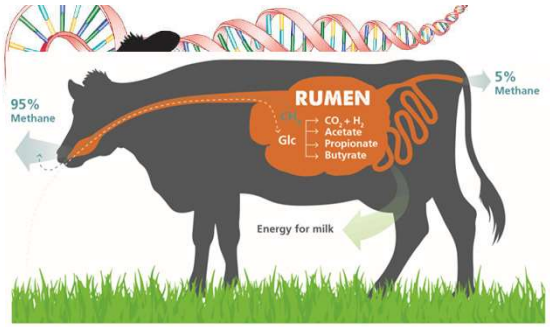



Canadian SMEs face major hurdles to green manufacturing, cleantech

Report from Excellence in Manufacturing Consortium outlines challenges, offers path forward

Technology Cleantech National Apr. 9 2024

Environmentally Adjusted Productivity and Efficiency: The Role of Science & Technology

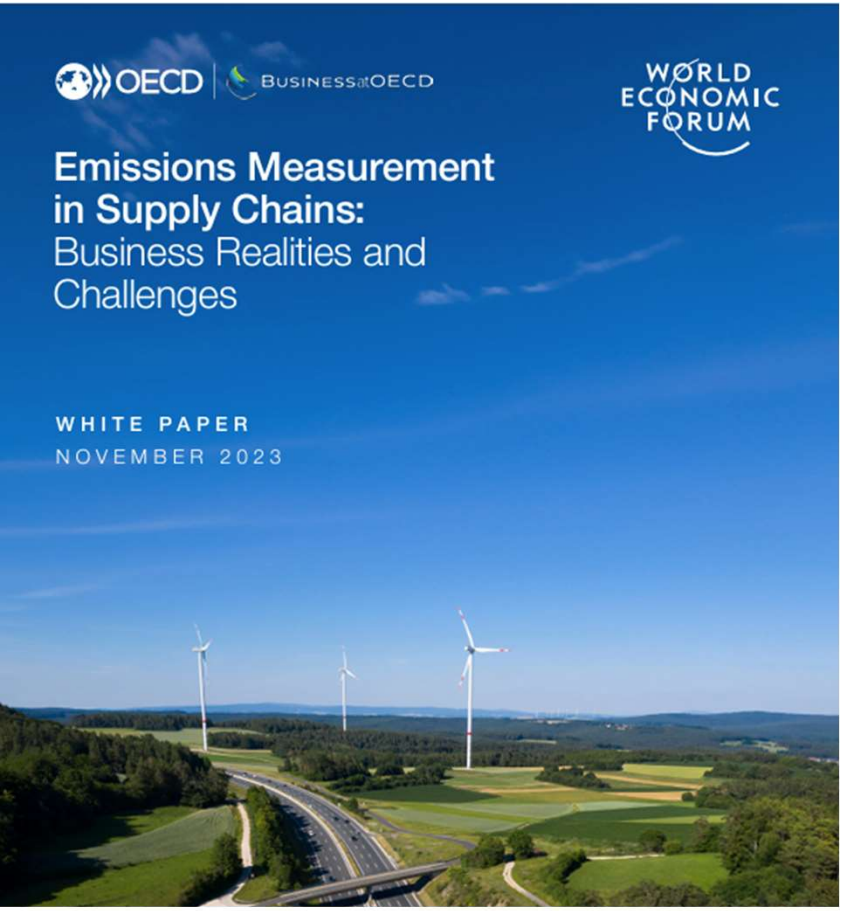
Getu Hailu

UNIVERSITY of GUELPH

ONTARIO AGRICULTURAL COLLEGE

DEPARTMENT OF FOOD, AGRICULTURAL AND RESOURCE ECONOMICS

Breeding for Resiliency – 2024 RDGP Symposium
Monday, November 18, 2024, Delta Guelph Hotel



Executive summary

Measuring and reporting emissions in supply chains can be a key lever for decarbonization globally, but inclusive discussions are needed to standardize approaches

Main Objectives: Green Productivity Measure

- Develop a **comprehensive measure** of productivity that **considers the effect of dairy production on greenhouse gas emissions (Canada)**.
- The twin challenge of productivity growth and emission reduction.
- Why measure?
  - Important to monitor progress
  - Important for designing policy responses.

Tremendous growth in productivity for every cow breed?

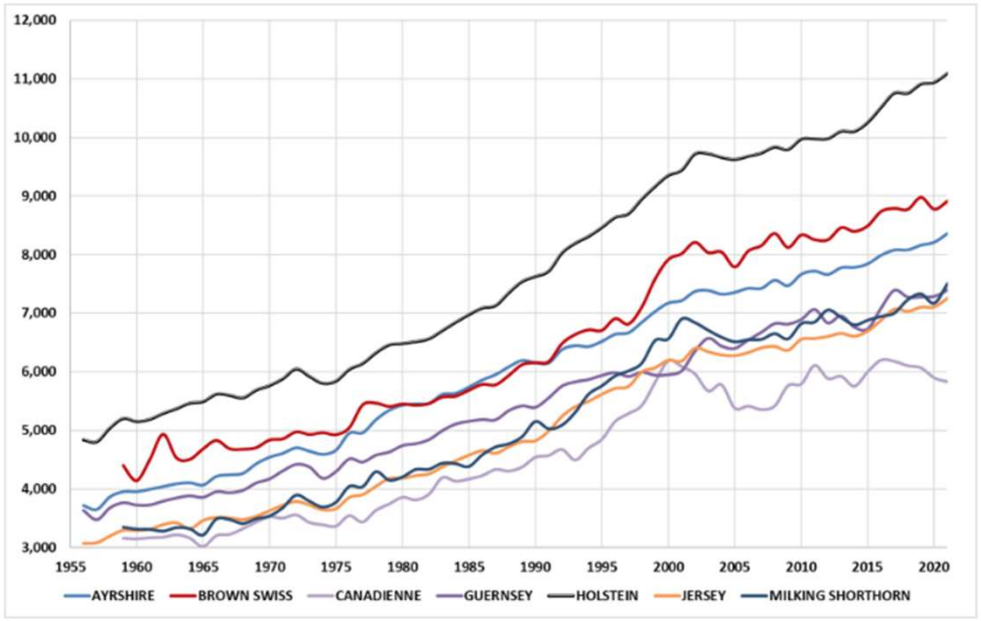
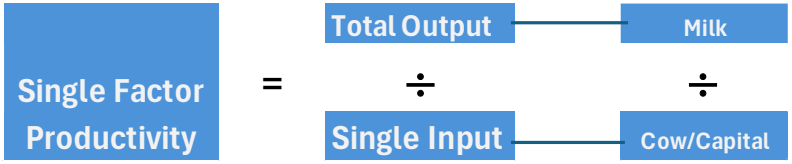


