

Impacts of Global Greenhouse Gas Mitigation on Heterogeneous Livestock Sectors

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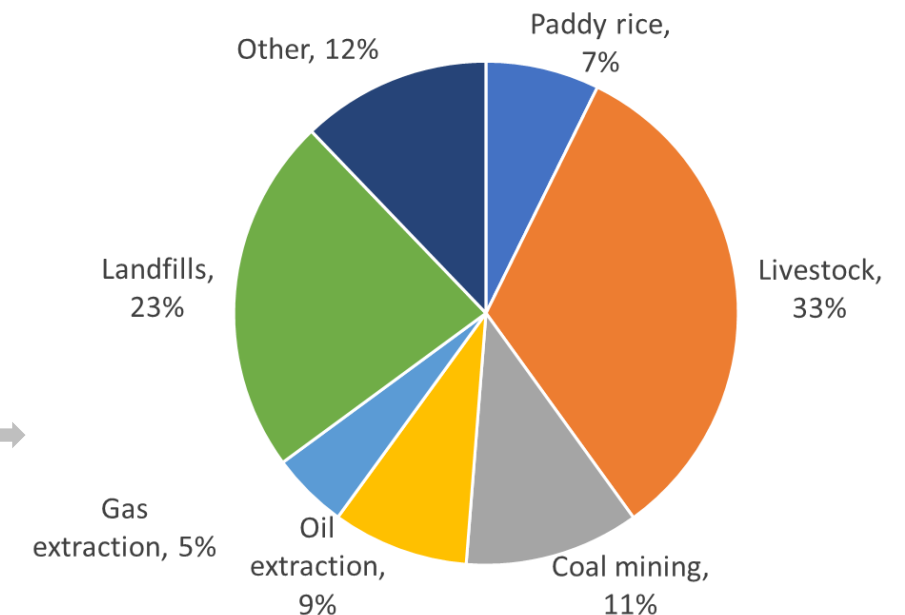
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Introduction

- Methane is a powerful, short-lived, and the second most abundant anthropogenic GHG after carbon dioxide
 - Responsible for around 30% of the rise in global temperatures since the Industrial Revolution (Global Methane Tracker, 2024)
- Global Methane Pledge (GMP) initiative
 - Launched at COP26 in 2021
 - 159 participating countries committed to cut global methane emissions 30% below 2020 levels by 2030
- Major human sources of methane
 - Agriculture (livestock, paddy rice)
 - Fossil fuel extraction
 - Waste



<https://www.globalmethanepledge.org/>

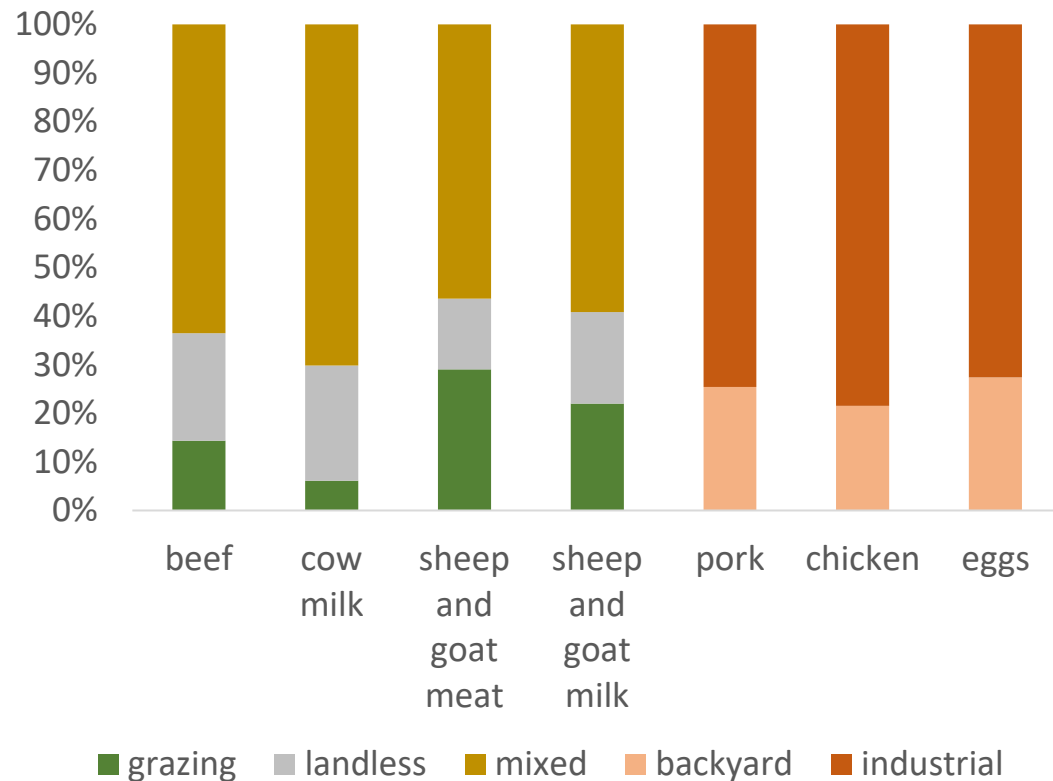


Source: GTAP database v. 11

Introduction (cont.)

