Global Trade Analysis Project

Global Greenhouse Gas Taxes on Food Products: Economy-wide, Environmental and Dietary Implications

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Outline

1. Motivation
2. GTAP Data Base and model
3. Methodological approach
4. Policy scenarios
5. Results
6. Concluding remarks

1. Motivation

Motivation

- **Agricultural and food systems contribute over 25% of global GHG emissions (FAO, 2018).**
  - For many countries they can represent even higher share.
- **Demographic changes and increasing income are expected to further push the global diet towards more meat-oriented and emission-intensive food items**.
  - According to Hedenus et al. (2014), food-related emissions could increase by over 80% between 2000 and 2070.
- **This alone would make it almost impossible to keep the global temperature increase *well below 2ºC*, as desired by the Paris Climate Agreement.**
  - Reducing the food-related GHG emissions is a crucial component in meeting the stringent climate change targets.

Overview of the existing literature

- **Number of recent studies have explored environmental and health implications of strategies to reduce food-related GHG emissions:**
  - Friel et al. (2009) showcase potential health benefits (reduction in ischemic heart diseases) from 50% reduction in agricultural and food-related emissions in Sao Paulo and UK. Agricultural tech improvements and reduction in livestock production is used as a main strategy.
  - Tilman and Clark (2014) explore environmental, health and land use implications of transitioning towards alternative diets (e.g. Mediterranean, pescatarian, vegetarian, etc.). They identify significant multiple benefits of such transitioning.
  - Springmann et al. (2016) focus on impacts of food-related GHG emissions taxation on health and environment. They report -9.3% reduction in food-related GHG emissions under \$52/tCO_2. Significant health co-benefits (reduced mortality) are also identified.

Drivers of the food-related GHG emissions reduction:

productivity change vs **taxation** vs **change in preferences**

Focus of this study

- **In this paper, we fill the gap in the existing literature, by focusing on following points:**
  - Economy-wide (global and regional) implications of food-related emissions' taxation.
  - Sectoral impacts of food-related emission reductions.
  - Assessment of possible air-pollution reduction co-benefits.
  - Dietary implications.
  - Methodological developments that underlie such assessment.

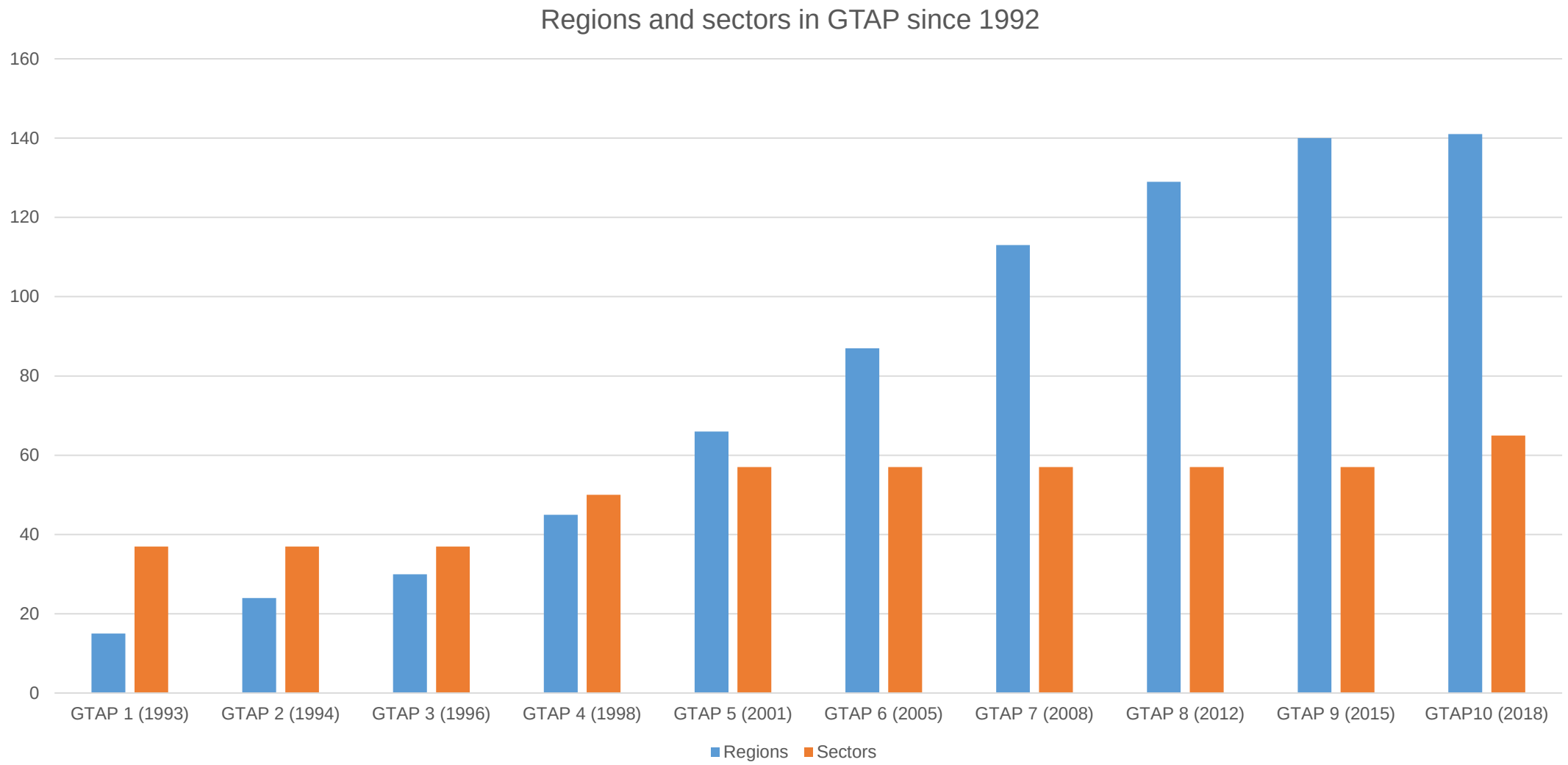
Global Trade Analysis Project (GTAP) Database and multi-sector multi-region computable general equilibrium (CGE) model is used for such assessment

2. GTAP Data Base and Model

What is GTAP?

- **Global Trade Analysis Project**
- **Based at Purdue University**
- **Consortium of international and government agencies, research institutes and universities, private sector**
- **International database for analysis of international policy issues**
  - Trade, migration, development, energy & the environment, etc.
- **Global GE model also available**
  - Model is known as the GTAP model and is coded using GEMPACK, see Hertel, Thomas, ed. (1997), *Global Trade Analysis: Modeling and Applications*, Cambridge University Press.

Evolution of the GTAP Data Base



Increasing Regional Coverage

GTAP 6 – 69 countries

GTAP 7 – 94 countries

GTAP 8 – 109 countries

GTAP 9 – 120 countries

Commodity coverage v9 (57 sectors)

Agriculture etc.	Processed food	Energy intensive	Oth. Manufacturing	Services	
Paddy rice	Coal	Wood products		Communication	
Wheat	Oil	Pulp, paper etc.	Other mach. & eqpt.	Financial services	
Other cereals	Gas	Refined oil etc.	Other manu.	Insurance	
Vegetables & fruits	Other minerals	Chemicals, rubber and plastics	Electricity	Other bus. services	
Oil seeds	Red meat		Gas distribution		
Sugar cane & beet	White meat		Water	Recreation etc.	
Plant-based fibers	Vegetable oils	Other mineral prod.	Construction	Public Admin., Educ, Health	
Other crops	Dairy products	Ferrous metals	Trade		
Beef etc.	Processed rice	Other metals			
Poultry, pork, etc.	Refined sugar	Metal products	Other transport	Dwellings	
Raw milk	Other food	Mot. vehicles & parts			
Wool etc.	Beverages & tobacco	Oth. trp. eqpt.	Sea transport		
Forestry	Textiles	Electronic eqpt.	Air transport		
Fishing	Clothing				
	Leather products				

Commodity coverage v10 (65 sectors)

Agriculture etc.	Processed food	Energy intensive	Oth. Manufacturing	Services
Paddy rice	Coal	Wood products	Electrical eqpt.	Communication
Wheat	Oil	Pulp, paper etc.	Other mach. & eqpt.	Financial services
Other cereals	Gas	Refined oil etc.	Other manu.	Insurance
Vegetables & fruits	Other minerals	Pharmaceuticals	Electricity	Real estate
Oil seeds	Red meat	Other chemicals	Gas distribution	Other bus. services
Sugar cane & beet	White meat	Rubber & plastics	Water	Recreation etc.
Plant-based fibers	Vegetable oils	Other mineral prod.	Construction	Public Admin.
Other crops	Dairy products	Ferrous metals	W & R trade	Education
Beef etc.	Processed rice	Other metals	Hotels, rests. etc.	Health
Poultry, pork, etc.	Refined sugar	Metal products	Warehousing etc.	Dwellings
Raw milk	Other food	Mot. vehicles & parts	Land transport	
Wool etc.	Beverages & tobacco	Oth. trp. eqpt.	Sea transport	
Forestry	Textiles	Electronic eqpt.	Air transport	
Fishing	Clothing			
	Leather products			

GTAP Data Base Release History

Release	Released	Regions	Sectors	Reference Years
GTAP 1	1993	15	37	1990
GTAP 2	1994	24	37	1992
GTAP 3	1996	30	37	1992
GTAP 4	1998	45	50	1995
GTAP 5	2001	66	57	1997
GTAP 6	2005	87	57	2001
GTAP 7	2008	113	57	2004
GTAP 8.1	2012	134	57	2004, 2007
GTAP 9a	2016	140	57	2004, 2007, 2011
GTAP 10	2019	141	65	2004, 2007, 2011, 2014

Structure of the GTAP Data Base

- **National input/output tables**
- **Bilateral trade and protection data**
  - Export taxes/subsidies
  - International trade and transport margins (FOB, CIF)
  - Bilateral import tariffs
- **Other international data sources**
  - Macro
  - Agriculture
  - Energy
- **“FIT” procedure to make consistent world accounting framework**

Satellite accounts

- **Standard**
  - Times series of bilateral merchandise trade flow (199x-201x)
  - Energy consumption in MTOE and CO_2 emissions from fuel combustion
- **Additional**
  - Bilateral stock of foreign-born population and workers (by skill)
  - Cross-border flows of capital income
  - Emissions of other greenhouse gases (N_2O, CH_4, F-gases)
  - Air pollution (10 air pollutants)
  - Land use (18 agro-ecological zones—AEZs) and forestry coverage
- **Special databases**
  - *Power database* (electricity production split into 11 sources (thermal, nuclear, hydro, renewables, etc.) + transmission & distribution)
  - *Water database* (rain-fed and irrigated crops, aggregate water use for livestock, municipal and industrial)
  - *Energy subsidies* database (country-specific fossil-fuel consumption subsidies)