FIGURE 5 Dairy cow milk yield per cow per year (kg/cow/year) Canada. *Source*: Agriculture and Agri-Food Canada (2023).



- **Single-factor productivity Indicator**
  - Focus on only one factor
- **Multifactor Productivity Indicator**

- Drivers: scale efficiency, technical efficiency, **technological progress**.
- **Animal Breeding Technologies**
- **Feed optimization**
- **Data Analytics**
- **Waste management technologies**

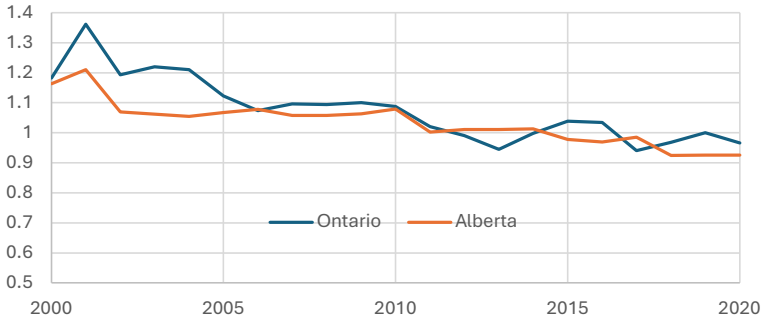
The role of science and technology

Multi-factor productivity measure (TFP)

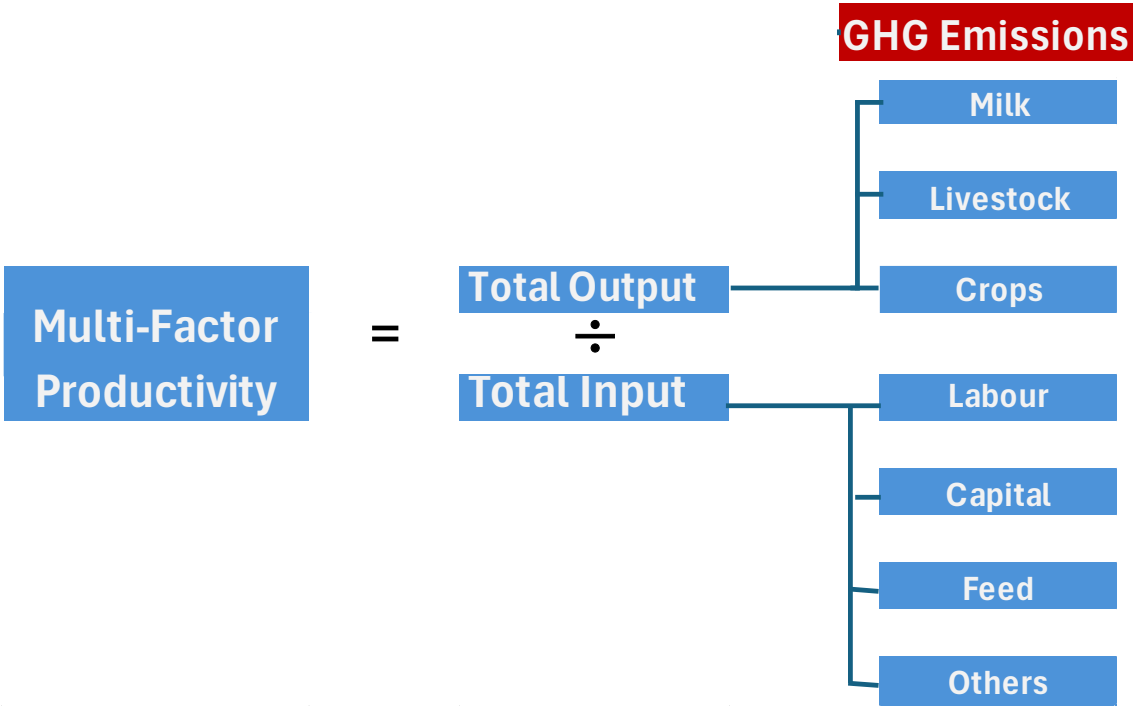
Comprehensive measure of economic efficiency of a farm or an industry

- Higher values indicate that fewer resources are needed to produce output.

