TOTAL FACTOR PRODUCTIVITY, MARKUPS, AND THE ROLE OF CLIMATE CHANGE IN THE CANADIAN AGRIFOOD INDUSTRY

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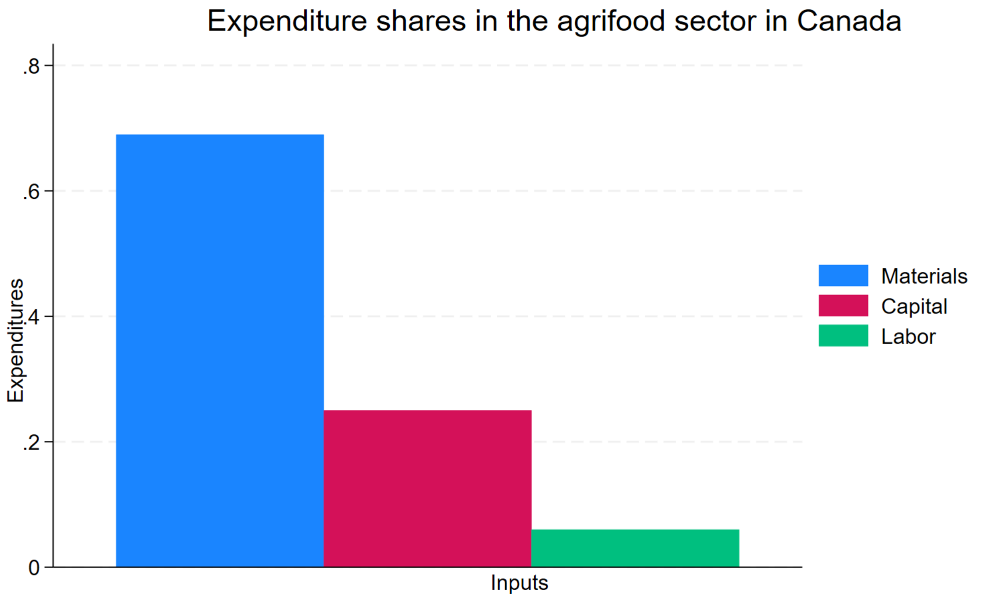
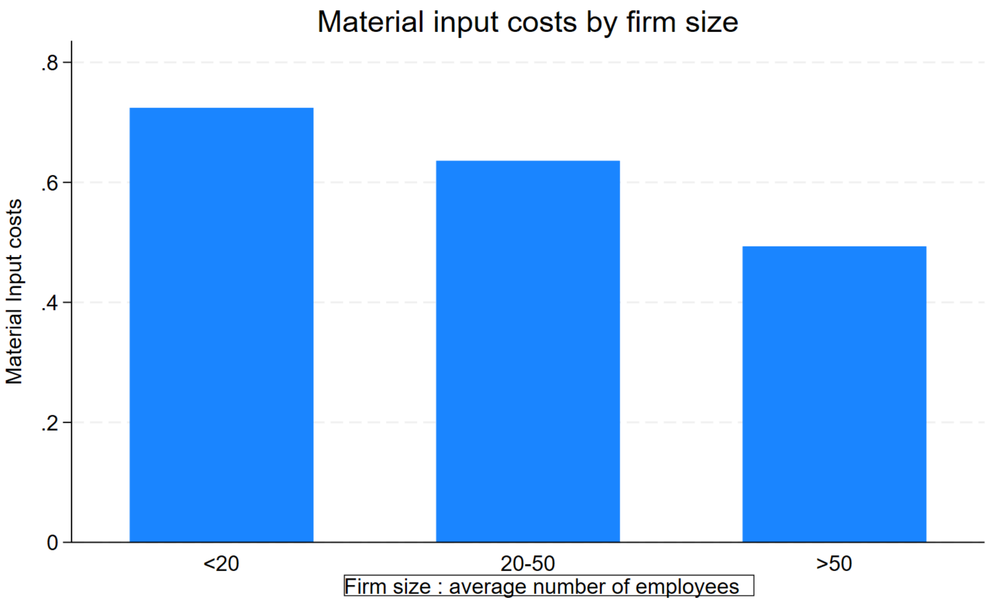
BACKGROUND

- Climate change poses a real challenge for the agricultural sector:
  1. Disruption of supply chains (Rahman et al., 2022)
  2. Greater variability in productivity (Rojas-Downing, 2017)
  3. Profitability fluctuation (Edmond et al., 2023)
  4. Higher prices for inputs $\implies$ higher production costs (Horbach and Rammer, 2025)

Background and motivation



BACKGROUND AND MOTIVATION



BACKGROUND AND MOTIVATION

- **Key issues**
  1. $Markup = \frac{Price}{Marginal\ Cost}$
  2. Markup variability arises when firms adjust prices to changes in costs, often exploiting market power or reacting to supply shocks.
  3. Δ Production costs $\implies$ Δ in Firm Profitability $\equiv$ Δ Markup

