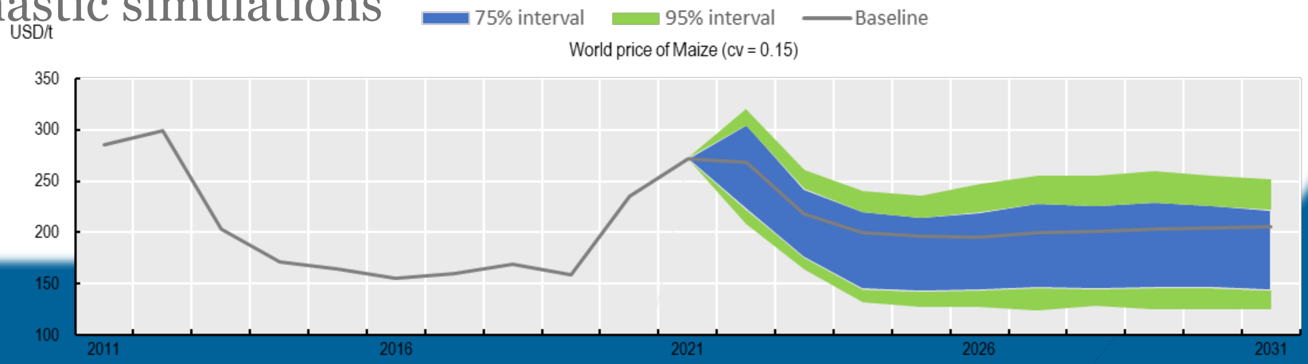
METHODOLOGY

The Aglink-Cosimo Model

- Aglink-Cosimo: an economic model of world agriculture managed by the Secretariats of the OECD and FAO
- Aglink-Cosimo is
  - recursive-dynamic (up to 2040),
  - partial equilibrium
  - used to simulate developments of annual market balances and prices for the main agricultural commodities produced, consumed and traded worldwide.
  - used in the production process of the OECD-FAO Agricultural Outlook and policy scenarios

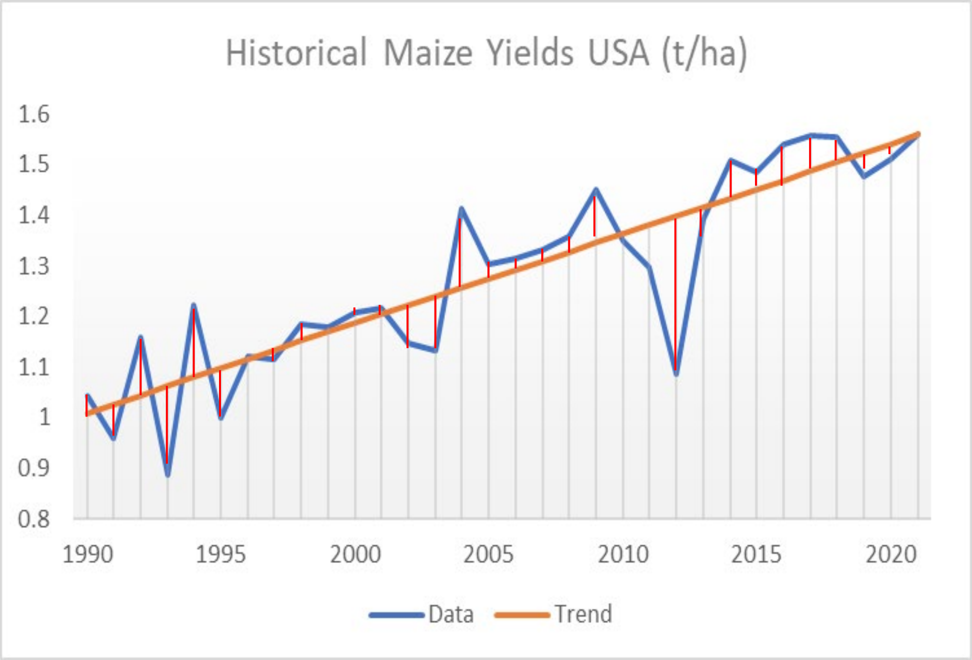
The standard stochastic approach

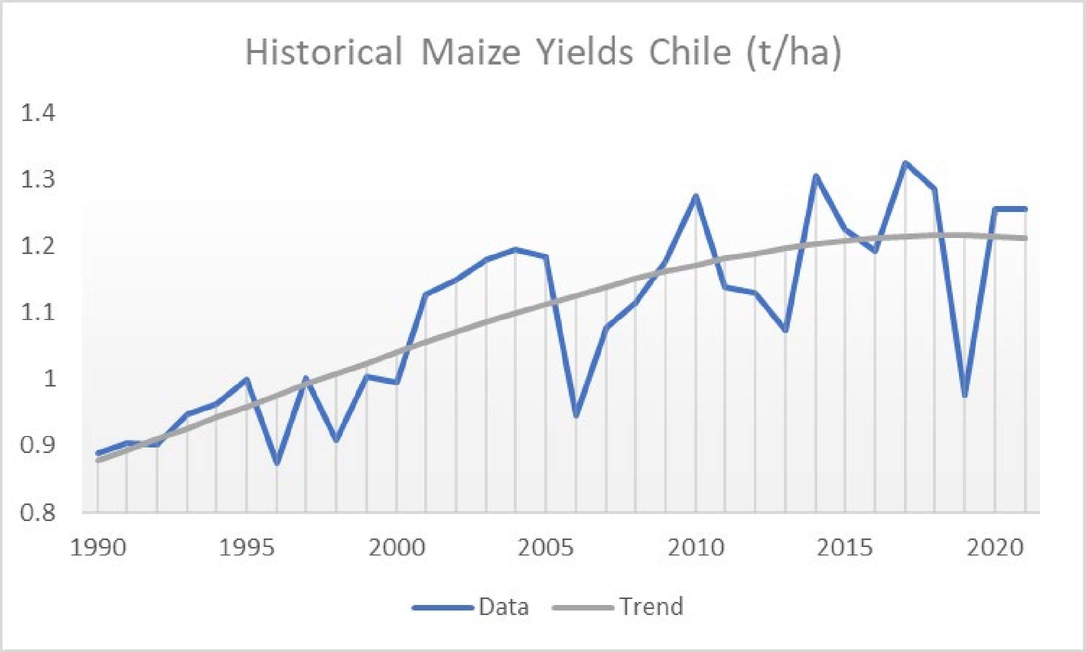
- Analysis is based on the *OECD-FAO Agricultural Outlook 2022-2032* and the corresponding Aglink-Cosimo release
- Stochastic variables target the main sources of uncertainty for agricultural markets (country specific macroeconomic variables including crude oil price, and country- and product-specific yields)
- First step: **Generate stochastic draws**:
  - Define historical deviations of actual yields to their trends
  - Use those deviations to draw 500 sets of stochastic variables for 2022-2040
- Second step: Run the Aglink-Cosimo model 500 times with those draws
- Third Step: Exploit results across stochastic simulations