What is missing in this measure is the environmental (indicators) impact of the production process



GHG Emissions Intensity (kg CO2eq kg-1 FPCM

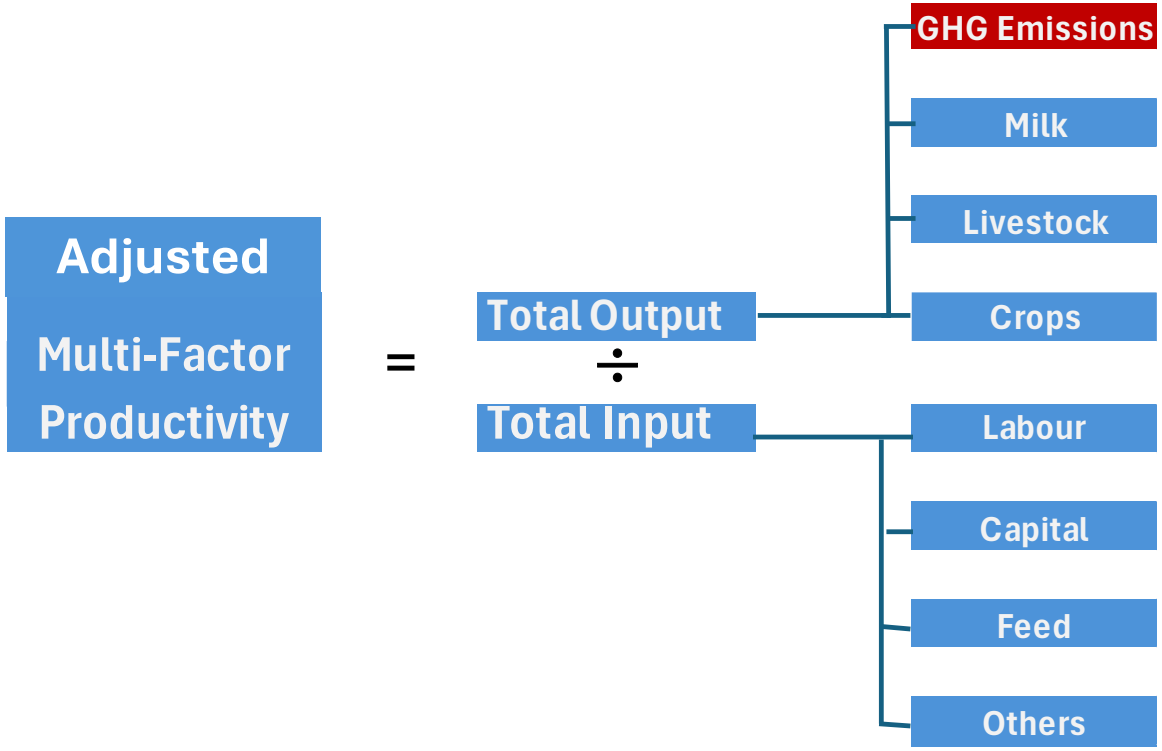


Growth Measure

$$\frac{dln(TFP)}{dt} = \frac{dln(total\ output)}{dt} - \frac{dln(total\ input)}{dt}$$

Green Agricultural Productivity Accounts and Growth Measure

- **Environmentally Adjusted Multifactor Productivity Indicator**
  - Limited reliable data on emissions
  - Difficult in measuring GHG
- **Significant progress in measuring environmentally adjusted productivity growth**
  - Theoretical and methodological advances in measuring environmental inputs and outputs.



