TOTAL FACTOR PRODUCTIVITY, MARKUP AND THE ROLE OF CLIMATE CHANGE

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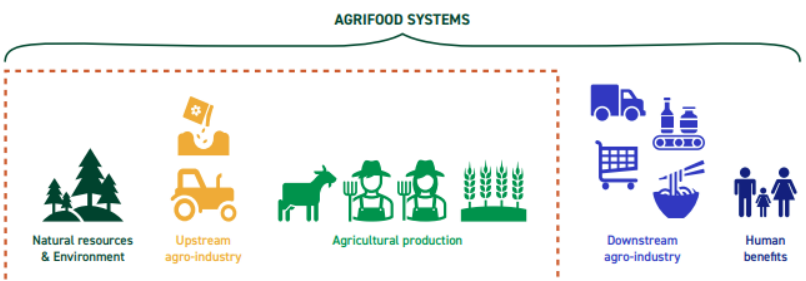
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Introduction

Background and Motivations

Figure 1: Overview of the agri-food system



Source: Campanhola and Pandey, 2019, adapted.

- The objective of this study is to investigate how climate change affects firm productivity and markup.
- We build on the simple observation that climate shocks affect:
  1. Firm productivity and hurt input providers.
  2. Downstream industry with material shortage, and firm production.
  3. Final consumers with price fluctuation.

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Introduction

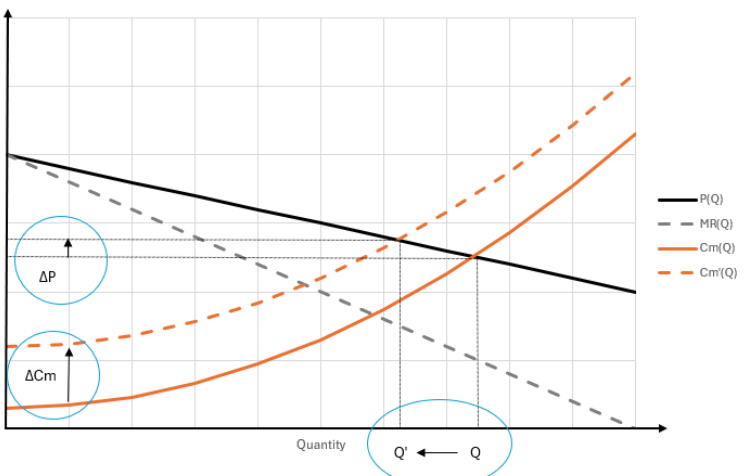
Background and Motivations

- In July 2023, the Agri-Food Analytics lab, in partnership with Caddle, surveyed 5450 Canadians about their eating habits and how climate change is impacting perceptions related to food security overall.
- Perceptions of climate change: 52.3% of respondents where extremely concerned about climate change in general.
- Supply: 61% of respondents believe climate change is impacting Canada's ability to produce during extreme weather
- Demand:
  1. 38% consider the environmental impact of they food choice.
  2. 60.3% are concerned about how climate change will affect their preferences for certain agri-food products.
- Substitution effect in agri-food products: 62% of Canadians reported modifying their diets in summer months with fresh fruits (61.4%), ice cream and desserts (60.7%), Vegetables (53%) and grilled meat and seafood (49.2%).

Potential implications of climate change:

- Disruption of supply chains (Rahman *et al.*, 2022)
  1. Reduction of crops and inputs during extreme weather events
  2. Struggles for some businesses to maintain competitiveness
- Greater variability in productivity (Rojas-Downing, 2017)
- Demand fluctuation $\Longrightarrow$ Price fluctuation (Edmond *et al.*, 2023)
- Low productivity $\Longrightarrow$ higher costs (Horbach and Rammer, 2025)

Figure 2: Market equilibrium

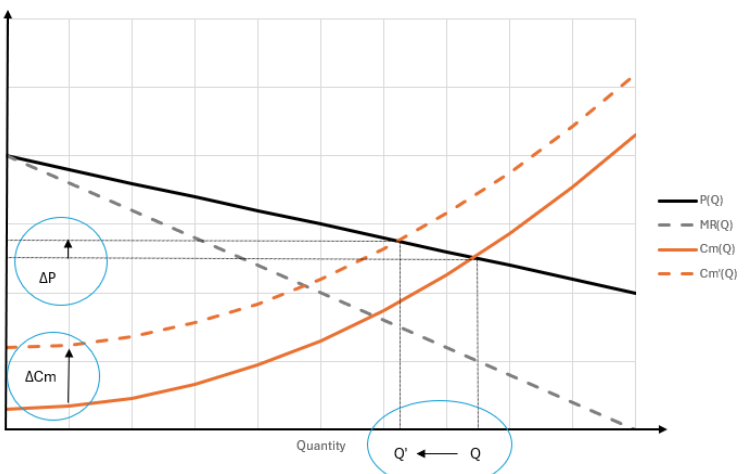


Source: Authors, 2025.