BACKGROUND AND MOTIVATION

Here are some reasons why we should care :

1. Climate change effects in the agri-food sector will be uneven among firms : some firms may experience more profitability, while most will may see an average decrease in their production
2. Climate induced shocks and unpredictable fluctuation in costs $\Longrightarrow$ raise prices more than the increase in costs $\nearrow$ higher markups $\Longrightarrow$ burdens to consumers (for e.g., in the event of a drought, grain prices may rise)
3. The increase in markup by a few firms can act as a barrier to entry for smaller firms, as they cannot absorb cost shocks or match the pricing strategies of dominant players

RESEARCH QUESTIONS

- **Research questions:**
  - How climate shocks affect firm productivity?
  - How climate shocks affect Markups?

METHODOLOGY

- **What we do?**
  - A theoretical model linking climate shocks to productivity among agri-food firms
  - Link between markup and climate induced heterogeneity
  - Estimation of production functions and output elasticities with material inputs as the flexible input
  - Assessment of production uncertainty when input decisions are made before output prices are known.

LITERATURE

- Climate shocks $\implies$ productivity dispersion at the firm level (Syverson, 2011; Foster et al., 2016; Gorodnichenko et al., 2018; Maue et al., 2020; Caggese et al., 2023)
- In addition , productivity and markup are related and depend on firm size (Edmond et al., 2023)
- There is a non-linear relationship between climate shocks and firm productivity (Caggese et al., 2023).
- Frameworks to analyze climate shocks :
  - A structural framework linking supply and demand (Gollin and Udry, 2021; Caggese et al., 2023; Edmond et al., 2023)
  - This work:
    1. We introduce a two-sector markets linked through price and quantity in a spirit of (Melitz, 2003) with a Leontief production technology in both markets: $y = A\min(X, (f(K, L))$
    2. We employ Canadian firm data to analyze the relationship between climate shocks and markup in the agri-food sector

Theoretical Model : Partial Equilibrium Model Conditions

1. Supply shock θ_1 and demand shock θ_2
2. Supply and demand equilibrium
3. Cost minimization for the firm
4. Profit maximization for the firm
5. Demand function for each firm

Theoretical Model : Partial Equilibrium Model Conditions

- Farmers are price takers under uncertainty, which implies that:

$$E\left(p_\ell\left(s\right)\right) = E\left(\frac{\mathcal{C}_\ell}{A_\ell\left(\theta_1(T_{s(\ell)})\right)} \mid \theta_1(.)\right) \tag{1}$$

Theoretical Model : Partial Equilibrium Model Conditions

- Cost minimization implies :

$$E\left[\mathcal{C}_{i,k}\right] = \min_{g_{i,\ell}, X_{i,h}(s)} E\left(p_{i,\ell}\left(s\right)\, g_{i,\ell}\left(s\right) + \sum_{h} p_{i,k,h}\, X_{i,k,h} \left| \theta_1(.) \right. \right) \tag{2}$$

Theoretical Framework

- Profit maximization for the firm implies :

$$\mu_{i,k} = \frac{E\left[p_{i,k}\left(s\right)\right]}{\frac{E[\mathcal{C}_{i,k}]}{A_{i,k}}} \tag{3}$$

- The demand function faced by each firm is :

$$y_{i,k} = \omega_i \ \left(\theta_2(T_{s(\ell)})\right)^{\sigma-1} \left(\frac{p_{i,k}}{P_k}\right)^{-\sigma} (\rho_k Y_k), \tag{4}$$

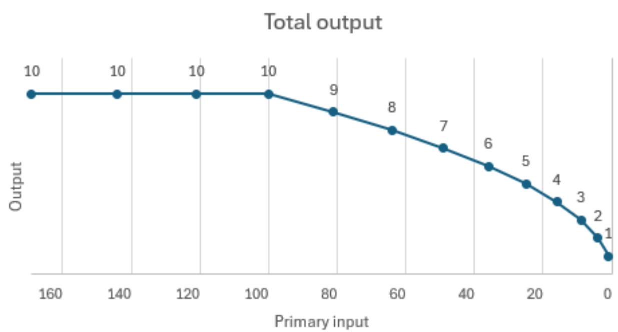
Theoretical Model : Implications

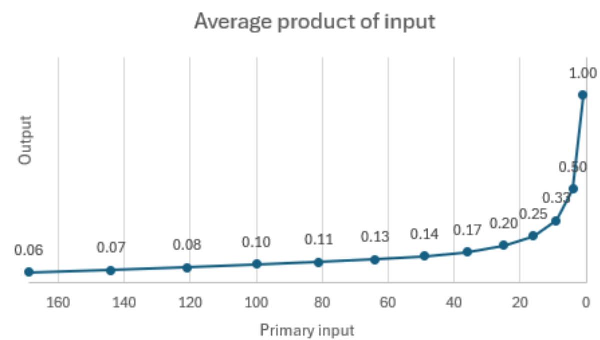
1. There is a nonlinear relationship between climate shocks and firm revenue, productivity and Markup
2. By controlling for consumer-driven demand effects, we can obtain consistent estimates of the impact of climate change stemming from input demand

Theoretical Model : implications

- Implications on average production: under decreasing returns to scale, climate shocks will negatively impact productivity.