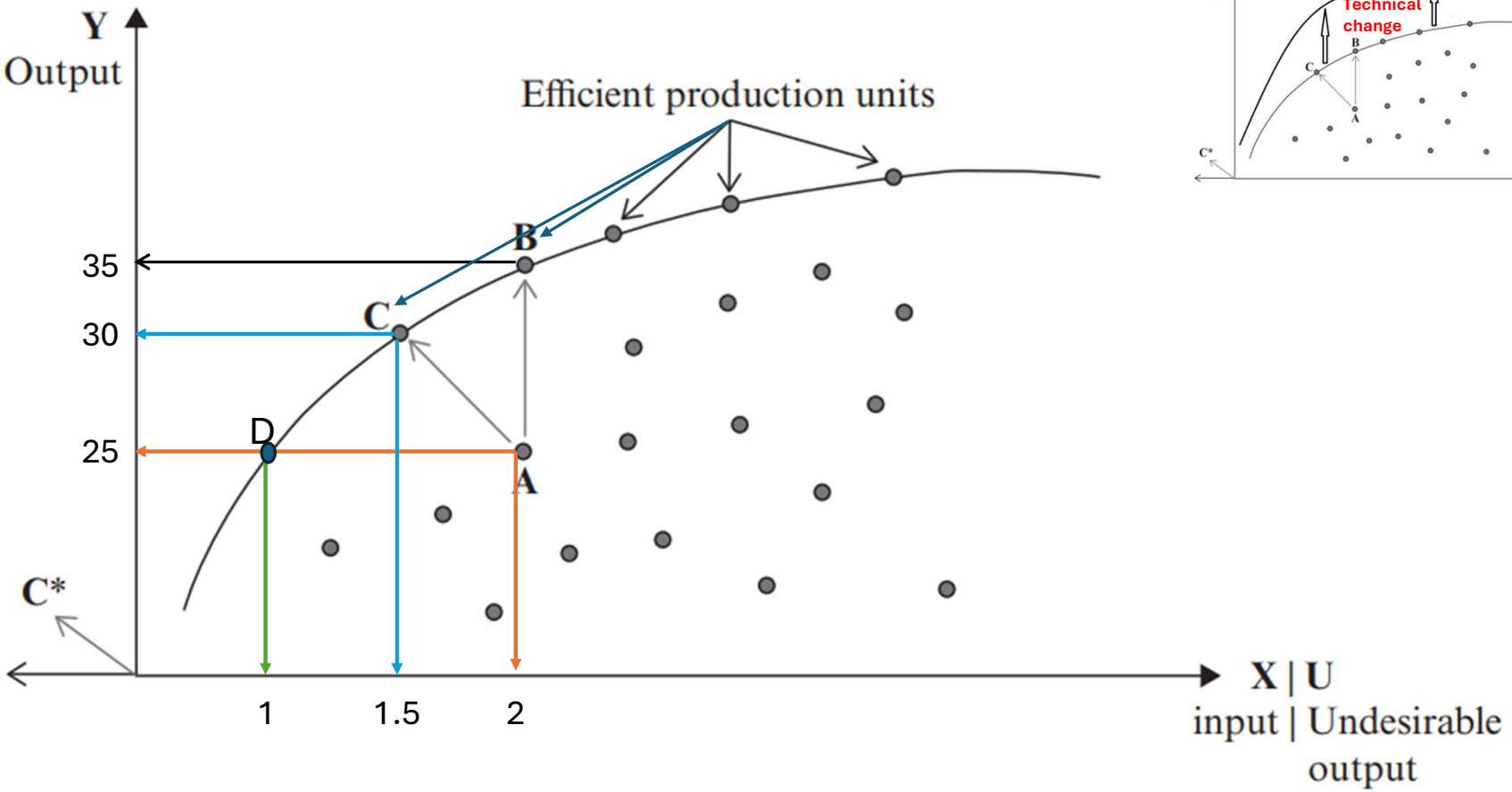
Growth Measure

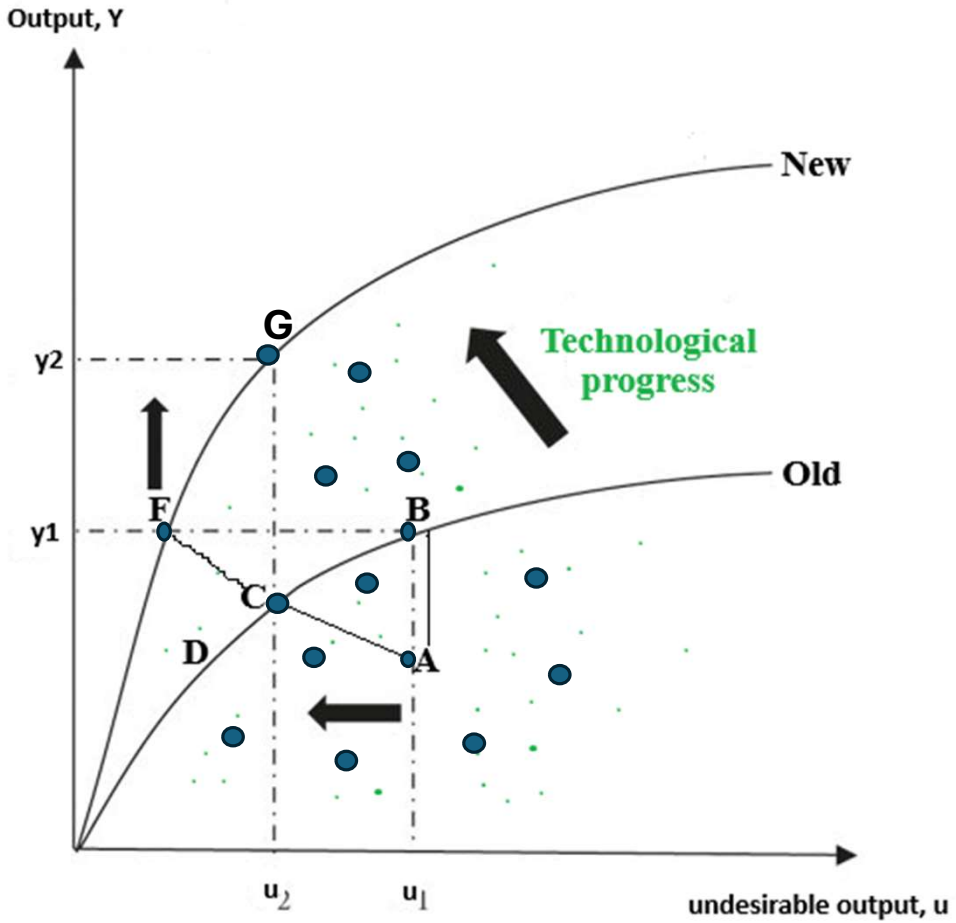
$$\frac{dln(TFP)}{dt} = \frac{dln(total\ output)}{dt} - \frac{dln(total\ input)}{dt} - \frac{dln(total\ GHG\ emissions)}{dt}$$

The Need for Environmentally Adjusted Productivity Measurement

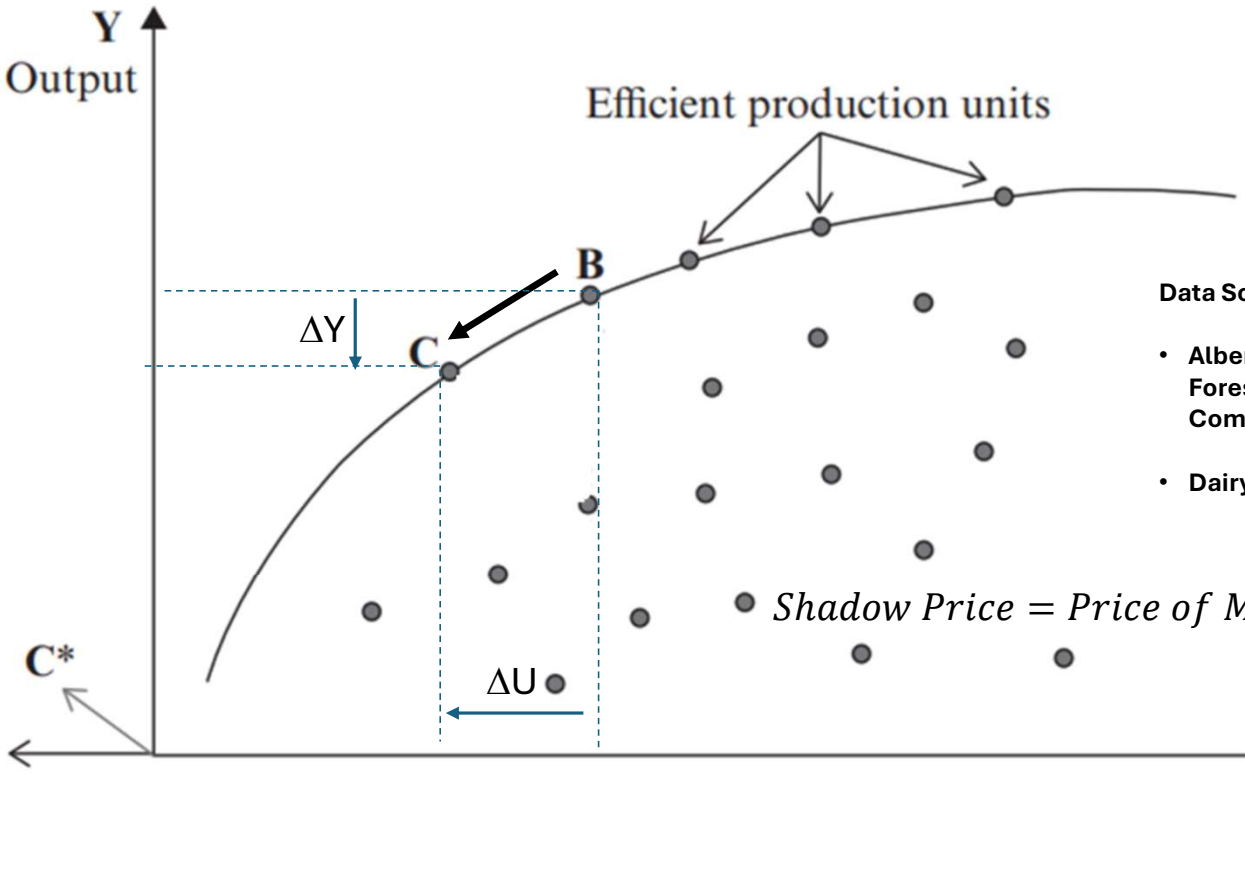
- Traditional productivity measures typically only consider marketable inputs and outputs – e.g., milk.
- They often **fail to account for undesirable outputs (externalities)**, such as GHG emissions, which are by-products of dairy farming.
- This can lead to an **underestimation of productivity growth** for farms that implement GHG mitigation measures and a failure to credit those that do.
- Therefore, it is essential to use environmentally adjusted productivity measures to **accurately assess** the sustainability of dairy farming.