GTAP Model

- **Multi-region static computable general equilibrium (CGE) model**
- **Describes the global economy which consists of many economies**
- **Trade links the economies**
  - Track exports by commodity, source and destination, domestic vs imported
- **Armington assumption:** product differentiation by country of origin
- **Each region is balanced**
  - S - I = X – M
- **World is balanced**
  - Global Saving = Global Investment
  - Total Exports = Total Imports

GTAP Model

- **Standard Features**
  - Perfect competition and constant returns to scale
  - Comparative static: No dynamics, No endogenous capital accumulation
  - Bilateral trade specified via Armington assumption

- **Non-Standard Features**
  - Private demand for commodities and services derived from a Constant Difference Elasticity (CDE) function
  - Regional Household collects all income and allocates across private consumption, government and saving
  - Sluggish primary factors
  - Explicit treatment of transportation costs in int'l trade via a global transport sector
  - Global investments linked to global savings via a global bank

GTAP Model

- **Accounting relations and price linkages**
  - Market clearing equations
  - Supplies and demands for domestic goods, imports, endowments, investment goods and transport
  - Regional household – allocation of income
  - Zero profits equation
  - Linking market prices to those paid by consumers, government, investors, firms and importers
- **Behavioral equations**
  - Consumer Behavior/Demand
  - Producer Behavior/Supply

3. Methodological Approach

General Framework

- **Static computable general equilibrium model (GTAP-E)**
- **GTAP 9.2 Database (2011 reference year)**
- **Data extensions:**
  - *FAO-based agricultural production targeting (APT)*. Covers 133 regions of the GTAP Database.
  - *GTAP-consistent food balance sheets* with dietary and nutritional information. Allows to track changes in food, fat and protein supply.
  - Include the *non-CO_2 GHG* emissions and *air pollution* accounts.
- **Policy scenario:**
  - \$35/ton CO_2-eq. (\$2010 PPP) tax of GHG emissions embodied into final households' consumption of food products.
  - Sensitivity analysis with tax lower bound of \$15/ton CO_2 and an upper bound of \$55/ton CO_2.

FAO-based APT: Motivation

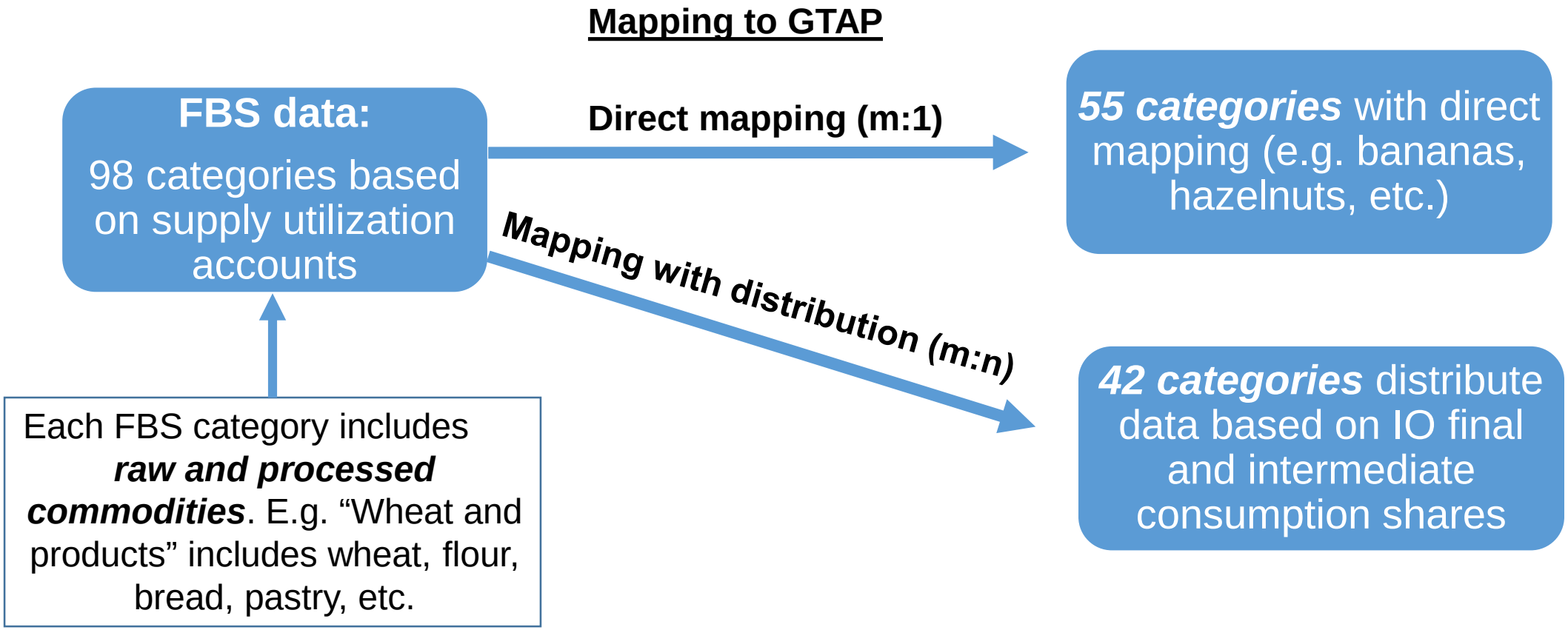
- **Detailed representation of the agricultural sector in GTAP:**
  - Agricultural and food IO table is used to split sectors if required (Peterson, 2016).
  - Agricultural production targeting (APT) for 12 agricultural sectors is applied to selected countries, using OECD (OECD, 2017) and EU data (Boulanger et al., 2016).

- **Limitations of the current APT approach:**
  - OECD-derived data include high share of unclassified commodities (40% in case of China).
  - APT covers 46 countries (70% of global agricultural output), but misses most developing countries (e.g. India).
  - Some agricultural commodities are not reported by OECD and food output is used for targeting (e.g. sugar output is used to derive targets for sugar cane).

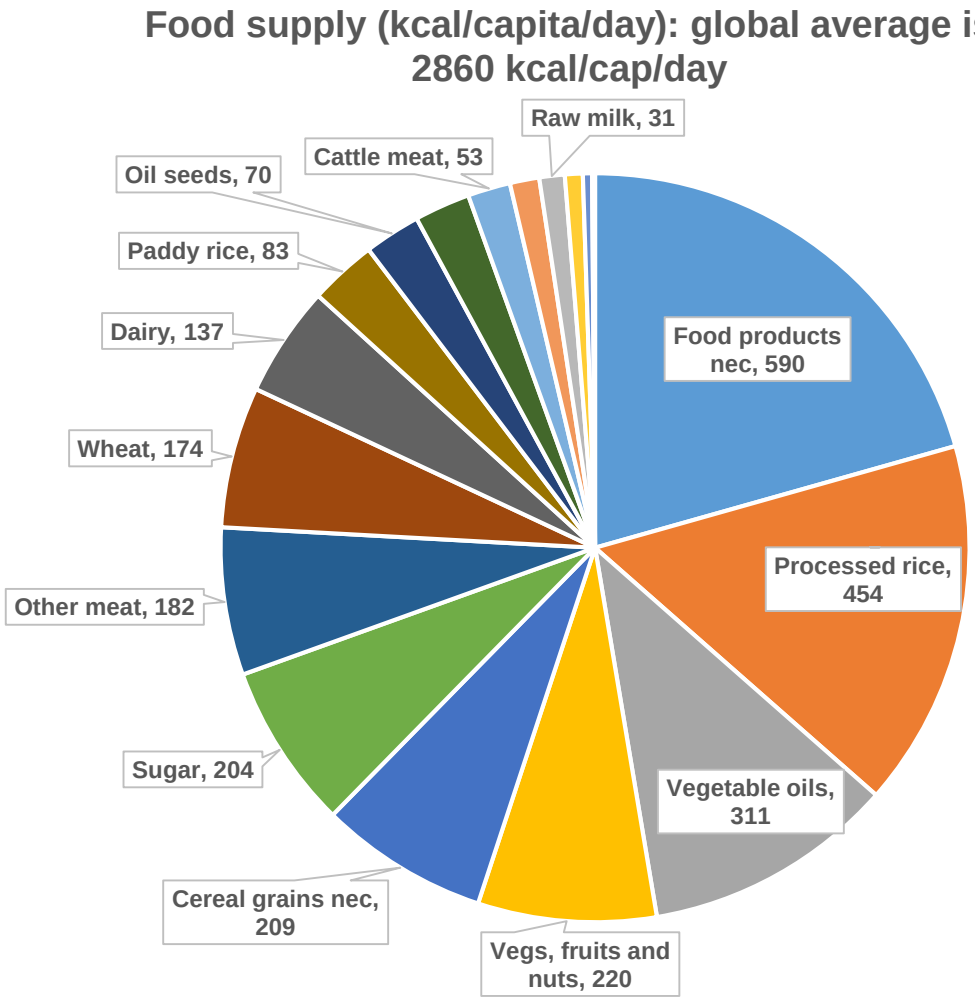
- **FAO reports 286 commodities for 217 countries (133 GTAP regions) with available price and quantity data**