Generating stochastic Draws: 1) Historical deviations

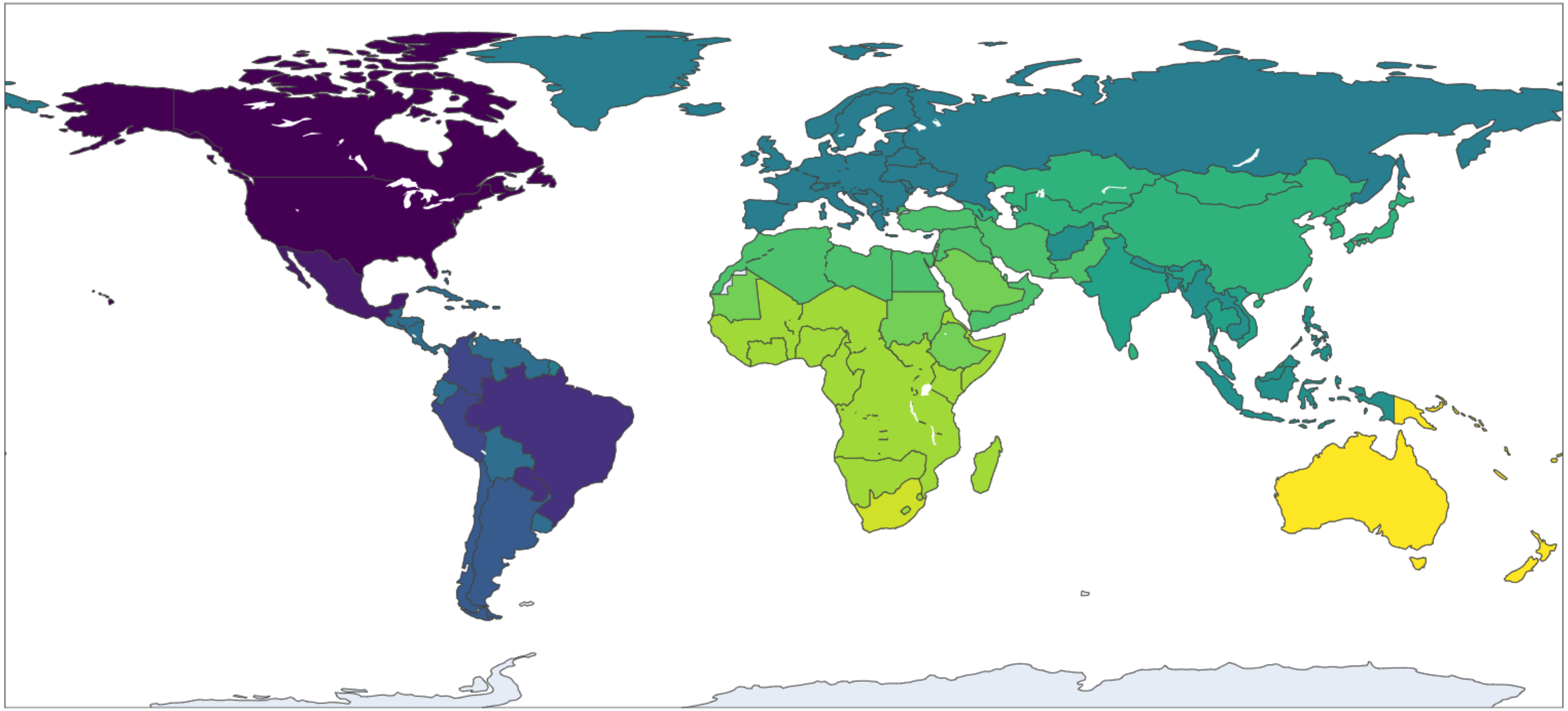
Uncertainty factors (data/trend) are stored for each country/crop/year combination





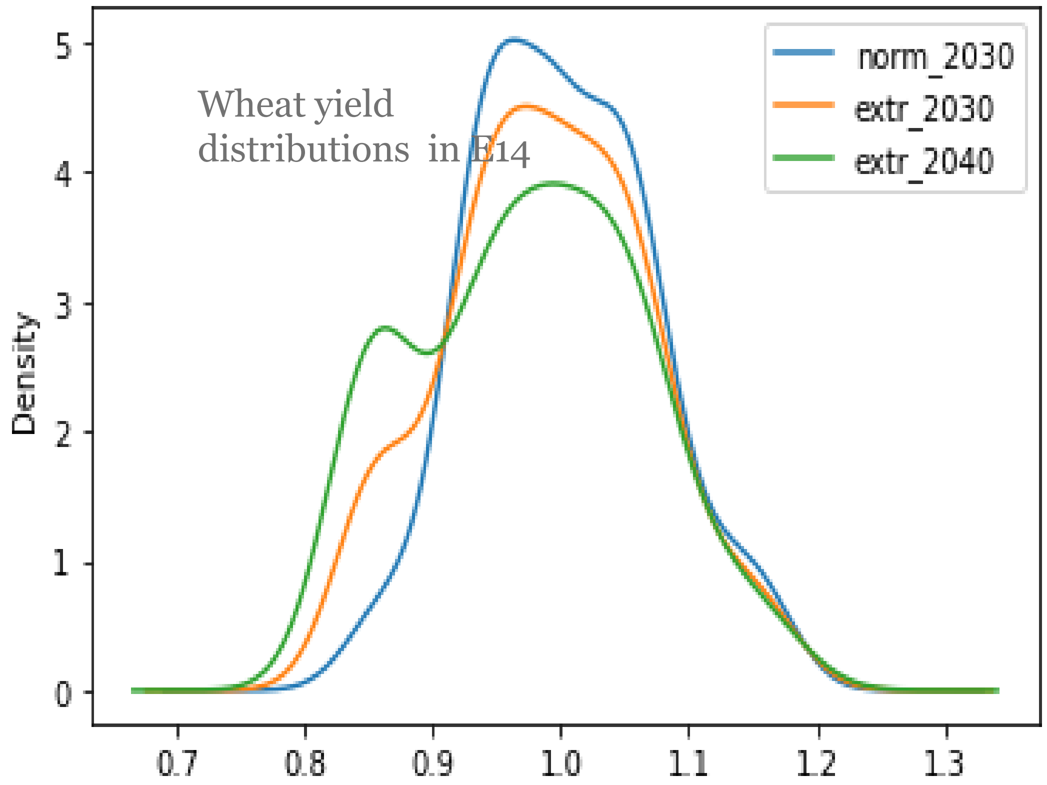
Generating stochastic Draws:
2) Drawing uncertainty factors – first adjustment