Measurement Framework




Output, Y
New
G
y2
Technological
progress
Old
F
B
y1
C
D
A
u_2
u_1
undesirable output, u

Shadow Price (Trade-offs):
The value of milk output farmers give up when they choose to reduce GHG (environmental externality).



Data Sources:

- **Alberta Agriculture and Forestry Economics & Competitiveness Branch**
- **Dairy Farmers of Ontario**

$$Shadow\ Price = Price\ of\ Milk * \left(\frac{\Delta Y}{\Delta U}\right)$$

Inputs
- **Labour**
- **Feed**
- **Capital**
- **Others**

Desirable Outputs
- **Milk**
- **Livestock**
- **Crop**

Undesirable Output
- **GHG**

Main Results

- The **environmentally adjusted productivity growth** was 0.07 (2.00) percentage points higher than **the conventional measure Ontario (Alberta).**
    - Ignoring the changes in GHG emissions **underestimates** productivity growth.
    - **Technical change is the primary driver**
        - **growth associated with** improved genetics, selective breeding, enhanced feed formulations, and advanced digital record keeping.
- The estimated shadow price of GHG emissions from Ontario dairy was CAN$286 per metric ton.
    - This represents the opportunity cost of forgone revenue due to emission reduction efforts.
    - The shadow price of GHG emissions increased over time, implying that **reducing emissions will become more costly.**

What do all these mean?

	Ontario		Alberta	
Inefficiency	Labour Hours savings (2020)	GHG Reduction (Kg)	Labour Hours savings (2021)	GHG Reduction (Kg)
15%	1,141 hrs ($28,525)	122,496 ($6,100)		
10%	761 hrs ($19,025)	81,664 ($4,100)	1,085 hours ($27,120)	213,007 ($10,650)
1%	76.1 hrs ($1,903)	8,166 ($400)	109 hours ($2,712)	21,301 ($1,065)

2020 (Ontario): Average Labour hours per farm = 7,606 hours (Average hourly wage rate for a dairy farmer in Ontario is $25/hour.
2021 (Alberta): Average Labour hours per farm = 10,848 hours
2020: Average GHG per farm = 816,642 Kg CO_2 eq). Carbon price = $50 (2022))
2021 (Alberta): Average GHG per farm = 2,130,073 Kg CO_2 eq

Average productivity growth (per year)

Alberta (2000 – 2021)	Productivity Growth	Technical Progress	Efficiency Change
Environmentally unadjusted	0.60%	0.41%	0.20%
Environmentally adjusted	2.60%	1.03%	1.57%
Ontario (2000- 2020)			
Environmentally unadjusted	0.38%	1.00%	-0.62%
Environmentally adjusted	0.45%	0.69%	-0.24%

Policy Implications and the Future

- Continued research on **environmentally adjusted productivity** and the **shadow price of carbon** can guide the development of effective climate change policies.
    - Investing in innovations (e.g., genomics, carbon capture, feed optimization, data analytics)
    - Policies that promote climate-smart practices and innovations in the dairy sector.
- Estimating the shadow price of GHG emissions can inform carbon pricing mechanisms and incentivize emission reduction efforts.
    - cost-sharing arrangements, subsidies, and cap-and-trade systems could help mitigate the costs associated with reducing emissions.
- Investing in environmental output (input) **data collection technology.**
    - Advances in technology to **capture & measure** methane emissions

Acknowledgements

- The Resilient Dairy Genome Project

- Alberta Agriculture and Forestry Economics & Competitiveness Branch
  - Pauline Van Biert and Shukun Gaun

- Dairy Farmers of Ontario (DFO)

Appendix

Production Transformation Process

Inputs (A)

Milk

(B)