- Livestock sector
 - Economic significance
 - Contributes 40% of the global value of agricultural output
 - Provides income for more than 1.3 billion people employed in different livestock product value chains (FAO 2018)
 - Plays a critical role in the solution to reducing food loss and waste (Dou et al. 2018)
 - Protein and micronutrients in human diets and valuable nutrients for crops
 - Responsible for 14.5% of human-caused GHGs
- Governments and private partners invest in developing cost-effective breakthrough technologies to reduce livestock emissions
- Emission intensities of livestock production and available mitigation options determine the impacts of efforts to reduce methane in livestock sectors

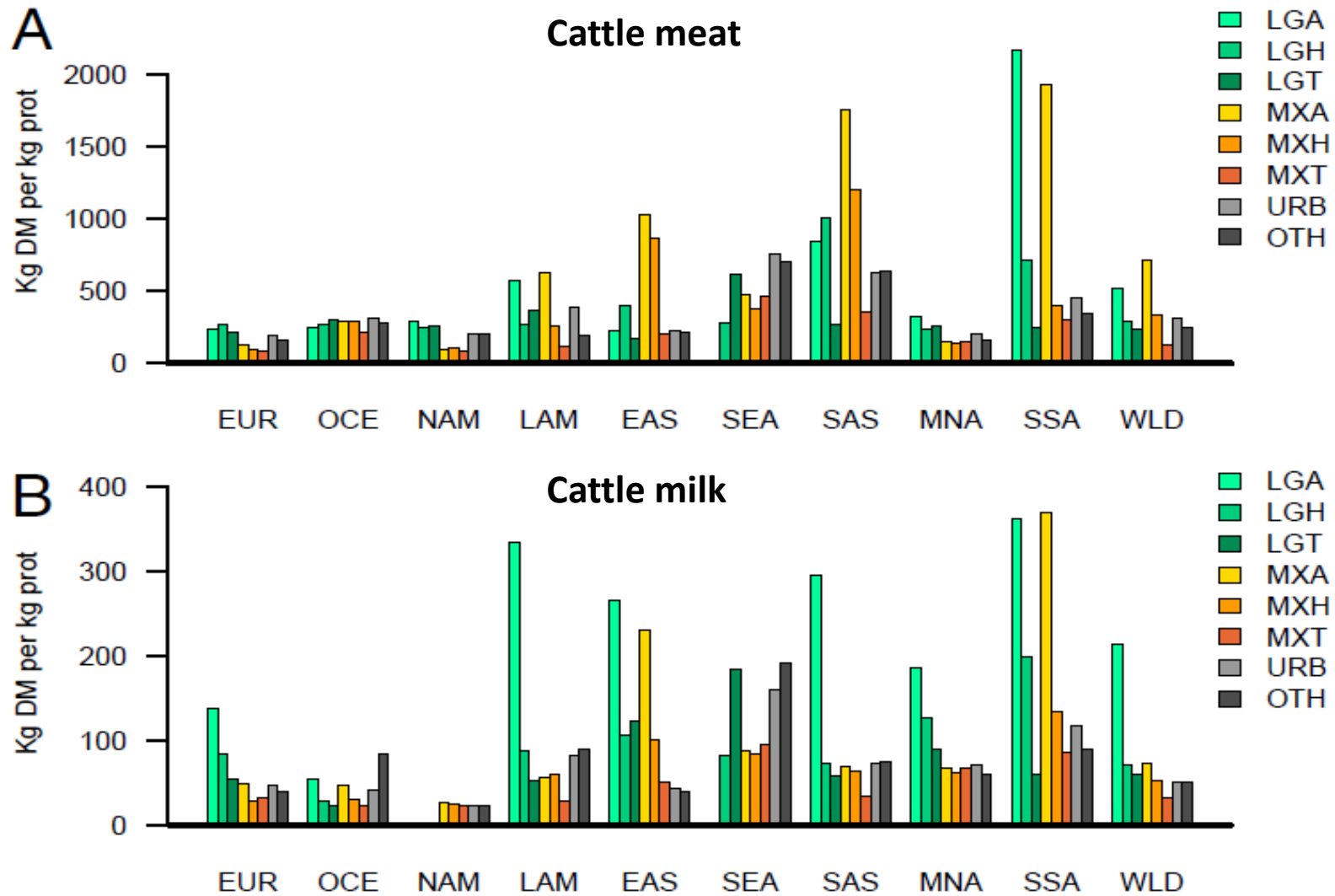
Global livestock production systems