Clustering countries according to climatic zones

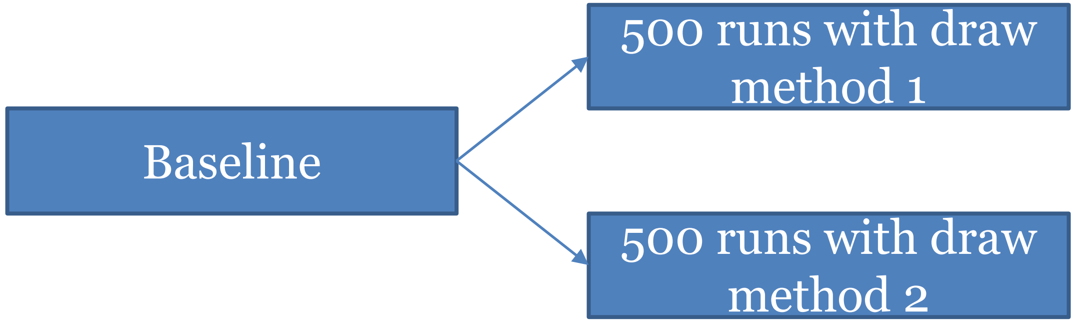


Generating stochastic Draws: 2) Drawing uncertainty factors – second adjustment

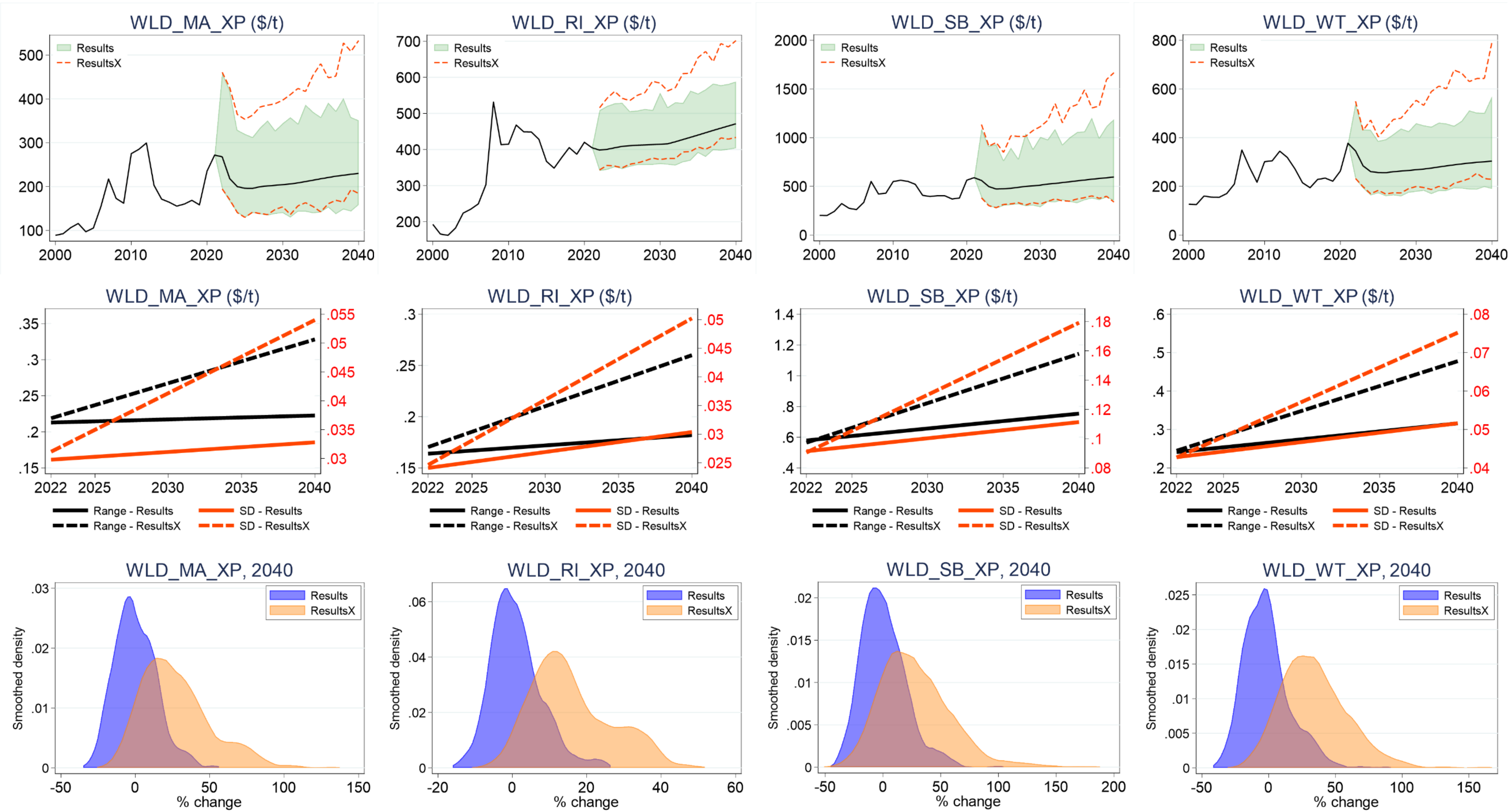
- Gradually increase the probability for the lowest historical uncertainty factor to 20% in 2040
- => yield distributions are shifted to the left