Potential implications of climate change:

- When demand remains constant, input shortages make the supply curve shifts to the left.
- This raises marginal costs and leads to higher prices and Low production levels for agri-food firms.
- **Key asumption:** The increase in marginal cost resulting from a climate shock is greater than the resulting increase in price, leading to a decrease in the markup of agri-food firms.

Figure 3: Market equilibrium



Source: Authors, 2025.

Implications on Markup:

- Markup variability arises when firms adjust prices to changes in costs, often exploiting market power or reacting to supply shocks.
- $Markup = \frac{Price}{Marginal\ Cost}$
- Δ Marginal Cost $\Longrightarrow$ Δ Markup
- Δ Price $\Longrightarrow$ Δ Markup
- How climate shocks affect markup will depend on the adjustment dynamics between price and marginal cost.

- **Research questions:**
  - How climate shocks affect total factor productivity in agri-food firms?
  - How climate shocks affect Markup?

LITERATURE

- There is a non-linear relationship between climate shocks and firm productivity (Caggese *et al.*, 2023): the magnitude and direction of the effect vary depending on the intensity of type of shock.
- Climate shocks $\implies$ productivity dispersion at the firm level (Foster *et al.*, 2016; Gorodnichenko *et al.*, 2018; Maue *et al.*, 2020; Caggese *et al.*, 2023; Conteduca and Panon, 2024)
- Productivity and markup are related and depend on firm size (Edmond *et al.*, 2023)
- Our contribution:
  - A two-sector markets linked through price and quantity in a spirit of Melitz, 2003.
  - Climate shocks are conceptualized as a technological shifter and as TFP shocks.
  - A Leontief production technology in both markets: $y = A\min(X, (f(K, L))$.
  - Firm-level data to analyze the relationship between climate shocks and markup in the agri-food sector.

- **What we do**
  - We present a theoretical model linking climate shocks to productivity among agri-food firms.
  - We present a link between markup and climate shocks.
  - A production function approach in the study by De Loecker and Warzynski, 2012 to obtain estimates of (i) productivity, (ii) and markup.
  - Estimation of production functions using the two-step GMM-IV estimator of Hu *et al.* (2020), addressing optimization errors in firms' input choice, unobserved idiosyncratic cost shocks, and measurement errors.
  - We specify a general Leontief cost function to estimate output elasticities.

METHODOLOGY

THEORETICAL FRAMEWORK

1. Two type of shocks: a supply shock θ_1 and a demand shock θ_2
2. Equilibrium between supply and demand
3. Farmers are price takers under uncertainty and processing firms, while behaving as a monopoly, source input upstream in order to produce.
4. Profit maximization $\Longrightarrow$ A demand function for each firm
5. A non-linear relationship between climate shocks and firm revenue, productivity, and Markup.

Markup expression:

$$\mu = \frac{P(q, \theta_2, .)}{C(q, a(\theta_1), .)} \tag{1}$$

- Where $P_q > 0$, $P_{\theta_2} > 0$; $q = Q(\theta_2, a(\theta_1), .)$ is the optimal demand, $Q_{a(\theta_1)} < 0$, $C_q \geq 0$ and $C_{a(\theta_1)} > 0$.
- Markup is a function of supply shocks, denoted $a(\theta_1)$ and demand shocks θ_2.
- To assess the impact of climate shocks on markup, we rely on the comparison between relative elasticities.

- Climate shocks will reduce markup if price increase only slightly and if sales drop is much larger than the marginal cost increase so that:

$$\eta^{C_{a(\theta_1)}} < (\eta^{P_q} - \eta^{C_q}) \left(\eta^{Q_{a(\theta_1)}}\right)$$

where η indicates cost, price and quantity elasticities.

- **Measurement of climate shocks:**
  - We measure climate shocks using extreme heat degree days (HDD), and we include Growing Degree Days (GDD) and precipitation as control variables (Roberts *et al.*, 2013; Schuurman and Ker, 2024).
  - GDD is the accumulated, typically beneficial, exposure to heat over the growing season bounded between 10 and 29°C.
  - Following Schuurman and Ker, 2024 we determine extreme heat degree days HDD as Growing Degree Days, with damaging heat exposure above 29°.
  - GDD and HDD are determined for each month of the growing season.