Source: Authors' calculation

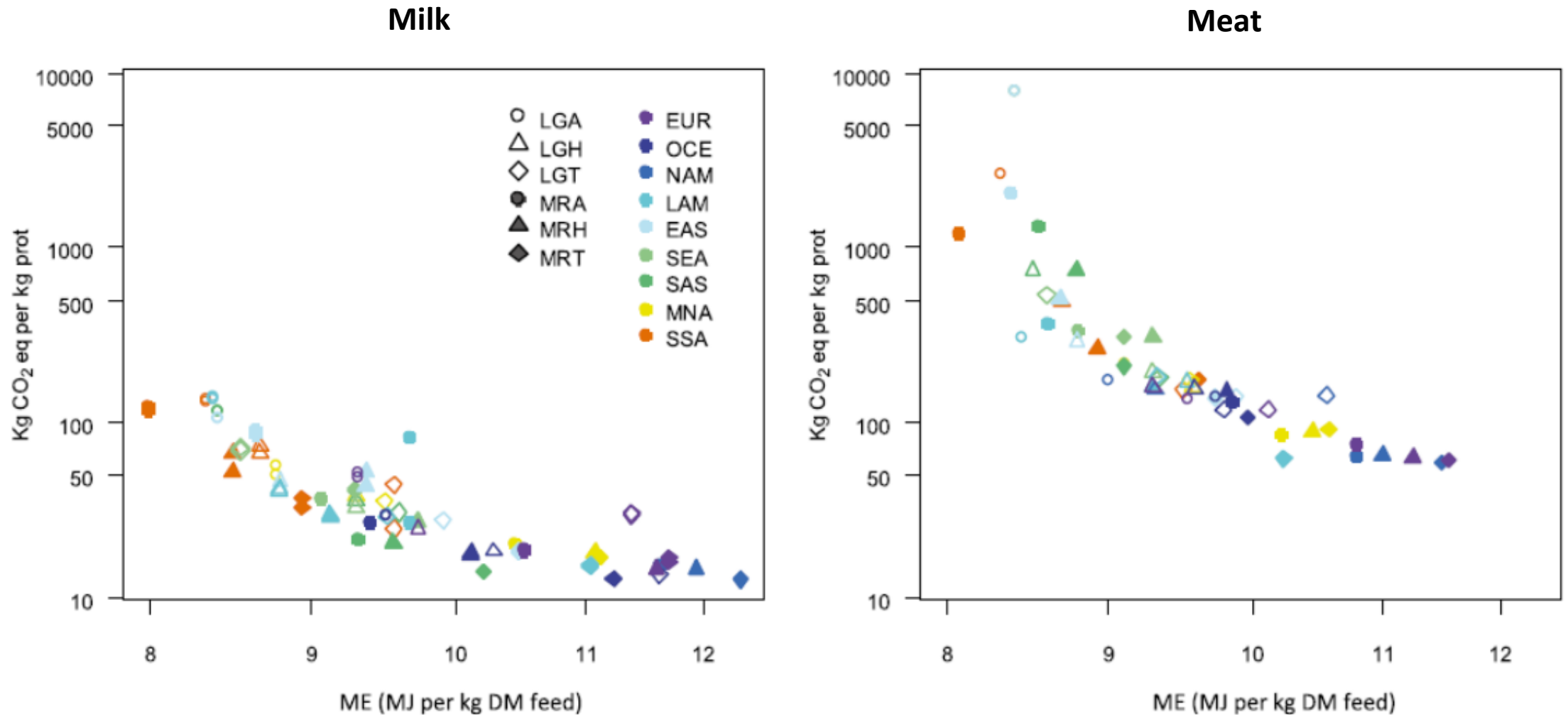
- Solely livestock systems: More than 90% of dry matter fed to animals comes from rangelands, pastures, annual forages and purchased feeds, and less than 10% of the total value of production comes from non-livestock farming activities.
 - **Grazing system:** More than 10% of the dry matter fed to animals is produced on the farm, annual average stocking rates are less than 10 tlu/ha
 - **Landless system:** Less than 10% of the dry matter fed to animals is produced on the farm, annual average stocking rates are above 10 tlu/ha
- **Mixed crop-livestock systems:** More than 10% of the dry matter fed to animals comes from crop by-products or more than 10% of the total value of production comes from non-livestock farming activities.