Comparison



- How can we compare results of two different sets of 500 model runs?
- Straight forward: Moments of the distributions and similar measures across runs:


WLD_MA_XP ($/t)
WLD_RI_XP ($/t)
WLD_SB_XP ($/t)
WLD_WT_XP ($/t)
Results
ResultsX
Range - Results
Range - ResultsX
SD - Results
SD - ResultsX
WLD_MA_XP, 2040
WLD_RI_XP, 2040
WLD_SB_XP, 2040
WLD_WT_XP, 2040
Smoothed density
% change

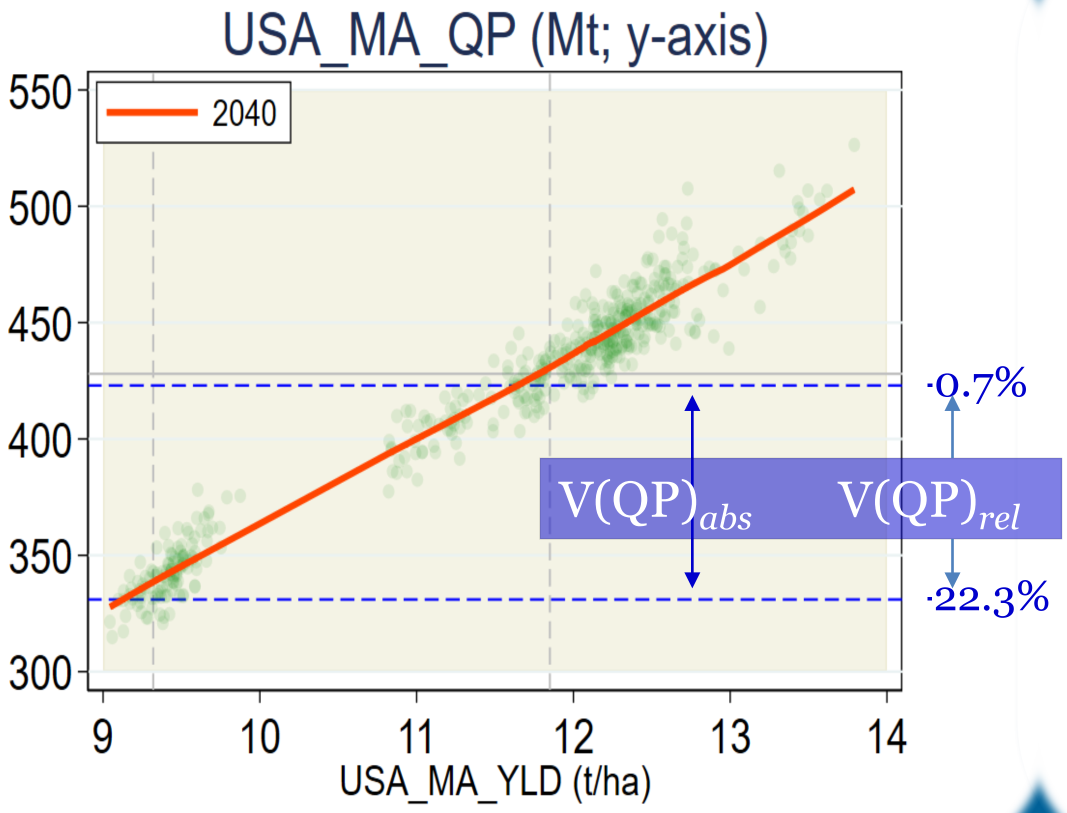
Market vulnerability: definition

- ***In a system at risk, a risk factor affects the elements at risk through a hazard condition.***
  - *Risk factor:* crop yields
  - *Elements at risk:* endogenous model variable (e.g., Production, consumption, trade, prices)
  - *Hazard condition:* $H = P(YLD_{scen} < YLD_{p5})$
  - *Extreme hazard condition:* $XH = P(YLD_{scen} \leq YLD_{p5})$

- **Vulnerability:** $V(\cdot) = |E(\cdot|NXH) - E(\cdot|XH)|$
  $= |E(\cdot|YLD_{scen} > YLD_{p5}) - E(\cdot|YLD_{scen} \leq YLD_{p5})|$

- A formal framework for probabilistic risk analysis with Aglink-Cosimo was recently published in *Environ. Res. Lett. 16 124021*

Market vulnerability: example of US maize production, 2040



- $P(XH) = 0.05$ (i.e., 1 even out of 20 is extremely damaging)
- $P(NXH) = 0.95$
- XH condition: $YLD_{scen} \leq YLD_{p5} = 9.28$ t/ha
- NXH condition: $YLD_{scen} > YLD_{p5}$
- $E(QP_{scen}|XH) = 331.04$ Mt
- $E(QP_{scen}|NXH) = 423.33$ Mt