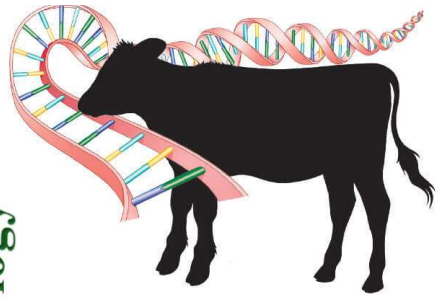
Gross Emissions

Pollution Abatement (C)

Good Output (D)

Bad Output (E)

The role of science and technology

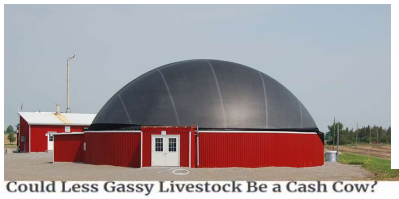


Animal Breeding Technologies

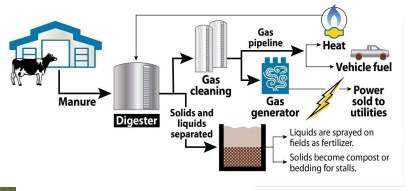
Genomic selection in breeding

Feed optimization

Precision feeding technologies and data analytics



Could Less Gassy Livestock Be a Cash Cow?



Waste management technologies

Manure management systems, such as anaerobic digesters

Methane capture, compress/storage, and utilization technologies

Where does output growth come from?

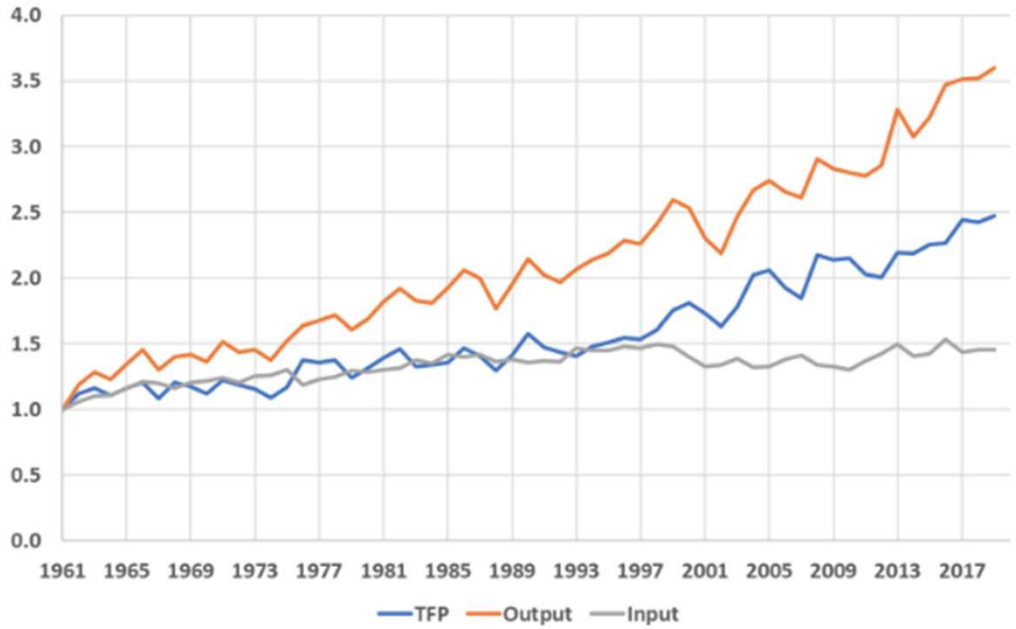


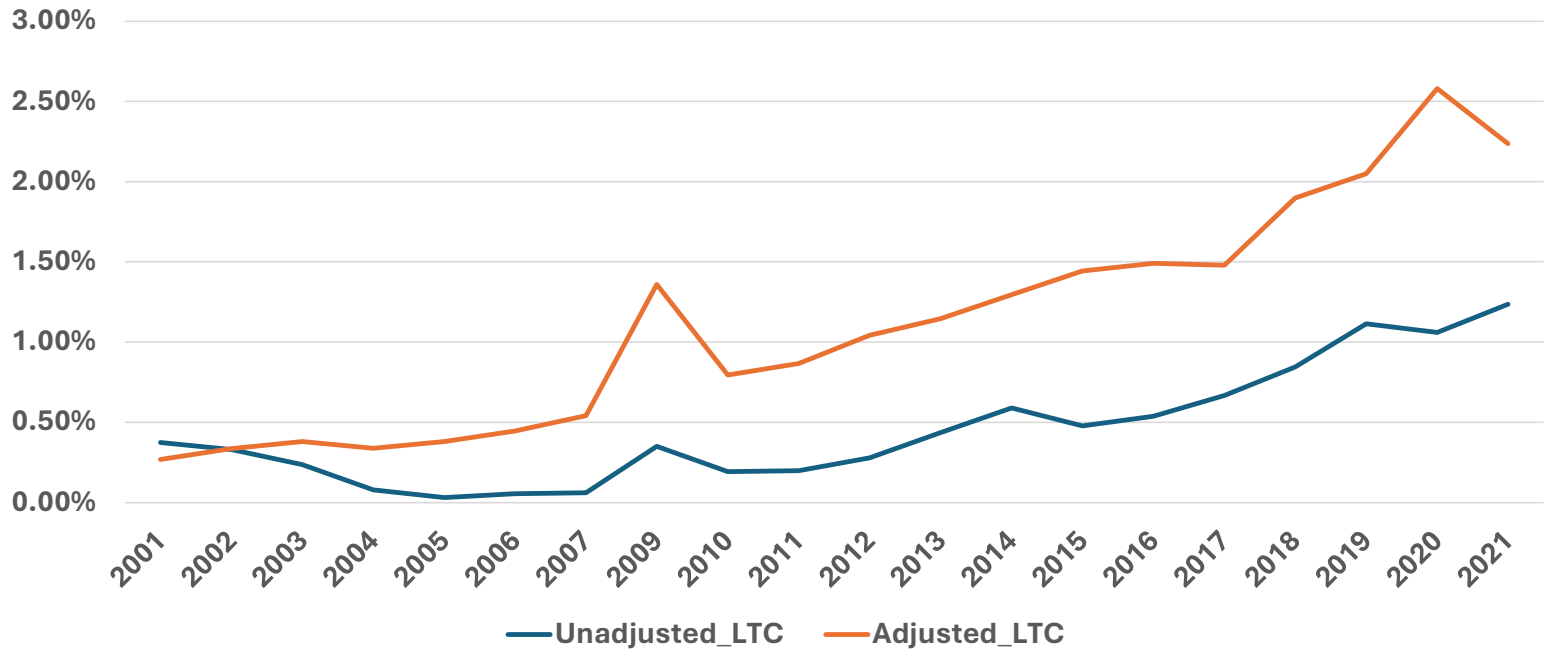
FIGURE 8 Output, input and productivity growth for Canadian Agriculture, 1961–2020 (Indexed to 1961 = 1.0). Data source: Statistics Canada (2023, 36-10-0217-01)