Variation in feed-use efficiency across ruminant production systems and regions



Source: Herrero et al. (2013)

Relationship between diet quality and non-CO₂ emission intensity in ruminants



Source: Herrero et al. (2013)

Objectives

- Develop GTAP - LVS -- GTAP data base with detailed representation of livestock sectors at fully disaggregated sectoral and regional levels
- Policy analysis
 - Evaluate the economic and environmental implications of the GMP, focusing on global livestock sectors
 - Emission intensities
 - Production practices
 - Food prices
 - Diets
 - Evaluate pricing of all GHGs (carbon dioxide, methane, nitrous oxide, and F-gases) in all sectors and analyze impacts, focusing on the livestock sectors

Outline

- Construction of GTAP-LVS data base
- Illustrative simulation of global methane reduction
 - Use GTAP-Power model (Peters 2016b) with GTAP-LVS data base
 - No mitigation technologies (methane is tied to activity output)
 - Costly to reduce methane emissions
- Marginal Abatement Costs Curves (MACCs) (US EPA 2019)
- Next steps

Key inputs to construct GTAP-LVS data base

- Disaggregated GTAP-Power data base (Chepeliev 2023, Peters 2016b)
 - 76 sectors and 160 regions
- Livestock data are provided by Food Systems and Global Change Initiative at Cornell
 - Animal species and breeds
 - Beef cattle, dairy cows, dairy sheep and goats, meat sheep and goats, pigs, chicken
 - Production systems
 - Ruminant: grazing, landless and mixed crop-livestock
 - Monogastric: backyard and industrial
 - Variables
 - Animal numbers
 - Output of meat, milk, eggs
 - Feed: grazing, barley, maize, rice, pulses, sorghum and millet, soybean, wheat, other cereals, other oilseeds, other crops, animal products
 - Livestock emissions are estimated using a process-based model that considers different animal diets and production systems
- FAOSTAT bilateral trade data and prices
 - Prices are used to convert quantity flows to monetary terms and construct shares for splitting procedure

Sectoral splits (1)

- Split GTAP gro, osd, ctl sectors

No.	New sector/ commodity	Description	Original GTAP sector	Description of original GTAP sector
1	cor	Corn	gro	Other grains
2	sor	Sorghum		
3	bar	Barley		
4	xgr	Other cereal grains		
5	soy	Soy	osd	Oil seeds
6	xsd	Other oil seeds		
7	bcg	Beef cattle, Grazing	ctl	Cattle
8	bcm	Beef cattle, Mixed		
9	bci	Beef cattle, Industrial		
10	org	Other ruminants, Grazing		
11	orm	Other ruminants, Mixed		
12	ori	Other ruminants, Industrial		
13	dcg	Dairy cows producing meat, Grazing		
14	dcm	Dairy cows producing meat, Mixed		
15	dci	Dairy cows producing meat, Industrial		
16	dmg	Other dairy producing meat, Grazing		
17	dmm	Other dairy producing meat, Mixed		
18	dmi	Other dairy producing meat, Industrial		

Sectoral splits (2)

- Split GTAP rmk and oap sectors

No.	New sector/ commodity	Description	Original GTAP sector	Description of original GTAP sector
19	cdg	Raw milk from cows, Grazing	rmk	Raw milk
20	cdm	Raw milk from cows, Mixed		
21	cdi	Raw milk from cows, Industrial		
22	odg	Other raw milk, Grazing		
23	odm	Other raw milk, Mixed		
24	odi	Other raw milk, Industrial		
25	pgi	Pigs, Industrial	oap	Other animal products
26	pgb	Pigs, Backyard		
27	pei	Poultry (eggs), Industrial		
28	peb	Poultry (eggs), Backyard		
29	pmi	Poultry (meat), Industrial		
30	pmb	Poultry (meat), Backyard		
31	xap	Rest of animal products		

- After sectoral splits (1) and (2), 102 activities (each producing single commodity) and 160 regions in the disaggregated GTAP-LVS data base

Aggregate some of the new sectors into multiproduct activities

No.	New sector/ commodity	Description	New activity	Description of new activity
13	dcg	Dairy cows producing meat, Grazing	mcg	<u>M</u> ulti-product dairy <u>c</u> ows, <u>G</u> razing
19	cdg	Dairy cows producing milk, Grazing		
14	dcm	Dairy cows producing meat, Mixed	mcm	<u>M</u> ulti-product dairy <u>c</u> ows, <u>M</u> ixed
20	cdm	Dairy cows producing milk, Mixed		
15	dci	Dairy cows producing meat, Industrial	mci	<u>M</u> ulti-product dairy <u>c</u> ows, <u>I</u> ndustrial
21	cdi	Dairy cows producing milk, Industrial		
16	dmg	Other dairy producing meat, Grazing	mog	<u>M</u> ulti-product <u>o</u> ther dairy, <u>G</u> razing
22	odg	Other dairy producing milk, Grazing		
17	dmm	Other dairy producing meat, Mixed	mom	<u>M</u> ulti-product <u>o</u> ther dairy, <u>M</u> ixed
23	odm	Other dairy producing milk, Mixed		
18	dmi	Other dairy producing meat, Industrial	moi	<u>M</u> ulti-product <u>o</u> ther dairy, <u>I</u> ndustrial
24	odi	Other dairy producing milk, Industrial		
27	pei	Poultry (eggs), Backyard	mpb	<u>M</u> ulti-product <u>p</u> oultry, <u>B</u> ackyard
29	pmi	Poultry (meat), Backyard		