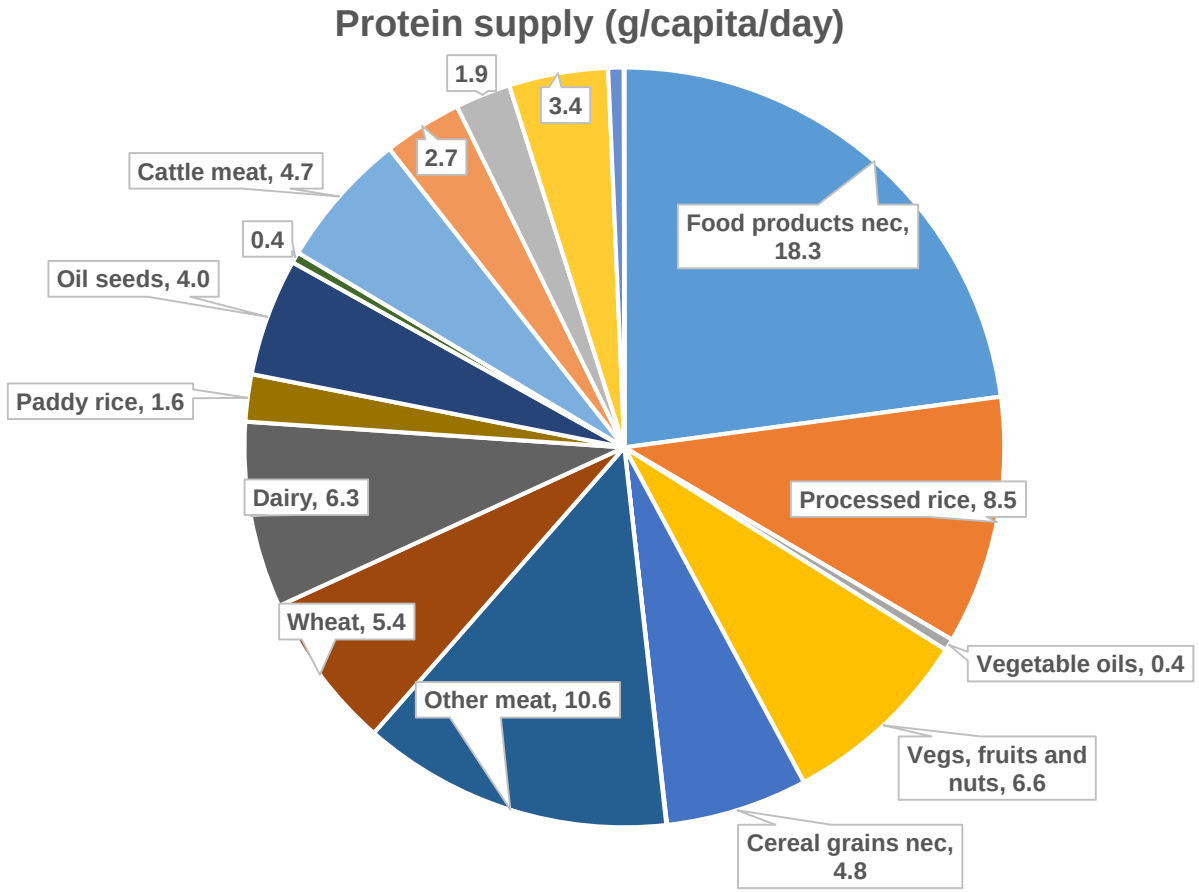
Dietary and Nutritional Data: Construction

- ***Key motivation*** **– track changes in food, fat and protein supply following implementation of carbon tax.**
- **Main data source – FAO Food Balance Sheets (FBS).**



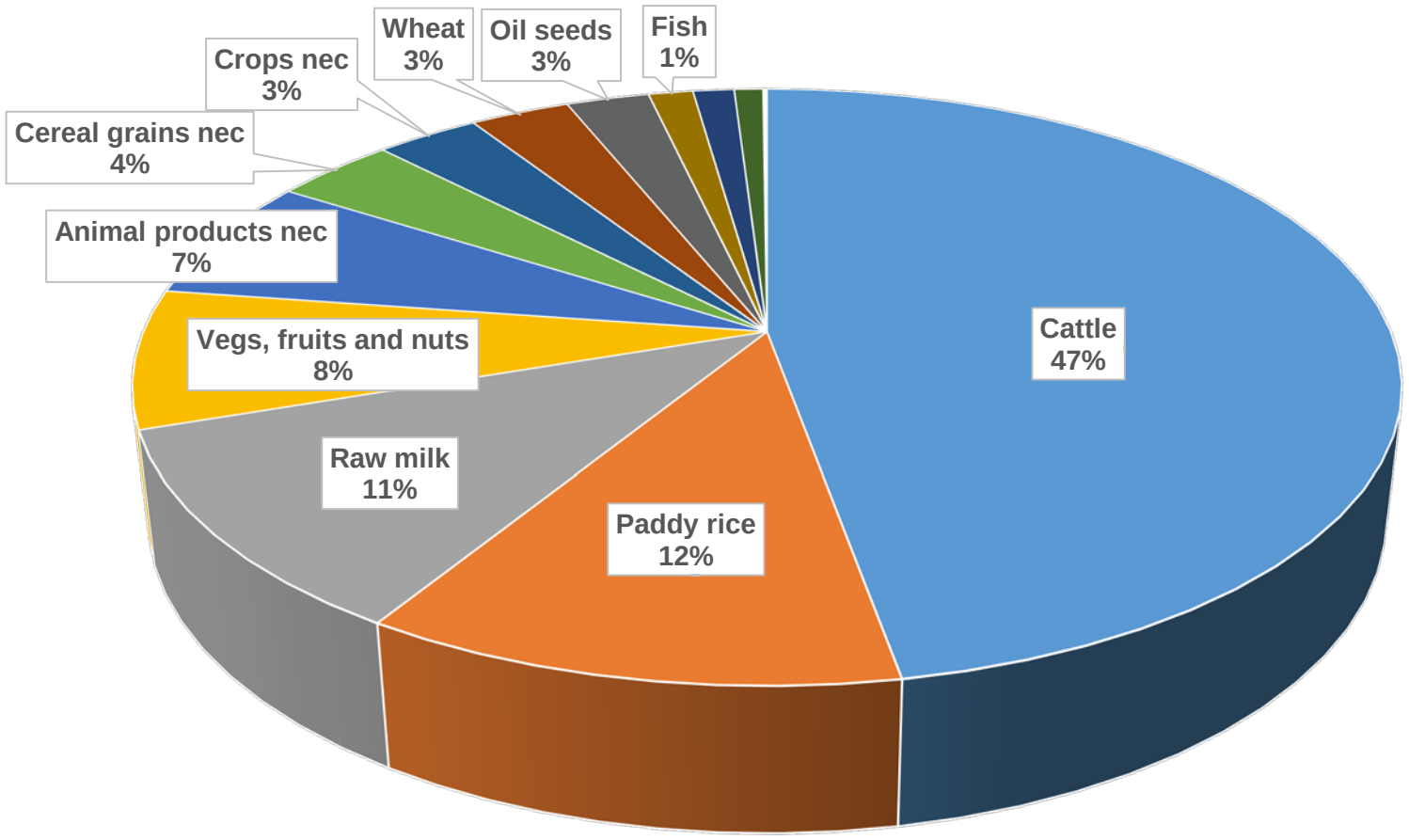
Nutritional Data: Sectoral Distribution





Global weighted average per capita distribution of food and protein supply by GTAP food and agricultural sectors

Non-CO_2 GHG emissions (direct accounting)



Non-CO_2-GHG emissions redistribution by GTAP sectors, 2011

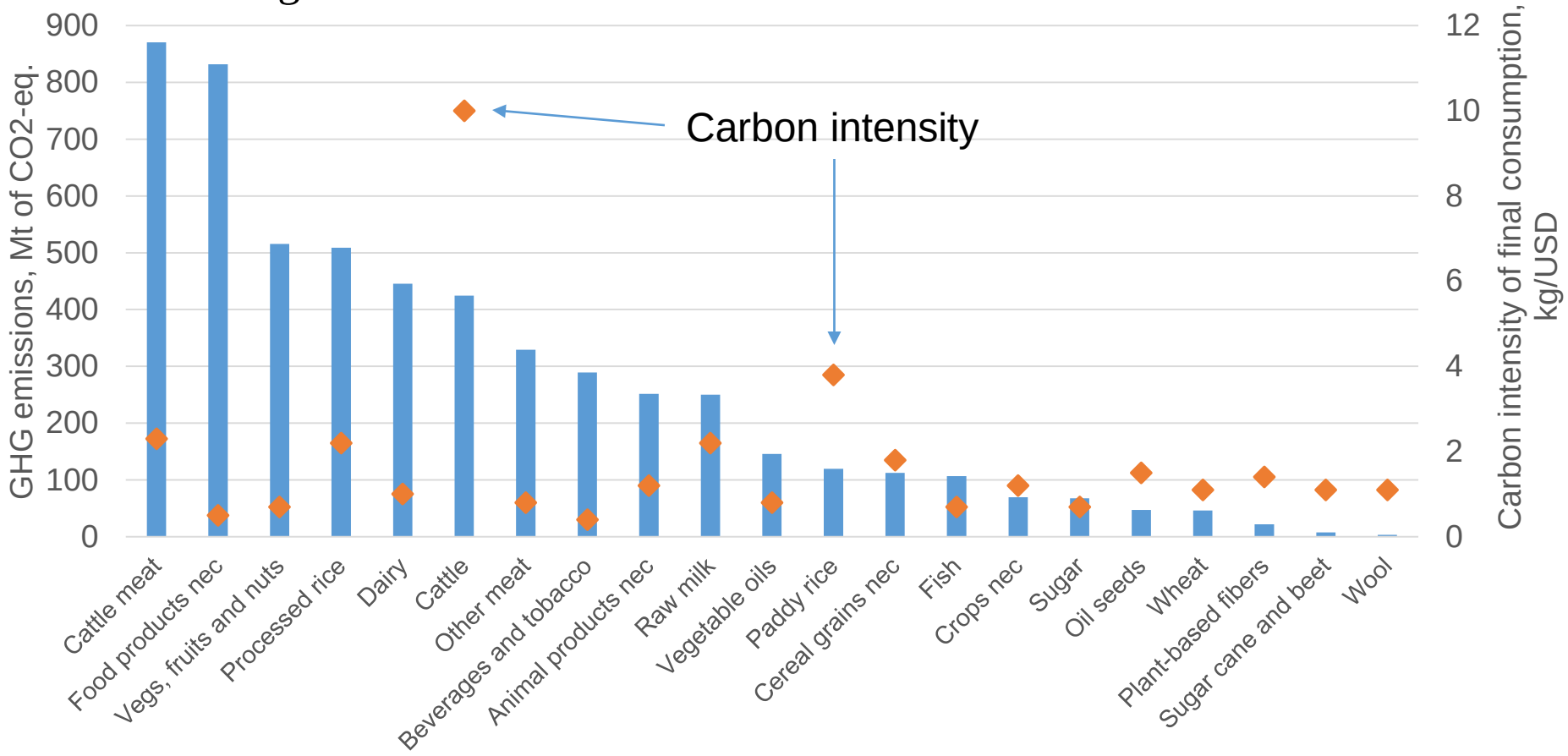
- **Emissions of N_2O, CH_4 and F-gases** are linked to three types of drivers (intermediate and final consumption, endowment and output). Based on Irfanoglu and van der Mensbrugghe (2015).