We have seen tremendous output growth driven mainly by productivity growth.

1. Precision technology
2. Carbon (Methane) capture, utilization, and storage
3. Anaerobic digesters
4. Controlled environment farming
5. Livestock feed additives
6. Agriculture biotechnology
7. Cellular agriculture

Alberta

The Luenberger Technical Change (GHG adjusted vs unadjusted)

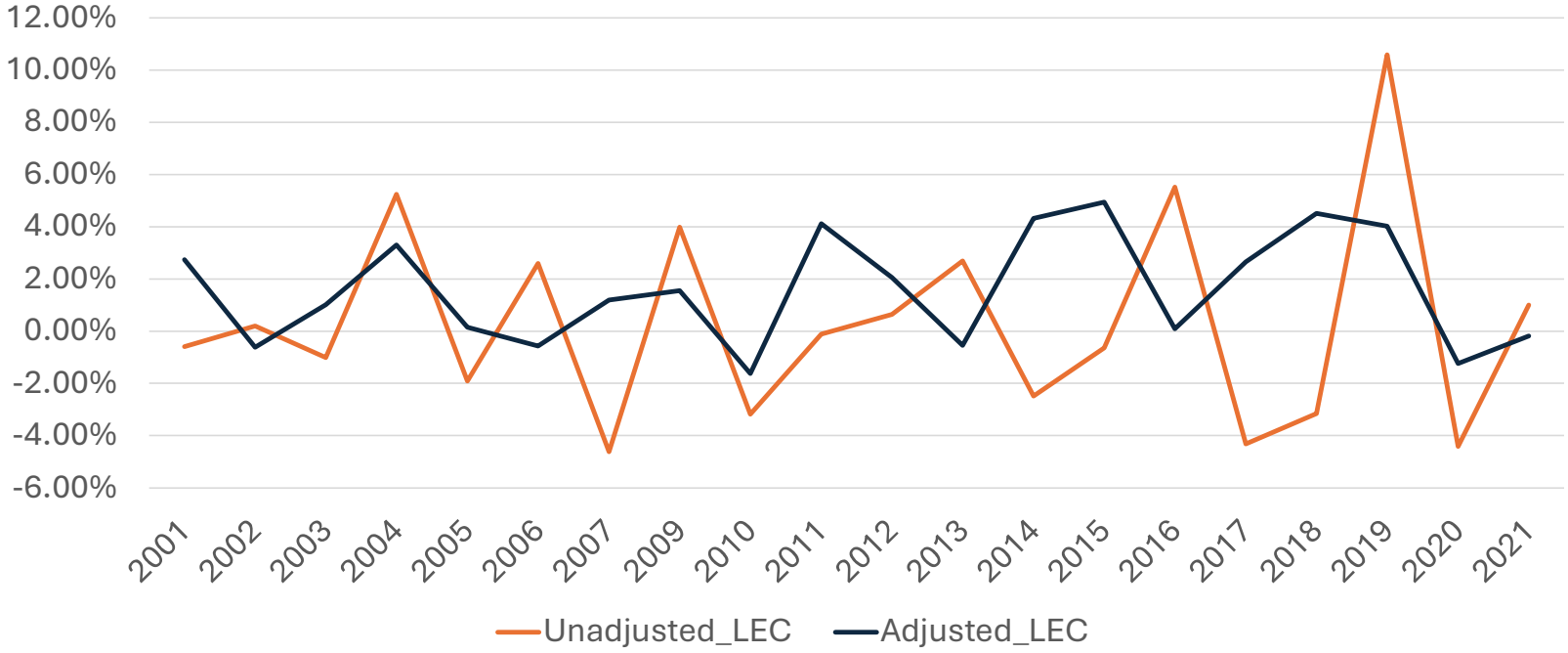


Average Luenberger technical change

- Environmentally unadjusted = 0.41 percent
- Environmentally adjusted = 1.03 percent