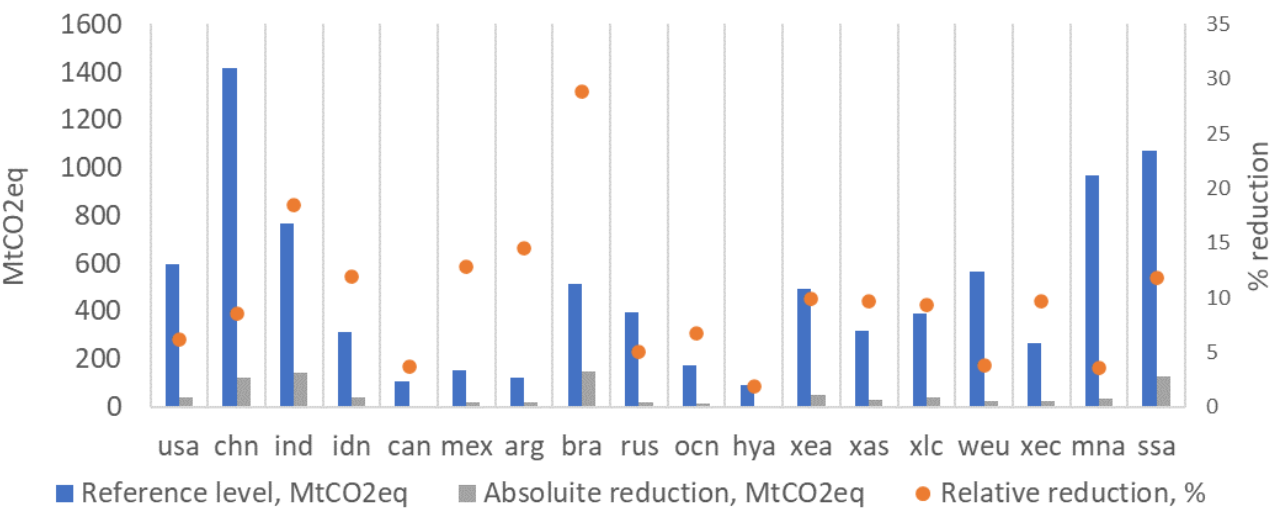
Aggregation for analysis

- 54 production activities, 44 commodities and 18 countries/regions in this analysis
- Structure of the “make” matrix

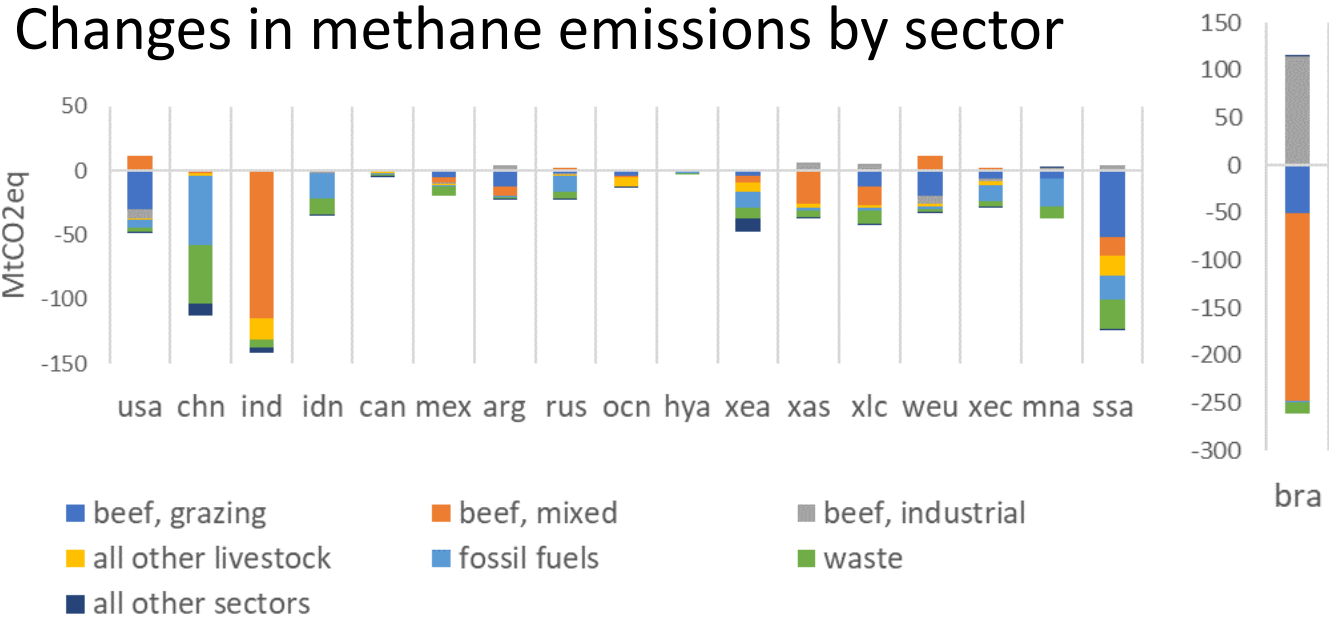
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Illustrative scenario:
global methane emissions are reduced by 10%