Absolute vulnerability

$V(QP)_{abs} = 423.33 - 331.04 = 92.29$ Mt

Relative vulnerability

$V(QP)_{rel} = V(QP)_{abs} / QP_{bas} = 0.216$

TRADE SCENARIOS

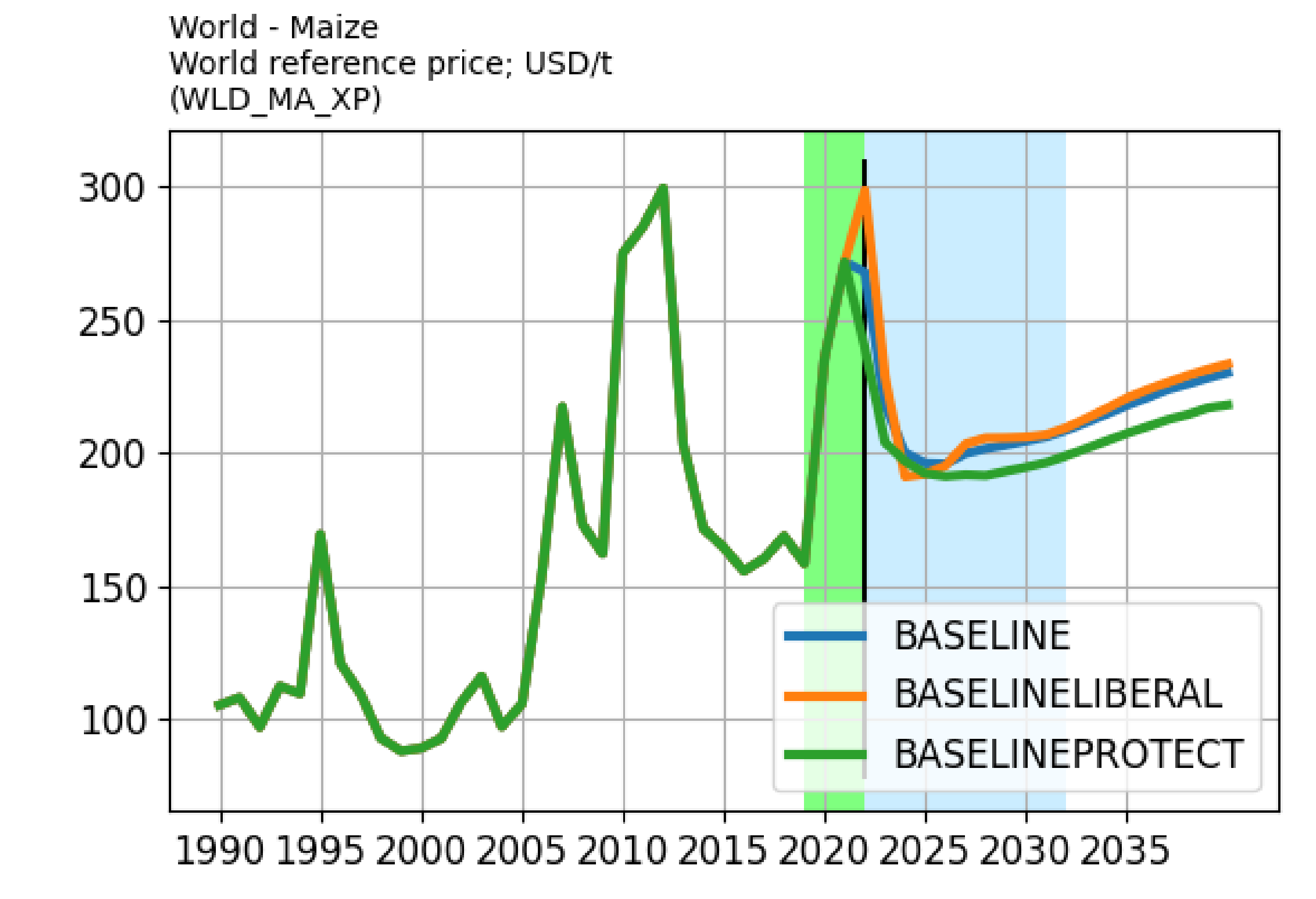
Scenario definition

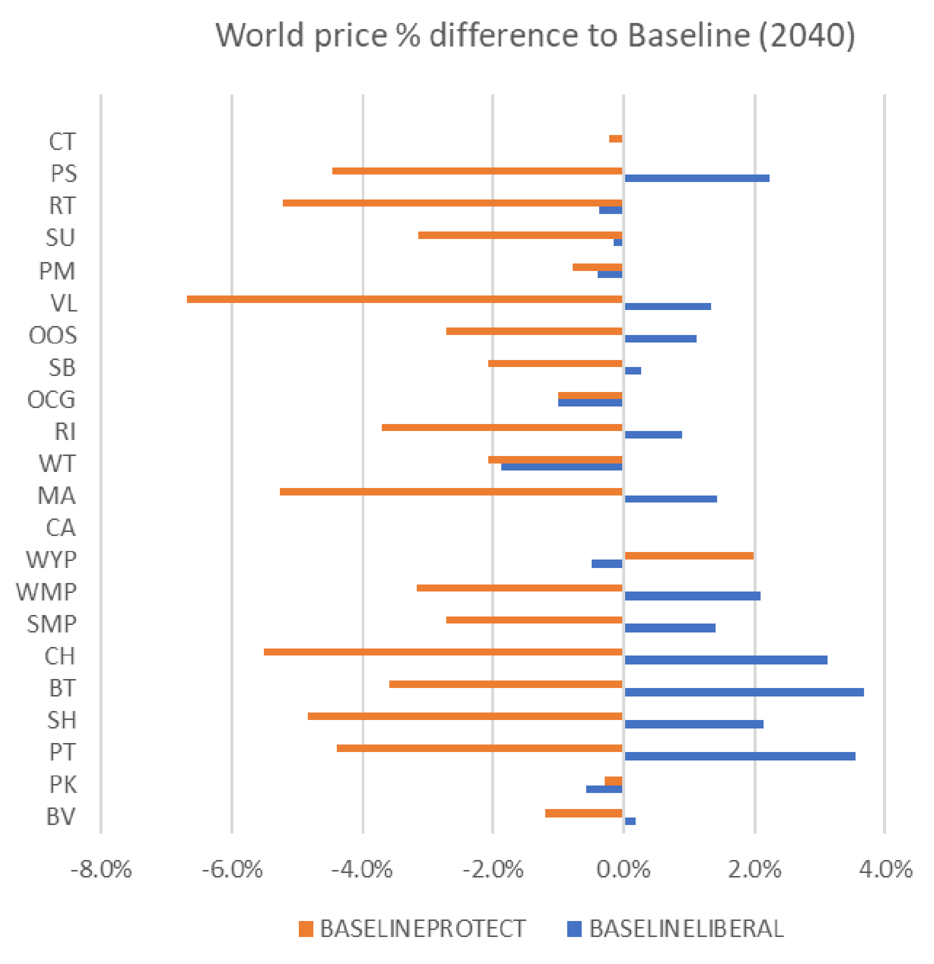
Run the stochastic framework for two model specifications:

1. The protected world
   - All tariffs for all ag-Products set to at least 10% or double the baseline value
   - TRQs are cut in half
   - Trade response parameters cut by 2

2. The liberal world
   - All tariffs set to 50% of the Baseline value
   - TRQs are doubled
   - Trade response parameters doubled