Alberta

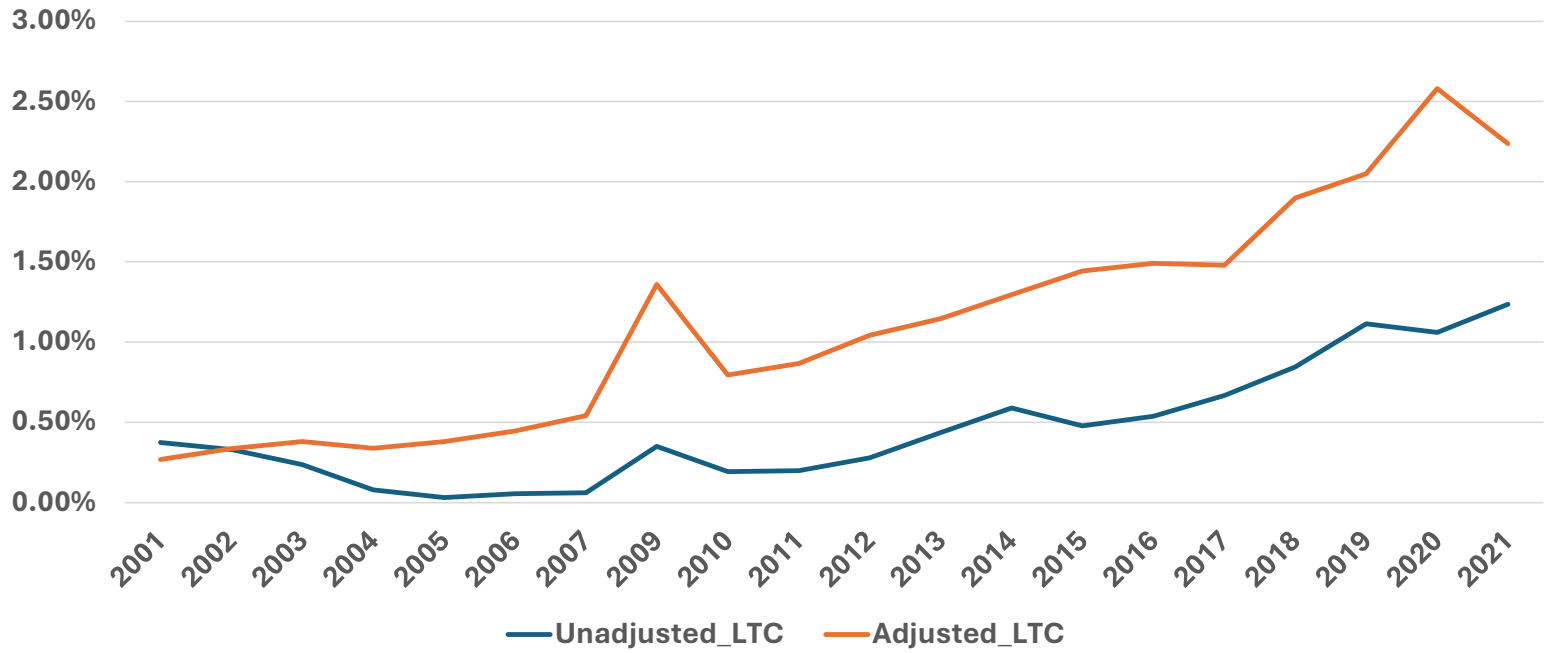
Luenberger Efficiency Change (GHG adjusted vs unadjusted)



Average Luenberger efficiency change

- Environmentally unadjusted = 0.20 percent
- Environmentally adjusted = 1.57 percent

The Luenberger Technical Change (GHG adjusted vs unadjusted)



Average Luenberger technical change

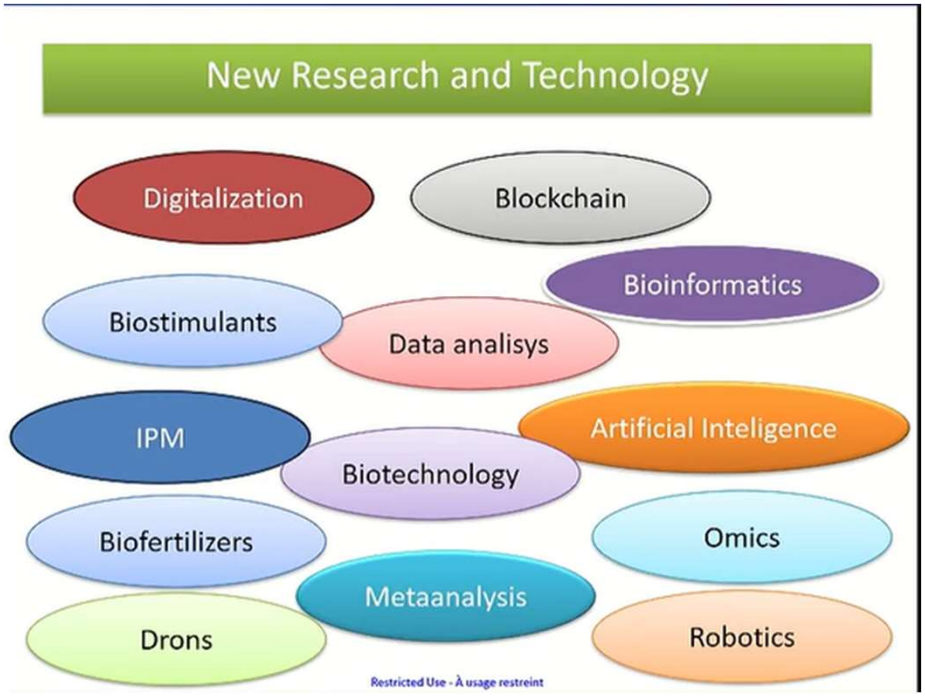
- Environmentally unadjusted = 0.41 percent
- Environmentally adjusted = 1.03 percent

The Canadian Dairy Sector: A Case Study

- Canada's dairy sector is significant, contributing CAN$7.3 billion in farm cash receipts in 2021.
- It operates under a supply management system, making its emission implications unique.
- The sector has invested in genetic improvements, innovation, and environmental footprint reduction.
- The Dairy Farmers of Canada (DFC) aims to reduce farm-level emissions substantially by 2030 and reach net-zero emissions by 2050.

GHG Emissions and the Dairy Industry

- The dairy sector is a significant contributor to GHG emissions, primarily methane, nitrous oxide, and carbon dioxide.
- These emissions stem from enteric fermentation, manure management, crop production, and energy use.
- While the carbon footprint of milk production in Canada is lower than the global average, there is substantial inter-farm variation, indicating room for improvement.
- Research shows that higher milk yield per cow is associated with a lower carbon footprint.



[Sustainable Agricultural Productivity to Address Food Systems Challenges: Measurement, Data, Drivers and Policies | OECD]