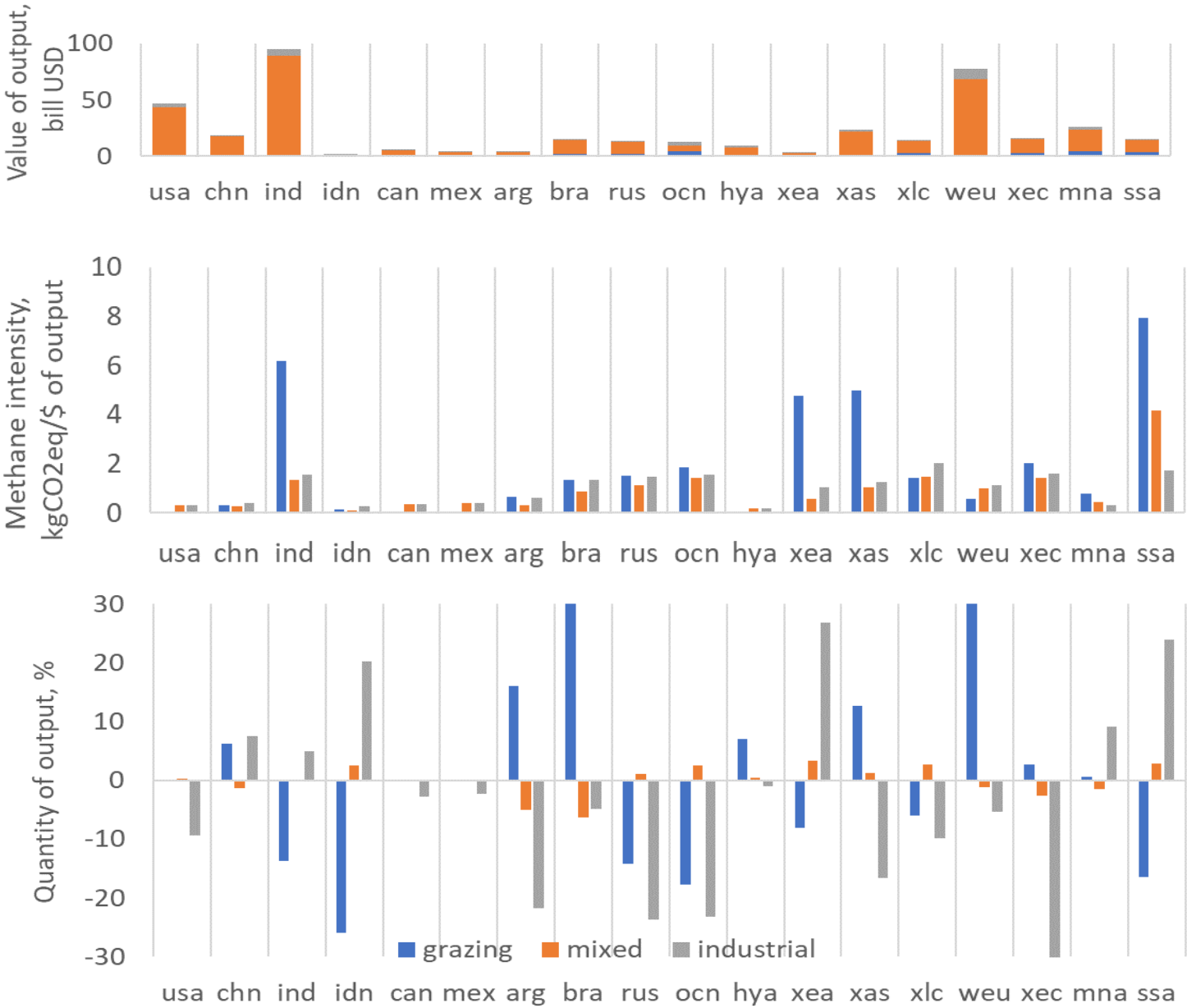
Methane reference levels and reduction by region