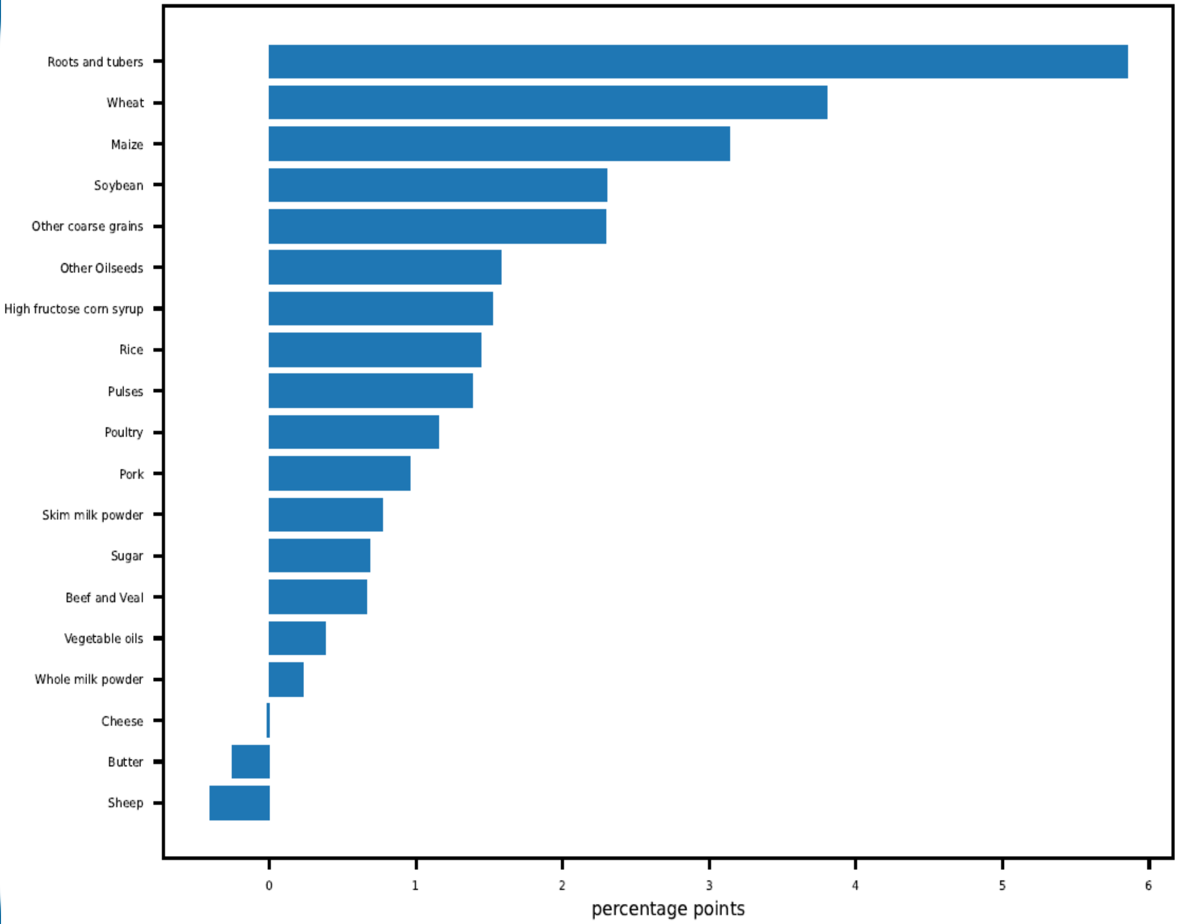
The deterministic scenario results: World prices



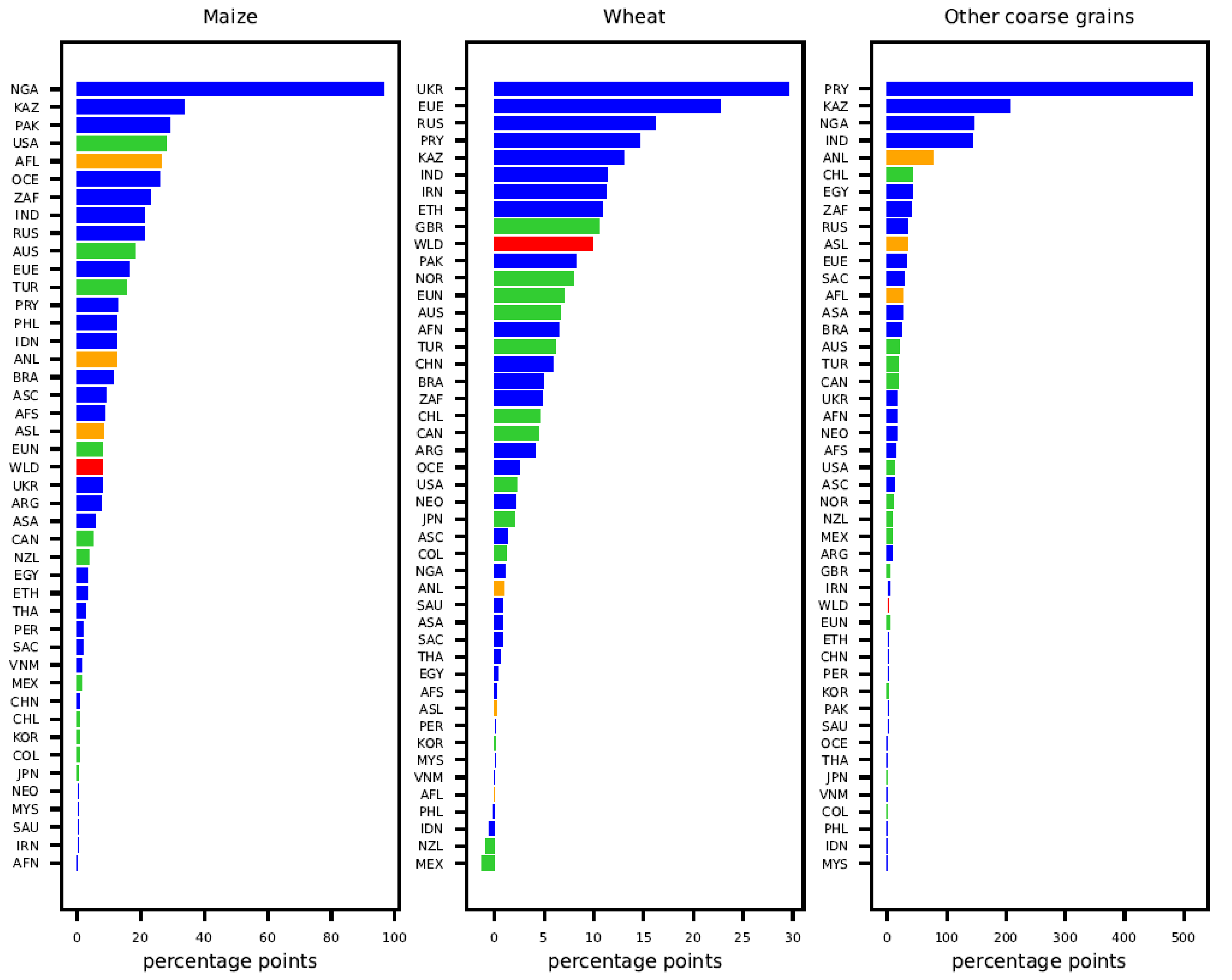


Difference in average (2022-2040) coefficient of variation of world prices, Protection vs Liberal