GHGs Embodied into Food Final Consumption

GHGs embodied into final households' consumption of region r (f_r)

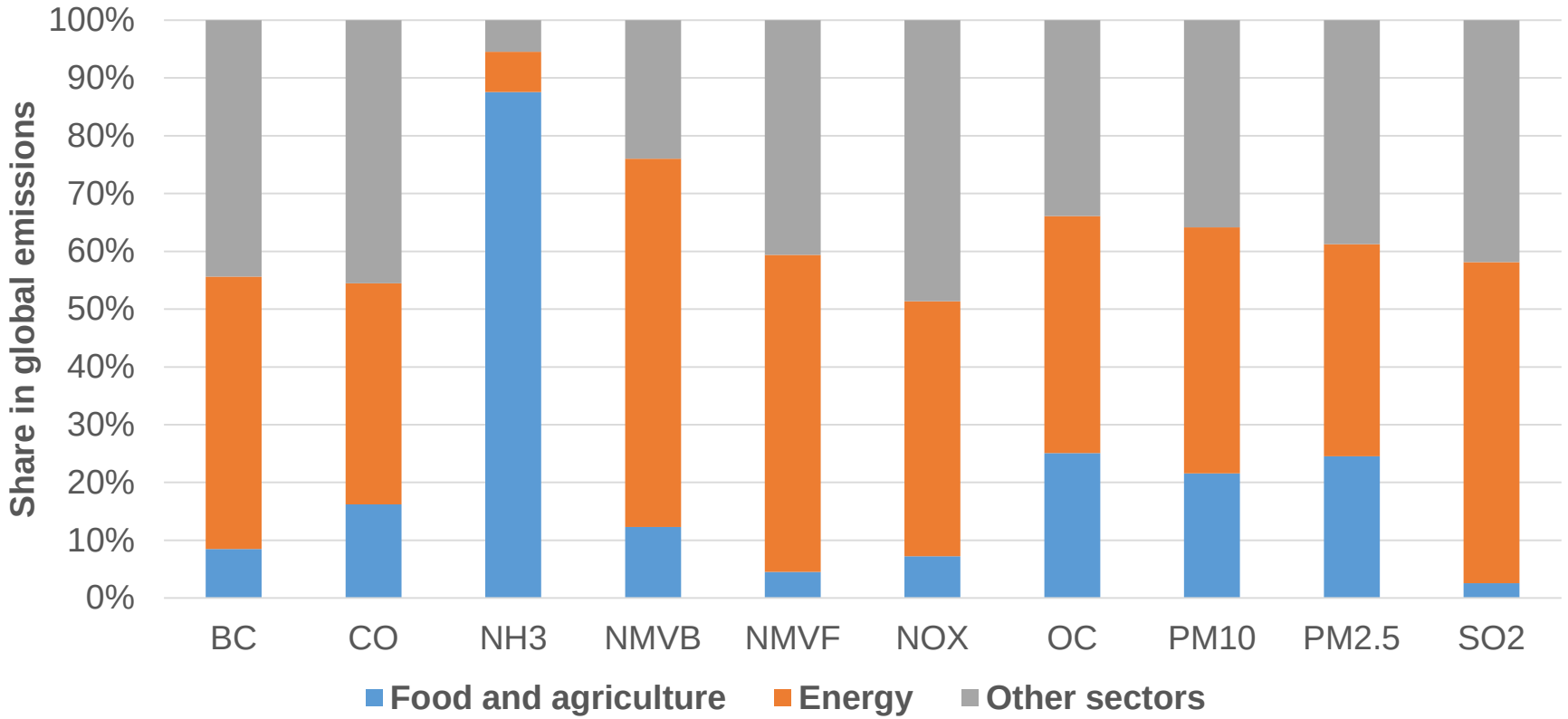
$$f_r = F_r(I - A_r)^{-1}e_r$$

where F_r is a vector of country-specific GHG emissions per unit of output by sectors, I is the identity matrix, A_r is the technological matrix for region r and e_r corresponds to the final households' consumption value in region r.



Air Pollutants

- Complement the modelling framework with ***air pollution accounts***.
- This allows us to ***estimate potential air pollution co-benefits*** from emissions taxation.
- Emissions ***are linked to the three groups of drivers*** (consumption, endowment and output).



Global emission shares by aggregate sectors and air pollutants

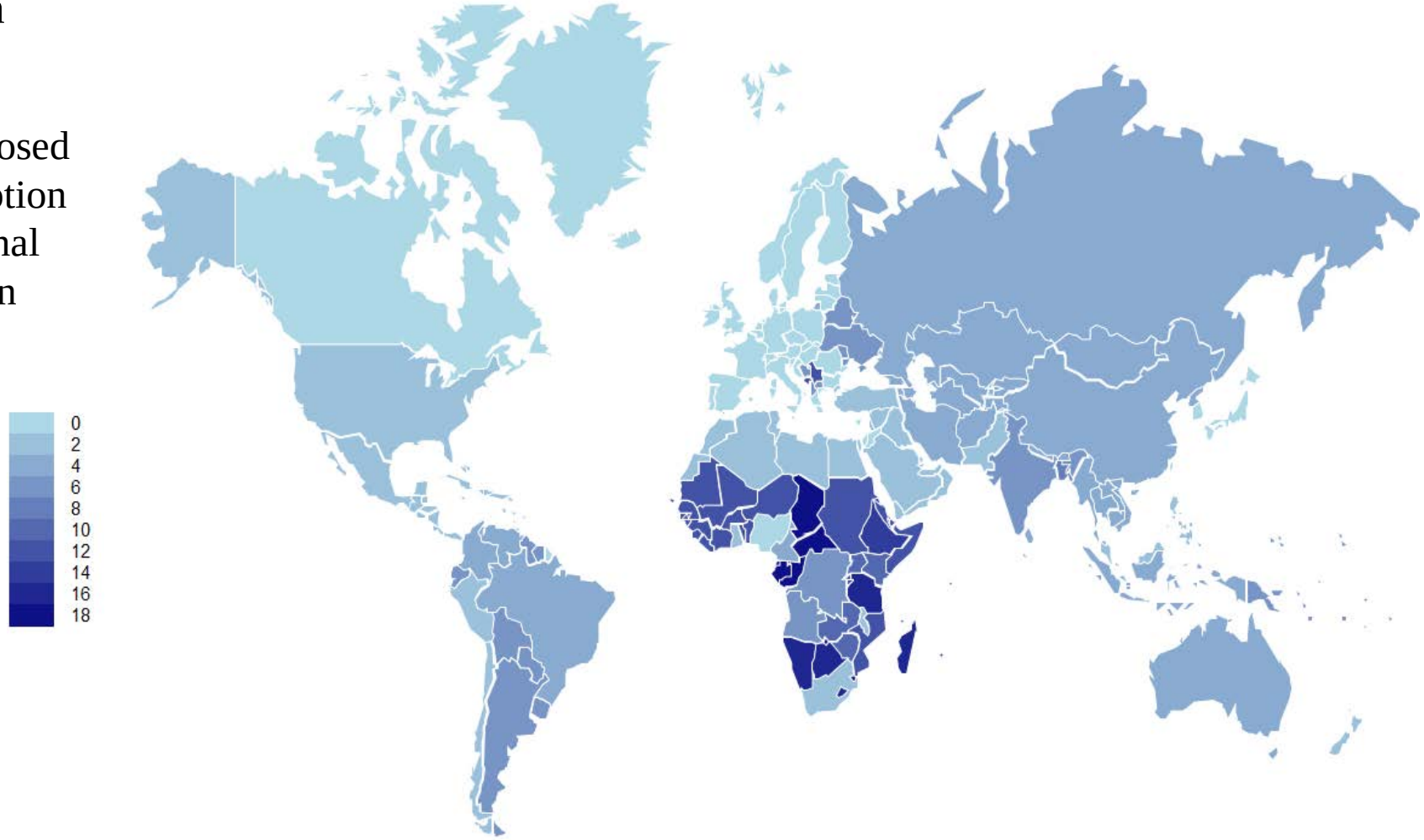
Source: Based on Chepeliev (2018).

4. Policy Scenarios

Policy Scenario

- Impose carbon tax on GHG emissions embodied into final households' consumption of food and agricultural commodities.
- Central value of $35/ton CO2-eq. ($2010 PPP), along with a lower bound of $15/ton CO2-eq. and an upper bound of $55/ton

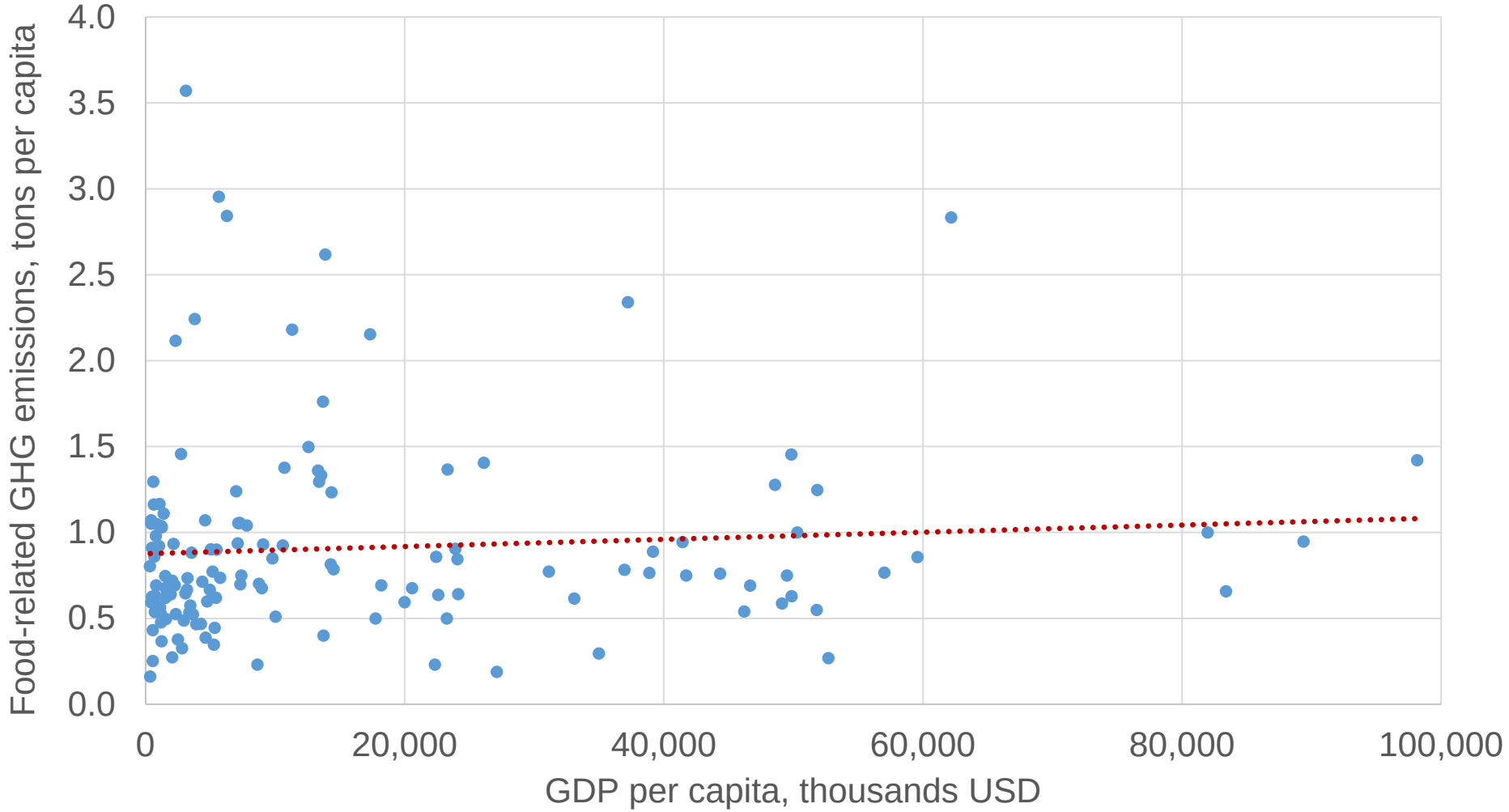
Region-average tax rates imposed on final households' consumption of food commodities, % of final households' food consumption value.