Changes in methane emissions by sector

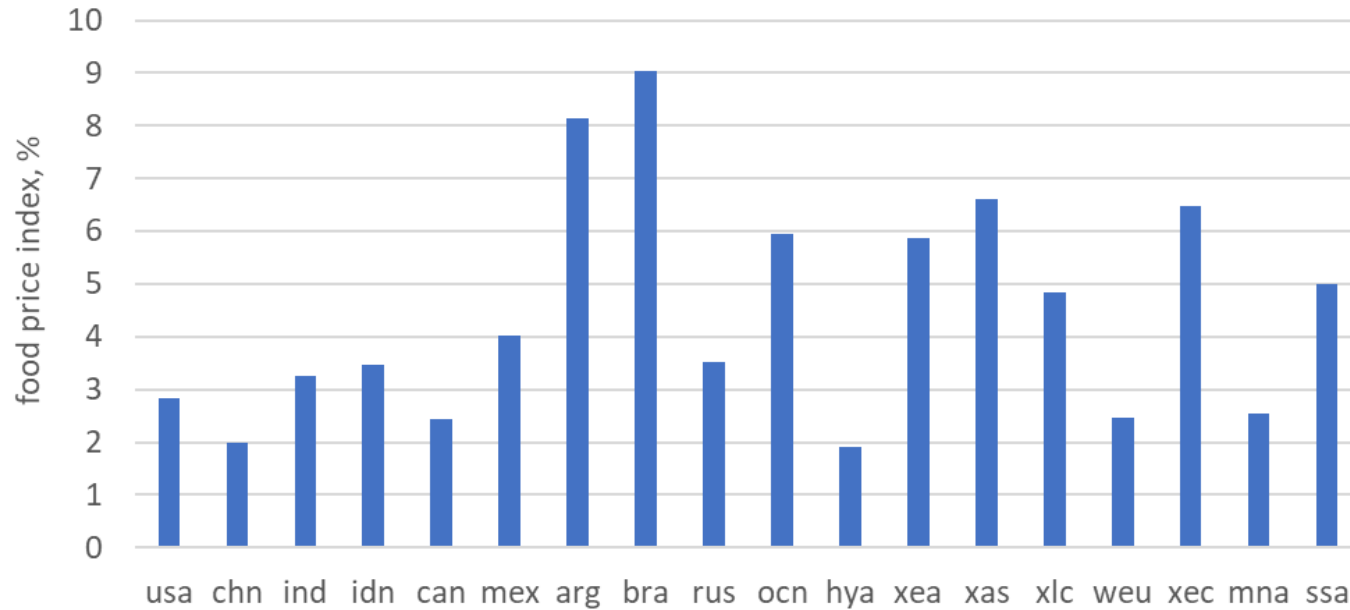


Impact on multiproduct dairy sectors



Prices

- Increase in food prices in global 10% methane reduction scenario



- Without mitigation technologies
 - 10% methane reduction at 100\$/tCO₂eq and increase in food prices 2-9%
 - 30% methane reduction at 700\$/tCO₂eq and increase in food prices 10-50%

MACCs

- US EPA constructed MACCs for aggregated livestock sector by country and year
 - 186 countries
 - Years 2015-2050 in 5-year timesteps
- Abatement technologies considered for emissions from enteric fermentation
 - Improved feed conversion, antibiotics, bovine somatotropin (bST), propionate precursors, antimethanogen, intensive grazing
- Abatement technologies considered for emissions from manure management
 - Complete-mix, plug-flow, fixed-film digesters with and without engine, covered lagoons with and without engine, dome digesters, centralized digesters
- Construct MACCs for GTAP-LVS disaggregated livestock sectors

Abatement technologies for emissions from enteric fermentation in disaggregated livestock sectors

	Improved feed conversion	Antibiotics***	bST	Propionate Precursors	Antimethanogen	Intensive grazing
Beef cattle, Grazing	yes*	no	no	no	yes	yes
Beef cattle, Mixed	yes*	no	no	no	yes	yes
Beef cattle, Industrial	yes*	yes	no	yes	yes	no
Other ruminants, Grazing	yes*	no	no	no	yes	yes
Other ruminants, Mixed	yes*	no	no	no	yes	yes
Other ruminants, Industrial	yes*	yes	no	yes	yes	no
Multiproduct dairy cows, Grazing	yes*	no	yes**	no	yes	yes
Multiproduct dairy cows, Mixed	yes*	no	yes**	no	yes	yes
Multiproduct dairy cows, Industrial	yes*	yes	yes**	yes	yes	no
Multiproduct other dairy, Grazing	yes*	no	yes**	no	yes	yes
Multiproduct other dairy, Mixed	yes*	no	yes**	no	yes	yes
Multiproduct other dairy, Industrial	yes*	yes	yes**	yes	yes	no
Pigs, Industrial	no	no	no	no	no	no
Pigs, Backyard	no	no	no	no	no	no
Rest of animal products	no	no	no	no	no	no
*in countries with low livestock growth and milk production rates						
**in countries where bST is allowed						
*** The use of antibiotics as growth promoters is banned in the EU						