- Specifications :

$$y_{it} = f\left(x_{it}, k_{it}, \ l_{it} \ ; \beta\right) + \ a^*_{it} + \varepsilon_{it} \tag{2}$$
$$= f\left(x_{it}, k_{it}, \ l_{it} \ ; \beta\right) + \beta_T \ T_{i,t} + \beta_P \ P_{i,t} + \ a_{it} + \tilde{\varepsilon}_{it}, \tag{3}$$

- Assumptions : $\tilde{\varepsilon}_{it}$ = firm unobserved factors, a_{it} is firm log-productivity estimate, x_{it} = log inputs, k_{it} = log capital, l_{it} = log labor, y_{it} = the log-revenue; both a^*_{it} and ε_{it} are unobservable; $T_{i,t}$ = climate shocks; $P_{i,t}$ = control variables.
- Cost function follows a specific form due to the proportional relationship between material and a capital-labor aggregate, with elasticities varying by output level, estimated using a generalized Leontief function.

METHODOLOGY

DATA

- **Sectors:** 9 Agri-food sectors from the National Accounts Longitudinal Micro database (NALMF) of Statistic Canada:
  - 3111: Animal food manufacturing
  - 3112: Grain and oilseed milling
  - 3113: Sugar product manufacturing
  - 3114: Fruit and vegetable food manufacturing
  - 3115: Dairy product manufacturing
  - 3116: Meat product manufacturing
  - 3117: Seafood product preparation and packaging
  - 3118: Bakeries and tortilla manufacturing
  - 3119: Other food manufacturing
- **Firm data:** Our application focuses on firms in the agri-food industries over 2000-2022.
- Climate data are from the Canadian Center for Climate Services (CCCS) (https://climatedata.ca/) of Environment and Climate Change Canada.
- **Climate data:** In each province, we collect daily climate data (Temperature and precipitations) by province throughout the entire growing season in Canada, from April to September.

RESULTS

- **Markup Distribution:** Uneven across industries
- **Weighted Avg. Log-Markup:** All Markup values are above 1 and 1.53 on average. Highest (1.82) in animal food manufacturing.
- **Dispersion:**
  1. Significant dispersion in Grain & Oilseed Milling sector, compared to : Higher variation than livestock processing
  2. 90-10 ratio: 4.76
  3. 75-25 ratio: 2.07
- **GMM-IV vs. General Leontief:** Lower elasticities for labor & capital in the GMM-IV specification; Higher elasticity for material inputs; Differences due to a restrictive functional form

RESULTS

Impact of Climate shocks on inputs, sales, productivity and marginal cost

- **Firms cut input spending in response to climate shocks, but sales decline more sharply** , especially in May–September (for e.g., a 1% increase in climate extremes in May reduces sales by 0.1%, and materials by 0.03%).
- **Productivity Decline:** Climate shocks lower total factor productivity (TFP), with input efficiency decreasing, except toward the end of the growing season.
- **Rising marginal production costs** (except in August–September) indicating that inputs inefficiencies increase unit production costs.

Impact of Climate Shocks on Firm Markups

- **Overall:** Climate shocks reduce firm-level markups, especially in May, June, and July, due to higher production costs and supply chain disruptions.
- **April:** Slight decline in markups (-0.0142%) in sectors like Fruit & Vegetable Food Manufacturing and Bakeries, but Seafood shows a positive demand-driven response.
- **May:** Markups drop significantly (-0.302%), with Meat Product Manufacturing and Bakeries being most affected.
- **June & July:** Strongest negative impact across almost all sectors.
- **August & September:** Unlike previous months, we denote a shift in the impact of climate shocks, with some sectors exhibiting positive and significant changes in markups.

RESULTS

Response of Markup to climate shocks

Table 1: Effect decomposition

	Productivity Shock Effects			**Output Change Effects**	
	$\eta^{Q_{a(\theta_1)}}$	$\eta^{C_{a(\theta_1)}}$	$\eta^{\mu_{a(\theta_1)}}$	η^{P_q}	η^{C_q}
Value	-1.010***	0.334***	-0.165***	0.00356***	0.535***
	(0.0593)	(0.0105)	(0.0115)	(0.000153)	(0.00861)

Notes: Standard errors are reported in parentheses. *** denotes statistical significance at the 1% level.

A negative TFP shock leads to higher marginal costs and a slight rise in prices, which drives down sales considerably. Firms adjust by lowering markups to absorb part of the cost pressure, especially in the short run.

CONCLUDING REMARKS

- We examine the impact of climate shocks on firm markups and Total Factor Productivity.

- **Key findings:**
  1. Climate shocks vs TFP? Climate shocks lead to a decline in Total Factor Productivity (TFP) and sales in the Canadian agri-food sector.
  2. Climate shocks vs Markup? Markups decline across nearly all sectors in response to climate shocks.
  3. There is a decline in markup among Canadian agri-food firms, driven by limited output price adjustments in response to climate shocks.
  4. Sales drop significantly more than the increase in marginal costs because of an increase in inputs prices, leading to lower markups. Firms face pricing constraints, balancing cost pressures with demand sensitivity.

Q&A

Thank you!

Questions and Comments?