Sectoral patterns:

Cattle meat faces the highest tax rate (36.3%), followed by Paddy rice (13.7%), Cattle meat (8.3%), Raw milk (8%) and Processed rice (7.8%).

Food-related GHGs vs GDP



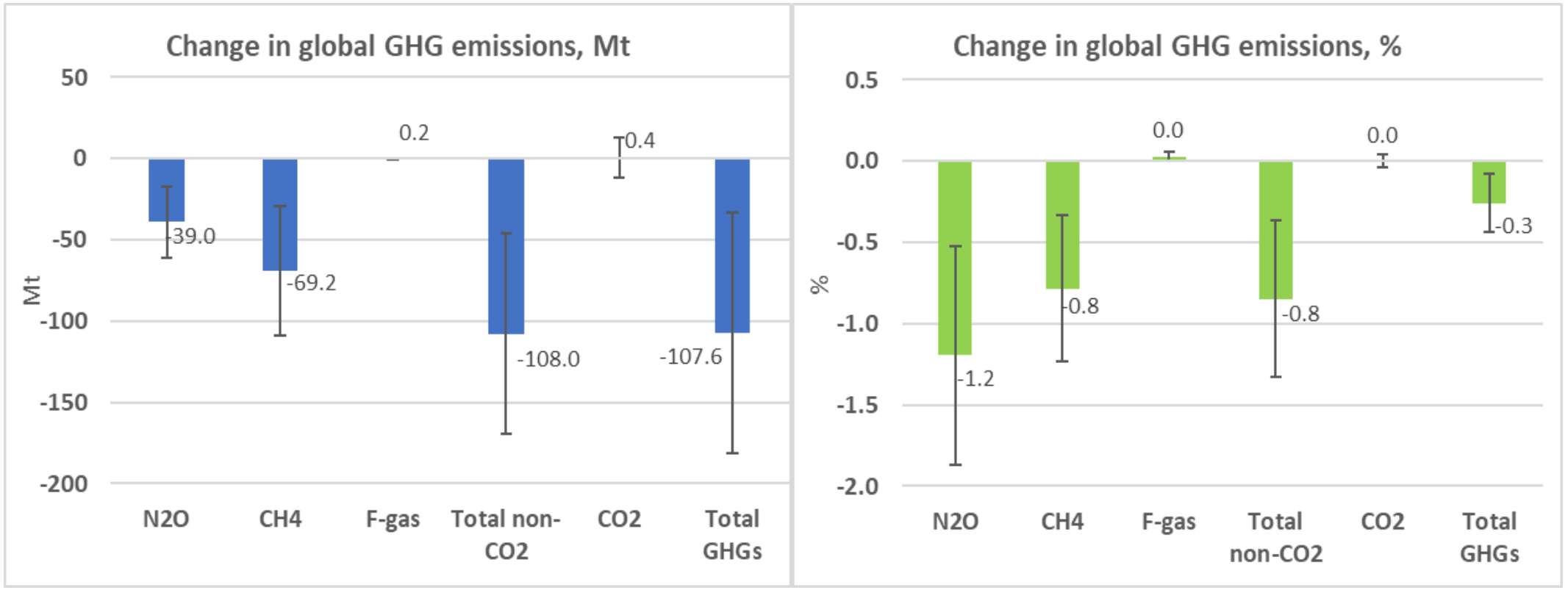
Drivers towards higher level of households' final expenditure on food in advanced economies are only partially offset by lower food-related emissions per capita in developing countries.

Modelling framework

- ***Static CGE*** model (GTAP-E) with ***2011 reference*** year
- Aggregation: ***64 regions and 35 sectors***.
- **Non-CO_2 GHGs and air pollutants are linked to three types of drivers (final and intermediate consumption, endowment and output).**
- **Dietary and nutritional changes are linked to changes in households' food consumption.**
- **Limitations:**
  - Have not imposed taxes and mapped nutrition data to the accommodation and food service activities (is aggregated with trade in GTAP 9.2; less than 5% of global non-CO_2 GHG emissions; would be a separate sector in GTAP 10).

5. Results

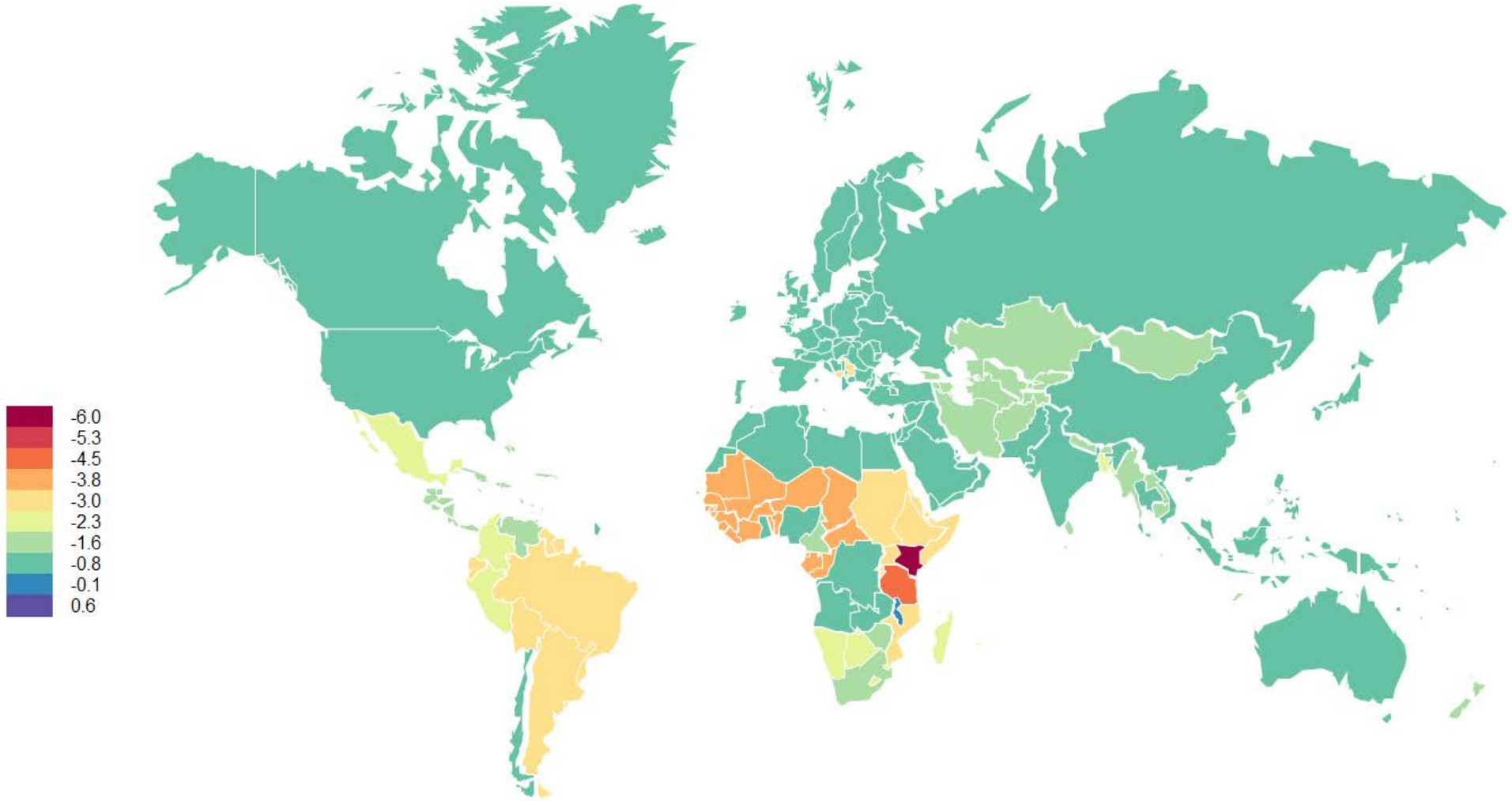
Changes in Global GHG emissions



Changes in global GHG emissions following imposition of carbon tax on food products, relative to 2011 levels