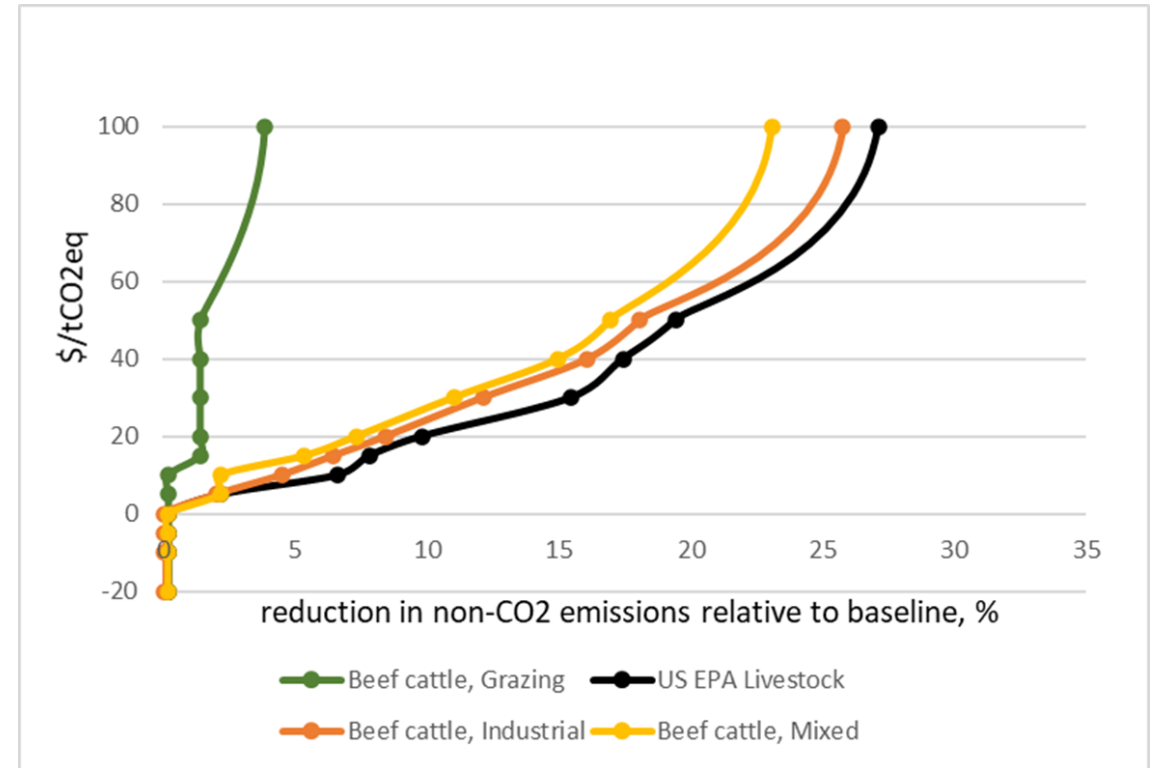
Abatement technologies for emissions from manure management in disaggregated livestock sectors

	Complete-Mix Digesters	Plug-Flow Digesters	Fixed-Film Digesters	Covered Lagoons	Dome Digesters	Centralized Digesters
Beef cattle, Grazing	no	no	no	no	no	no
Beef cattle, Mixed	yes	yes	yes	yes	yes	yes
Beef cattle, Industrial	yes	yes	yes	yes	yes	yes
Other ruminants, Grazing	no	no	no	no	no	no
Other ruminants, Mixed	yes	yes	yes	yes	yes	yes
Other ruminants, Industrial	yes	yes	yes	yes	yes	yes
Multiproduct dairy cows, Grazing	no	no	no	no	no	no
Multiproduct dairy cows, Mixed	yes	yes	yes	yes	yes	yes
Multiproduct dairy cows, Industrial	yes	yes	yes	yes	yes	yes
Multiproduct other dairy, Grazing	no	no	no	no	no	no
Multiproduct other dairy, Mixed	yes	yes	yes	yes	yes	yes
Multiproduct other dairy, Industrial	yes	yes	yes	yes	yes	yes
Pigs, Industrial	yes	yes	yes	yes	yes	yes
Pigs, Backyard	yes	yes	yes	yes	yes	yes
Multiproduct poultry, Industrial	yes	yes	yes	yes	yes	yes
Multiproduct poultry, Backyard	no	no	no	no	no	no
Rest of animal products	no	no	no	no	no	no

MACCs for disaggregated livestock sectors

- Assumption

If a technology is available in a disaggregated livestock sector, then the relative emission reduction at a given price is the same as in the aggregated livestock sector



Next steps

- Update GTAP-LVS data base using a new version of the FSGC data representing livestock sectors in 2020
- Use new MACCs US EPA(2025)
- Incorporate MACCs in the model
 - Livestock
 - All other sectors
- Policy analysis
 - GMP
 - Pricing of all GHG



Thank you!
Questions/Comments?

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