- Almost all world prices show more variation in the Protect-scenario
- Exception: some dairy products
- Broadly: world price extremes are less likely in a liberal world
- But countries might be more concerned about domestic price variability as price stability is a food security indicator

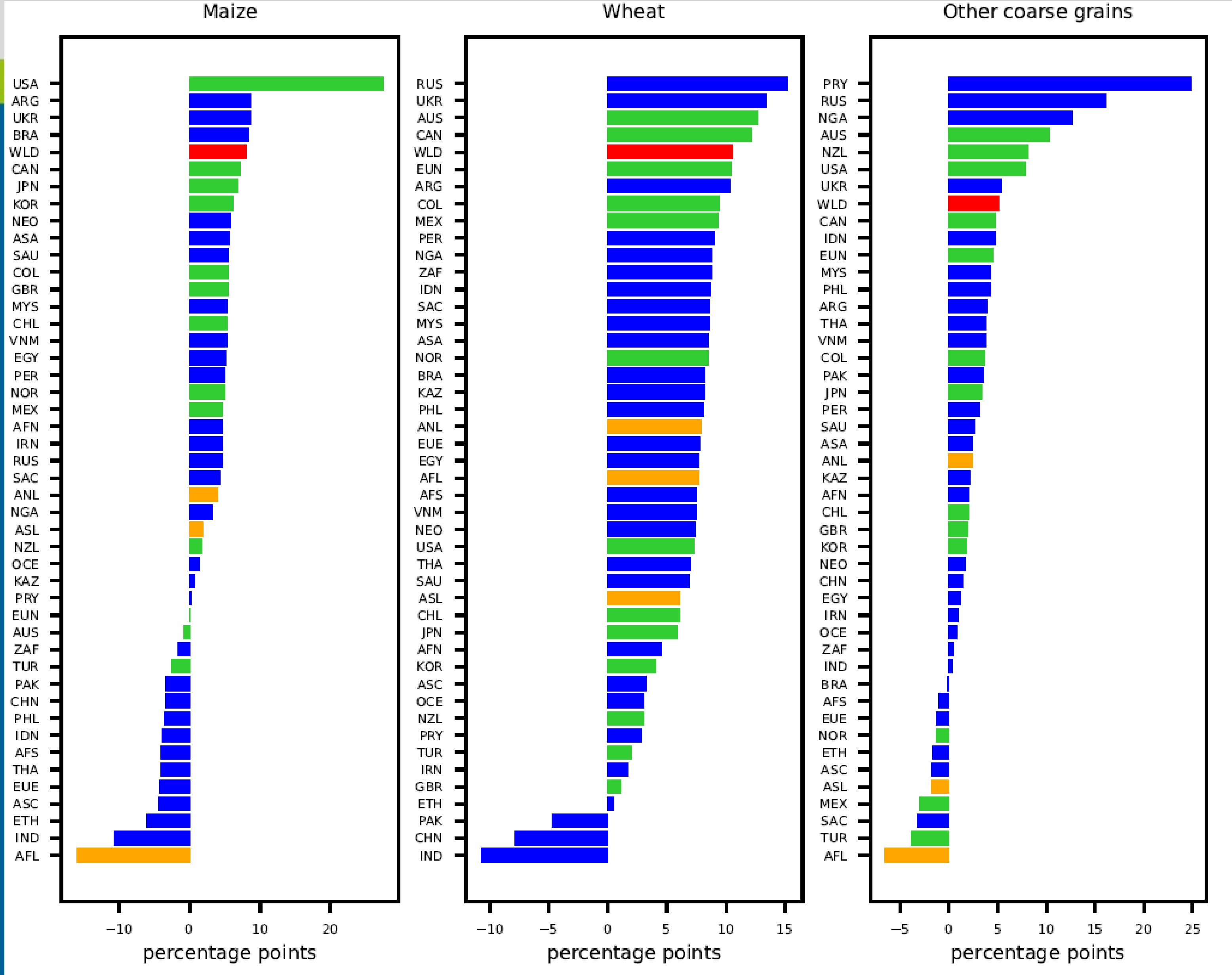


Price vulnerability to domestic yield extremes



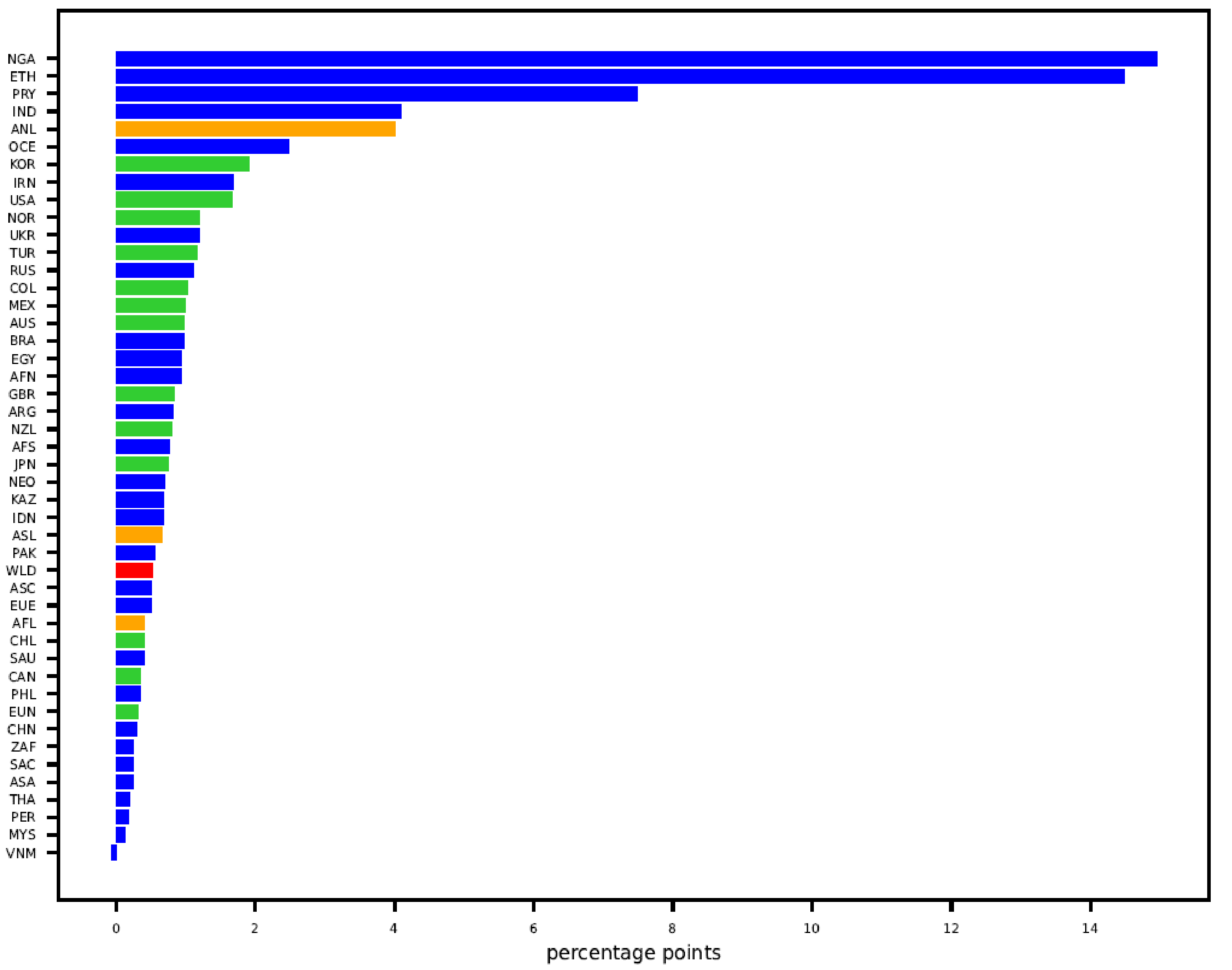
Difference of vulnerability index between the Protection and Liberal scenarios

Price vulnerability to yield extremes in the top 5 exporters



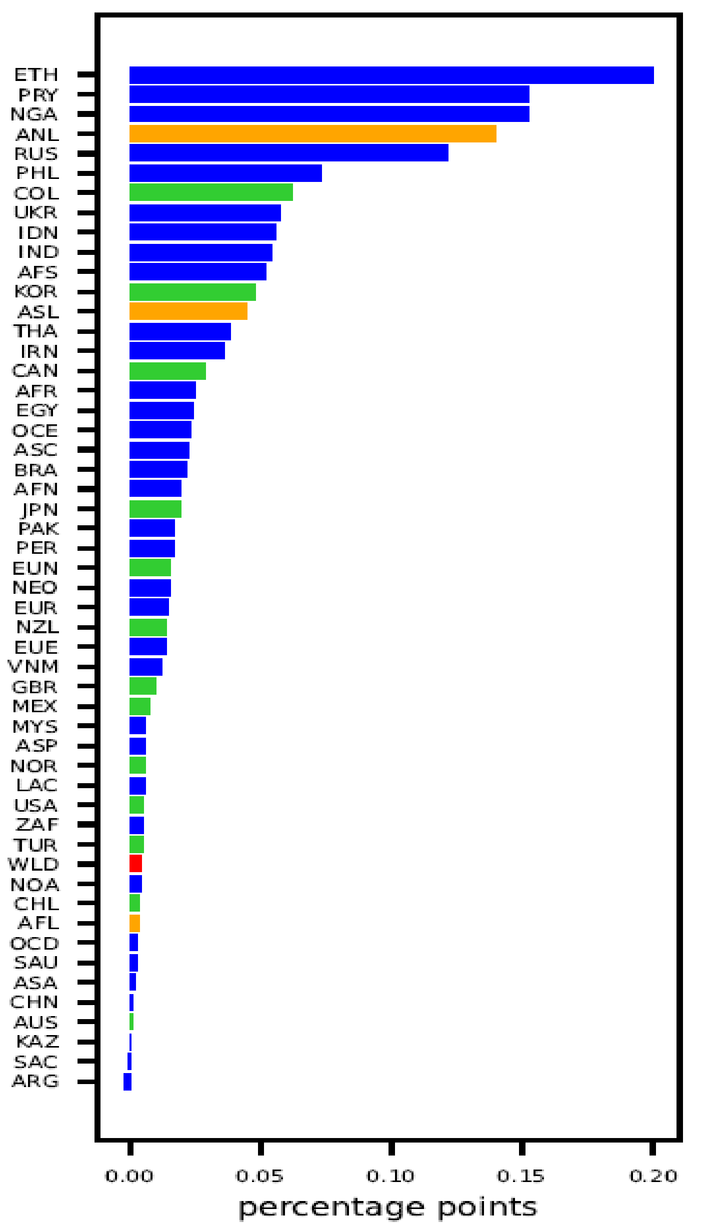
Difference of vulnerability index between the Protection and Liberal scenarios

Upper variability of national food price index



Difference between the Protection and Liberal scenarios

Downside variability of national food availability



Difference between the Protection and Liberal scenarios

Main findings

- Scenario results suggest that trade liberalisation reduces price vulnerability to extreme reductions in domestic yields.
- Despite concerns that countries may have about exposure to price volatility from international markets, trade liberalisation is also found to reduce price vulnerability to yield shocks occurring in key exporters.
- The risk of high domestic food prices decreases with greater trade integration, suggesting that open trade can help stabilise food expenditures.
- Trade integration moderates the extent to which extreme events reduce food availability, indicating that trade liberalisation can help stabilise food supply in case of extreme yield shocks.

Connection between trade parameters(x-axis) and trade integration (y-axis, USA)