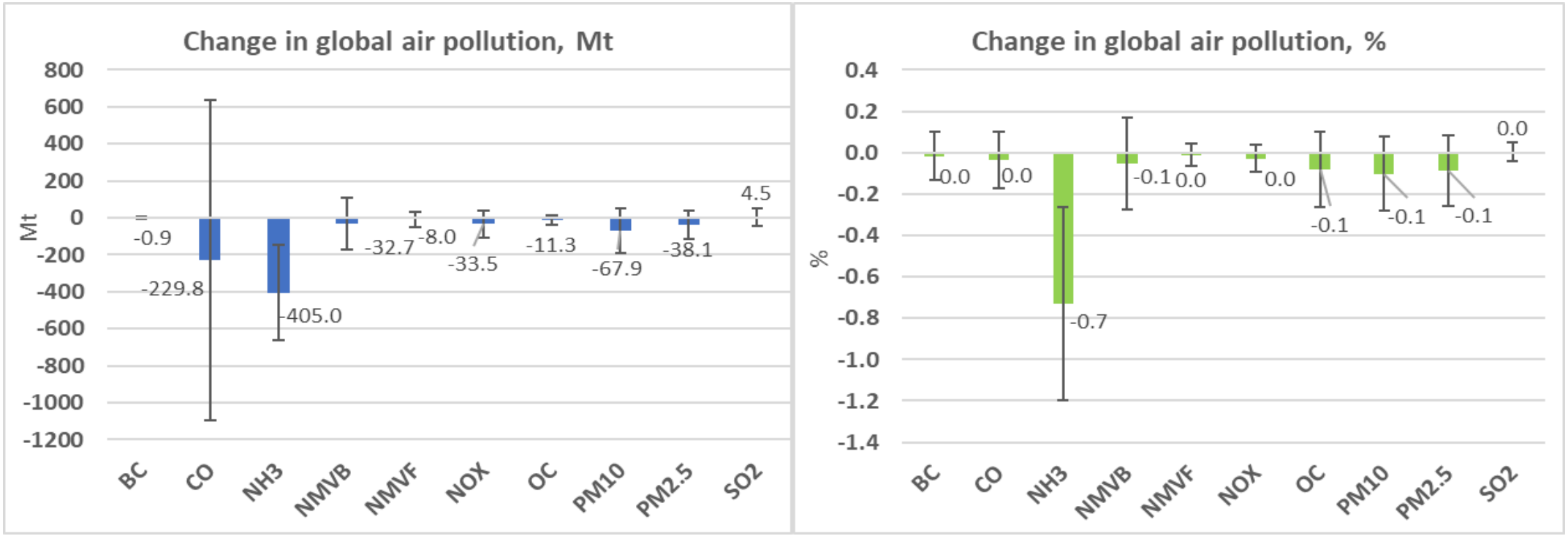
Note: Error bars indicate 95% confidence intervals following variation in emission tax rates between \$15/ton CO_2-eq. and \$55/ton CO_2-eq.

Changes in Regional GHG emissions



Changes in aggregate non-CO2 GHG emissions by regions following imposition of carbon tax on food products, % relative to 2011 levels

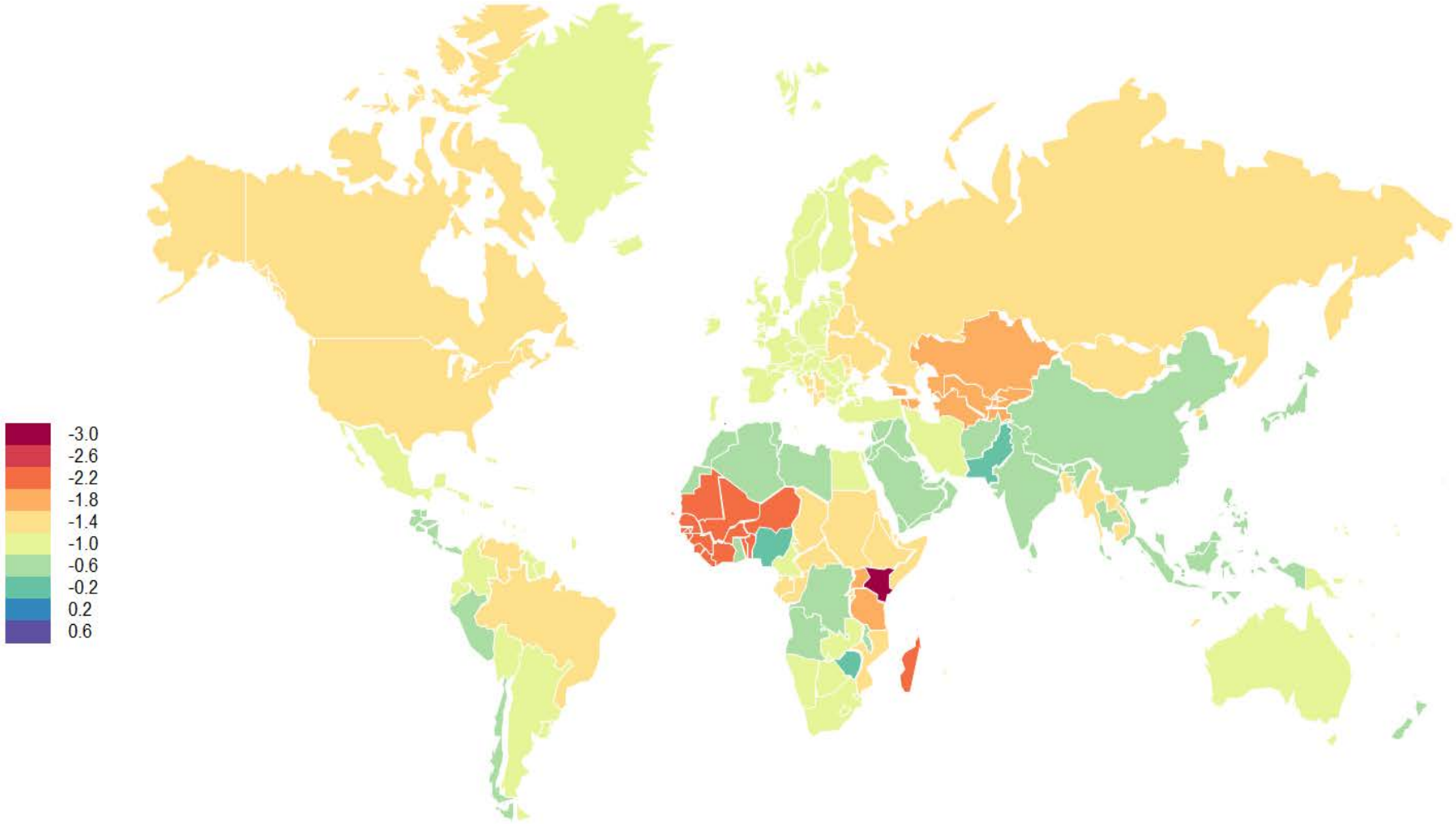
Changes in Air Pollution



Changes in global air pollution levels following imposition of carbon tax on food products, % relative to 2011 levels

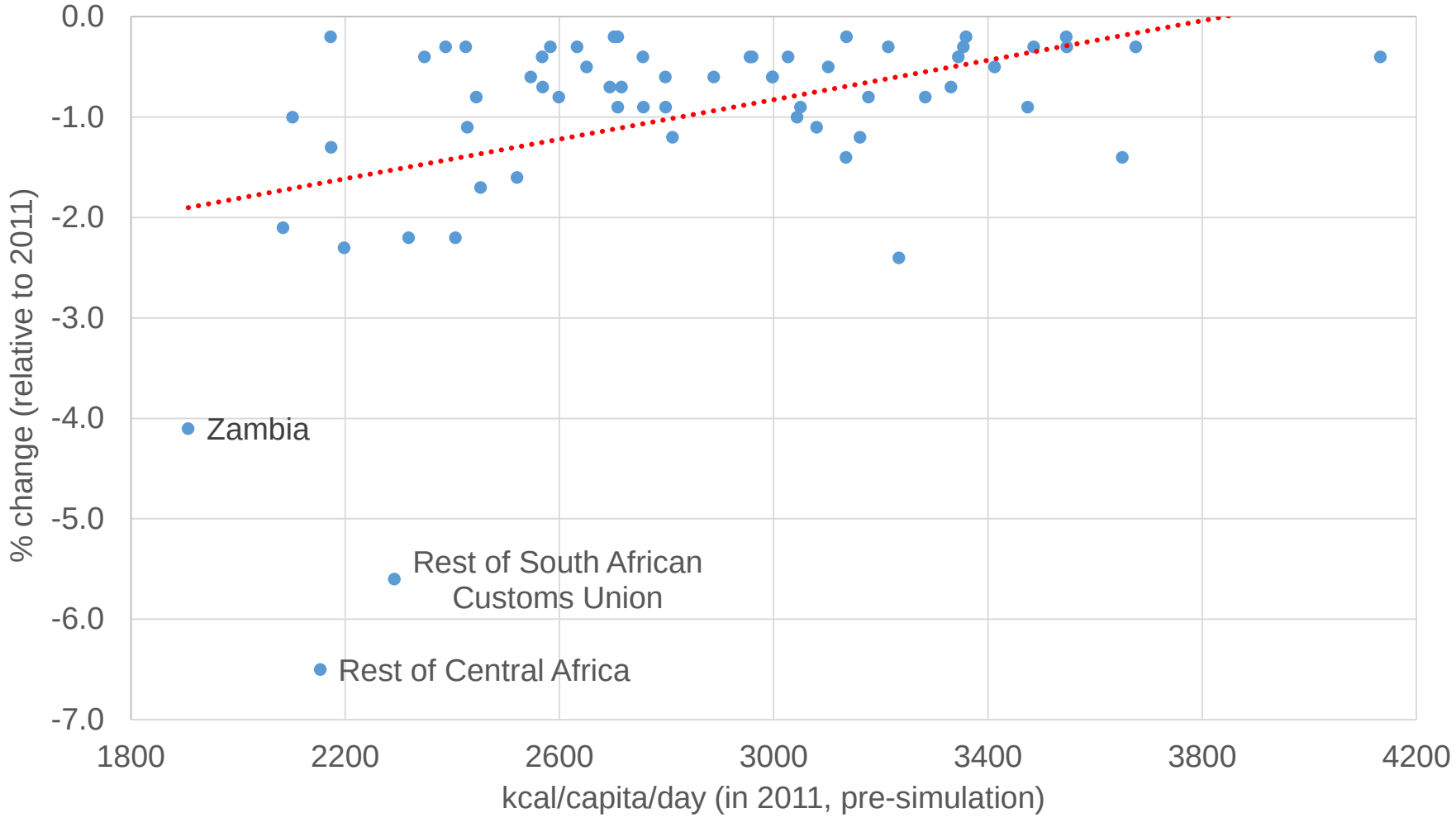
Note: Error bars indicate 95% confidence intervals following variation in emission tax rates between \$15/ton CO_2-eq. and \$55/ton CO_2-eq.

Changes in NH_3 emissions by regions



Change in NH_3 emissions by regions following imposition of carbon tax on food products, % relative to 2011 levels

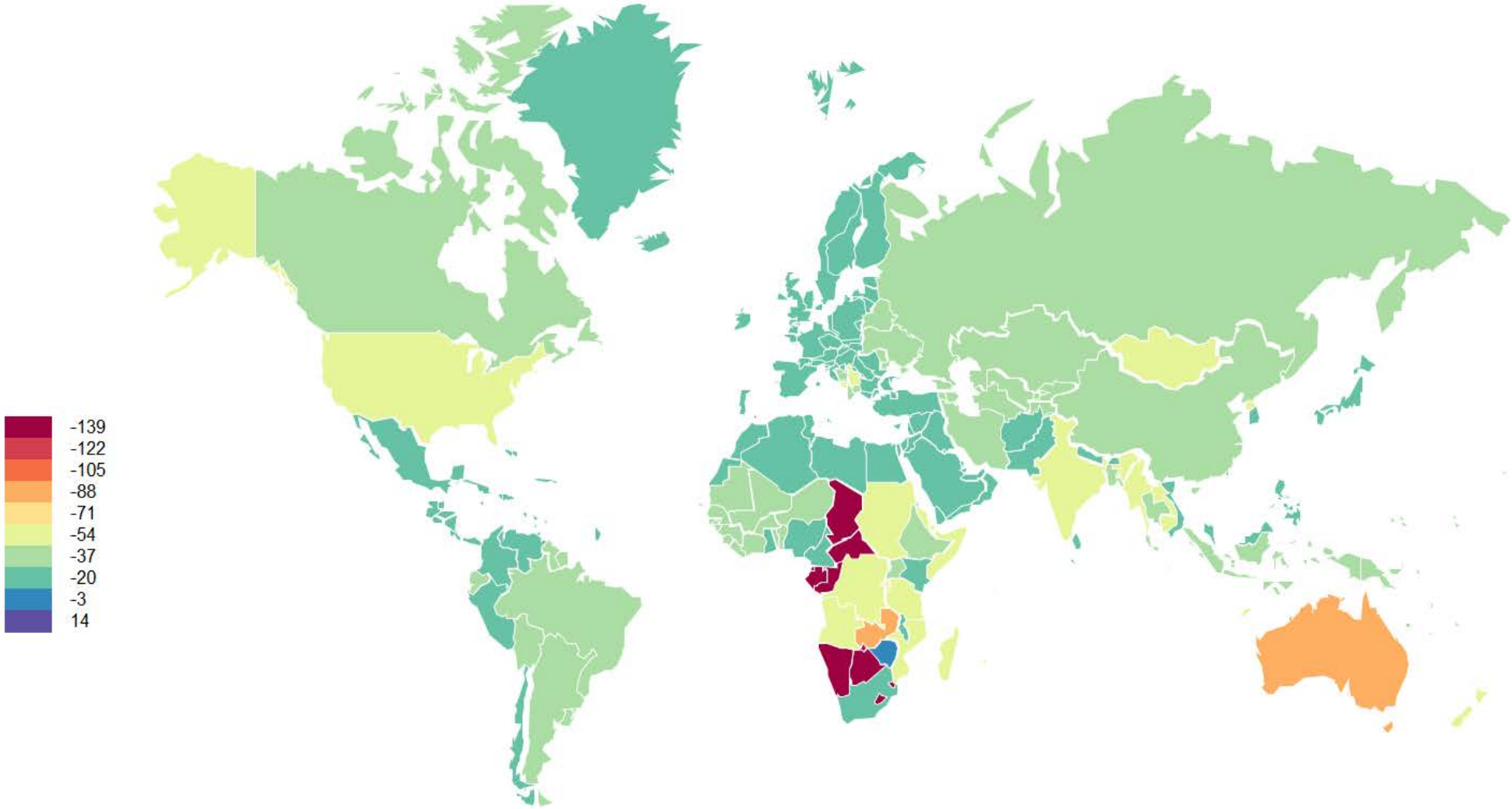
Changes in food supply



Changes in food supply by regions following imposition of carbon tax on food products, % relative to 2011 levels

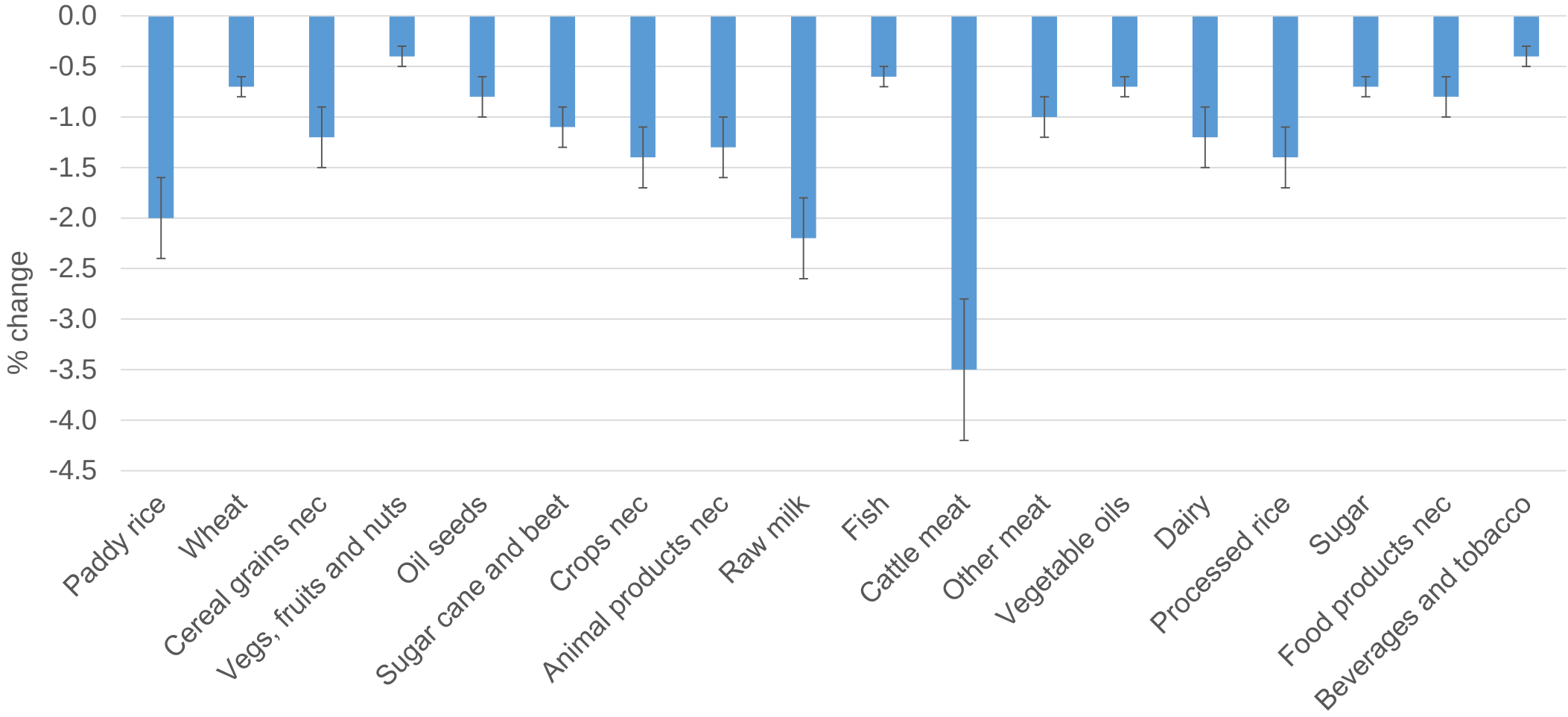
Note: Each point corresponds to one aggregate region.

Changes in food supply by regions



Changes in food consumption by regions following imposition of carbon tax on food products relative to 2011 levels, g/capita/day

Changes in food supply by sectors

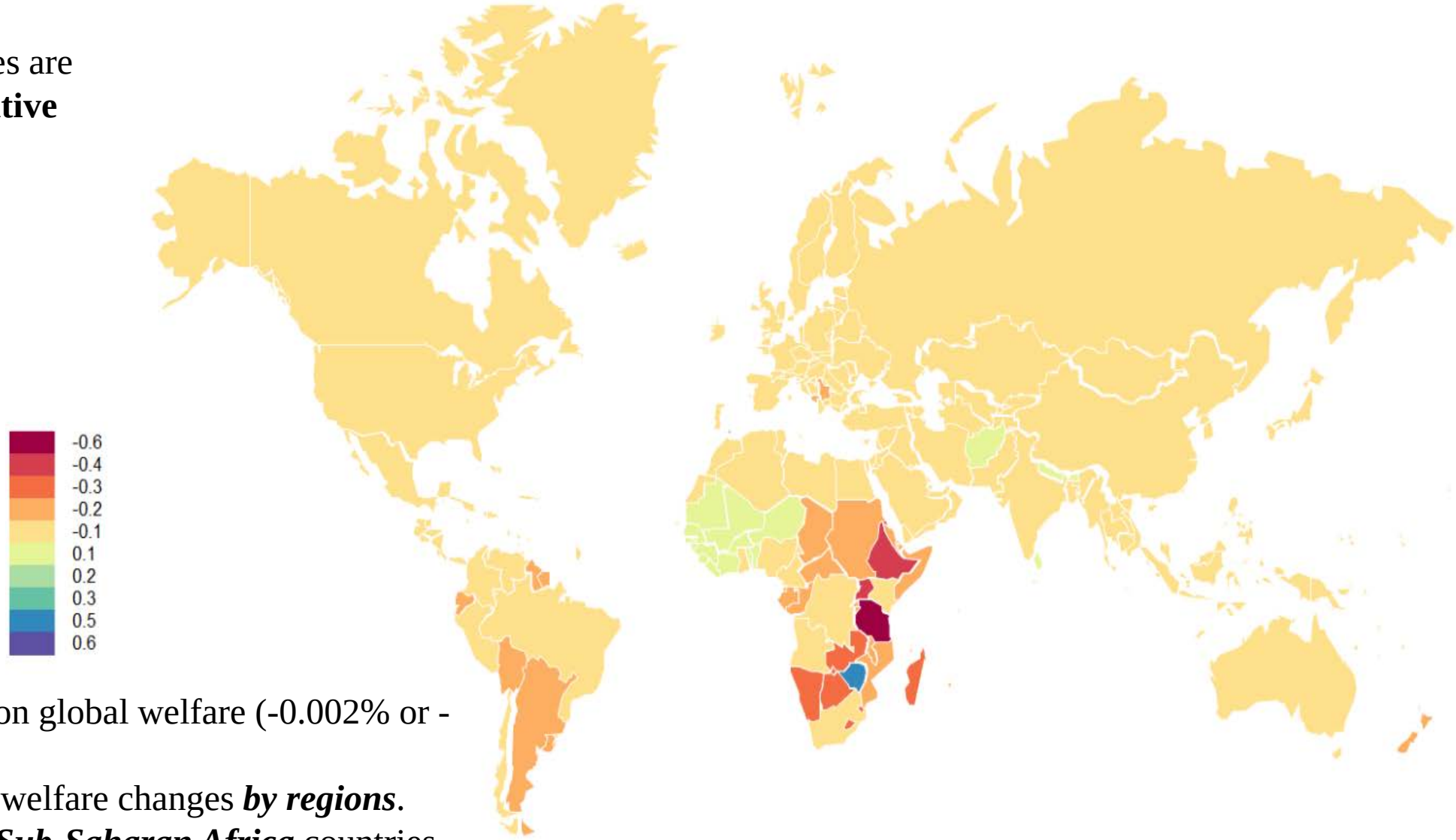


Changes in global food supply by sectors, % relative to 2011 levels

Note: Error bars indicate 95% confidence intervals following variation in emission tax rates between \$15/ton CO_2-eq. and \$55/ton CO_2-eq.

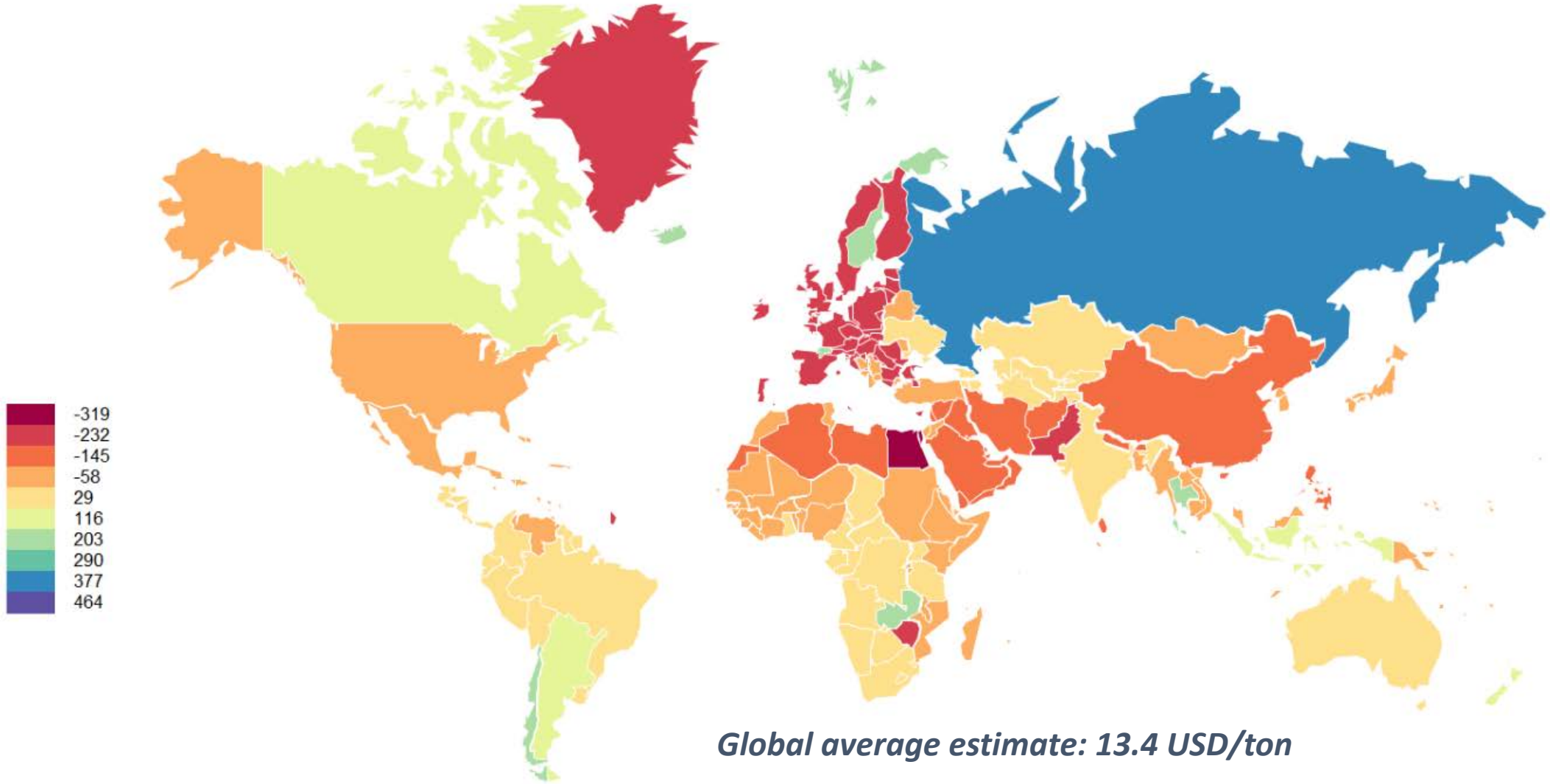
Welfare change, %

In our model carbon taxes are collected by **Representative Agent** (includes all final consumer)



- ***Insignificant impacts*** on global welfare (-0.002% or -$1.4 billion).
- ***Moderate variation*** in welfare changes ***by regions***.
- ***Largest reductions in Sub-Saharan Africa*** countries (over -0.4% in the cases of Uganda and Tanzania).

Welfare costs per ton of aggregate GHG emissions reduction, $/ton CO2-eq.



Global average estimate: 13.4 USD/ton

Note: Only countries with aggregate GHG emissions reduction below -0.1% are used to estimate the cost of reduction. Negative values imply that welfare is increasing, while GHG emissions are falling.

Summary

Moderate impacts on food-related emissions reduction:

- 0.8% (0.4%-1.3%) reduction in non-CO_2 GHGs under \$35/ton-CO_2-eq.
- 0.3% reduction in global GHGs.
- Limited co-benefits from air pollution changes (-0.7% for NH_3, insignificant for other gases).
- Average welfare costs of reduction: \$13.4/ton CO2-eq. (highly vary by regions)

Dietary and welfare impacts:

- Regressive dietary consequences for developing countries.
- Cattle meat, Raw milk, Paddy rice and Processed rice – food supply reductions.
- Small global welfare changes (-0.002% or \$1.4 bn), but large regional variations.

Discussion

Further improvements:

- Improve dietary and nutritional data representation and mapping.
- Move to a newer version of GTAP database (GTAP 10) with more detailed sectoral structure and 2014 reference year.
- Link CGE model to PE model with disaggregated agricultural and food commodities representation (e.g. 79 vegetables fruits and nuts in GTAP-HS).
- Compare results with production-based taxation scenarios.
- Explore trade implications of food-related emission taxation.
- Sensitivity analysis w.r.t. substitution elasticities.

Comparison with other studies:

- Our estimates suggest much smaller reductions than some of the existing studies (e.g. Springmann et al. report -9.3% in food GHG emissions under $52/ton tax).

Global Trade Analysis Project

Thank you!

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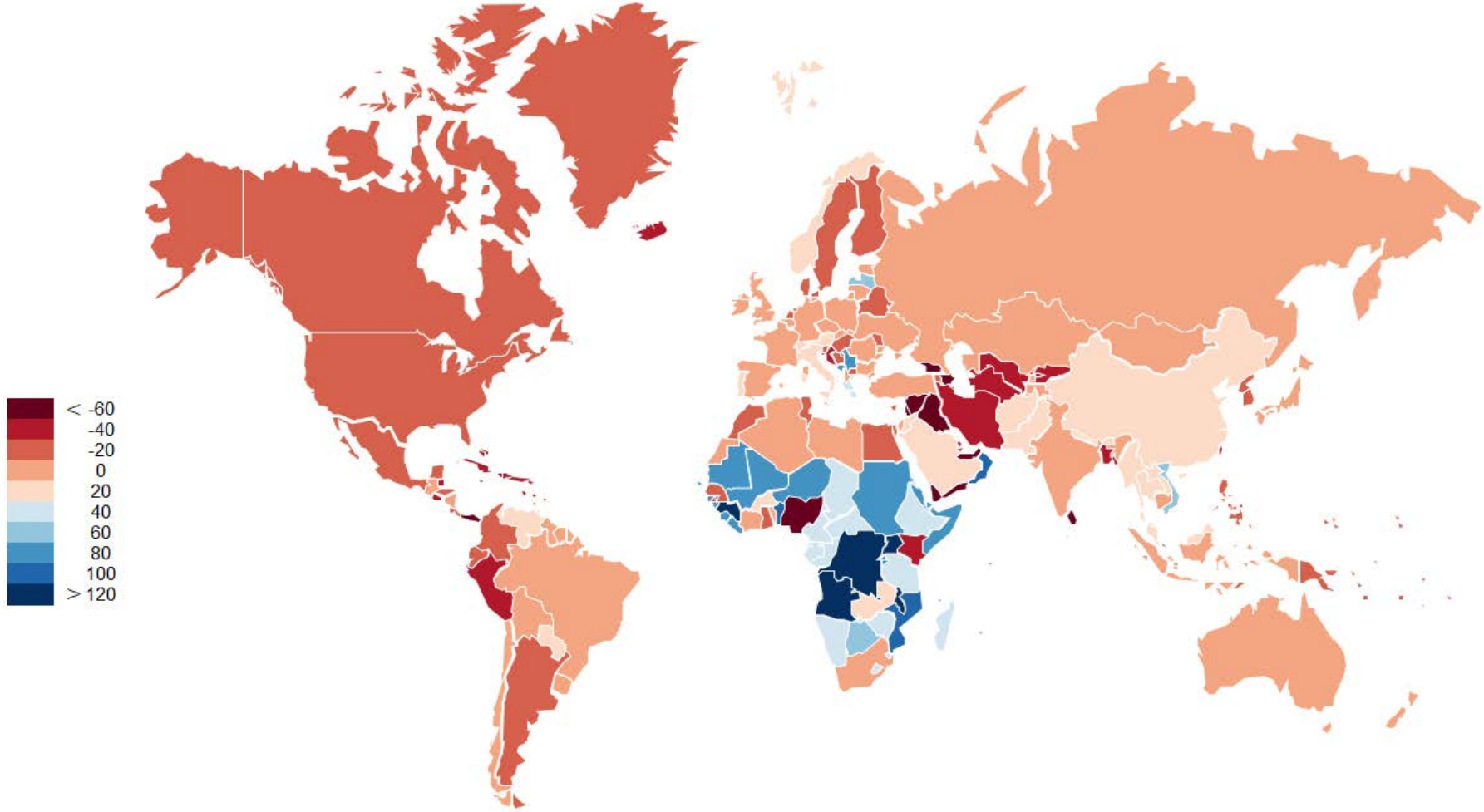
FAO-based APT: Results



Difference between aggregate agricultural output in the GTAP 9.2 with FAO-based APT and standard GTAP 9.2, %

Source: Chepeliev and Aguiar (2018).