Figure. Total output and average product of input in full capacity equilibrium and under decreasing return to scales. We assume that farmers will need 10 unit of input to produce TFP * 10 unit of output.





Data

- **Firm data:** our application focuses on firms in 03 agri-food industries over 2000-2022.

Table. List of industries (NAICS 03 Digits)

Name	NAICS 03 Digits	Material inputs
Food manufacturing	311	Grains, meat
Beverage and tobacco product manufacturing	312	e.g., barley for beer, grapes for wine, etc.
Chemical manufacturing	325	From corn and soybeans

Source: NALMF

DATA

- **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).
- Source : https://climatedata.ca/

Empirical framework

- **Measurement of climate shocks:** We use growing degree days (GDD), extreme heat degree days (HDD), as measures of climate shocks, and growing precipitation as control variables (Roberts et al., 2013; Schuurman and Ker, 2024).

Empirical Framework

- **Measurement of climate shocks:**
  1. GDD is determined for each month within the growing season. With T_ℓ as the lower temperature boundary , T_h as the upper boundary (29 $^\circ$C), and T_d being the daily average temperature for day d, the degree days calculation for that specific day is :

$$GDD_{d;T_l:T_h} = \begin{cases} 0 \text{ if } T_d \leq t_l \\ T_d - T_l \text{ if } T_l < T_d \leq T_h \\ T_h - T_l \text{ if } T_h < T_d \end{cases}$$

Empirical Framework

- Estimation of equations (4) and (3) will require a robust estimation of (*i*) the production function, (*ii*) output elasticities, and (*iii*) firm Markup.
- **What we do?** In a simple empirical exercise, we estimate 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.
- Specification :

$$y_{it} = f\left(x_{it}, k_{it},\ l_{it}\ ; \beta\right) + \beta_T\ T_{i,t} + \beta_P\ P_{i,t} +\ a^*_{it} + \varepsilon_{it}, \tag{5}$$

- Assumptions : a translog specification; ε_{it} = firm unobserved factors, a^*_{it} is firm log-productivity 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.

RESULTS

- Agri-food firms are experiencing increasing Return to Scales.

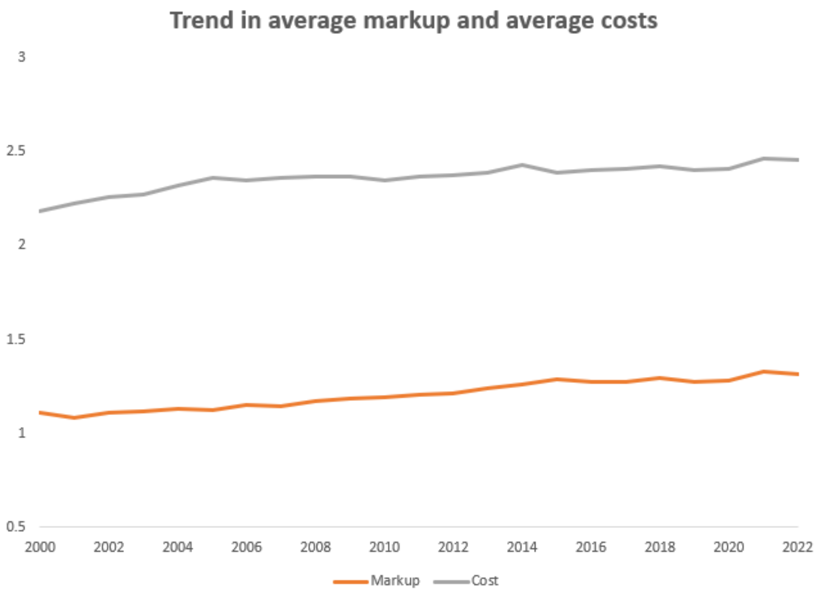
Table. Output Elasticities and Returns to Scale by Sector with a trans log specification

Variables	**311**	**312**	**325**
Average Elasticities			
log capital	0.011	0.050	0.015
Log labor	0.007	0.064	0.017
log materials	1.204	1.162	1.181
Retun to scales (RTS)	1.221	1.275	1.213
Number of Observations	171,430	32,105	61,235
Number of firms	16,350	3,920	6,075

Note: 311 = Food manufacturing; 312 = Beverage and tobacco product manufacturing ; 325 = Chemical manufacturing

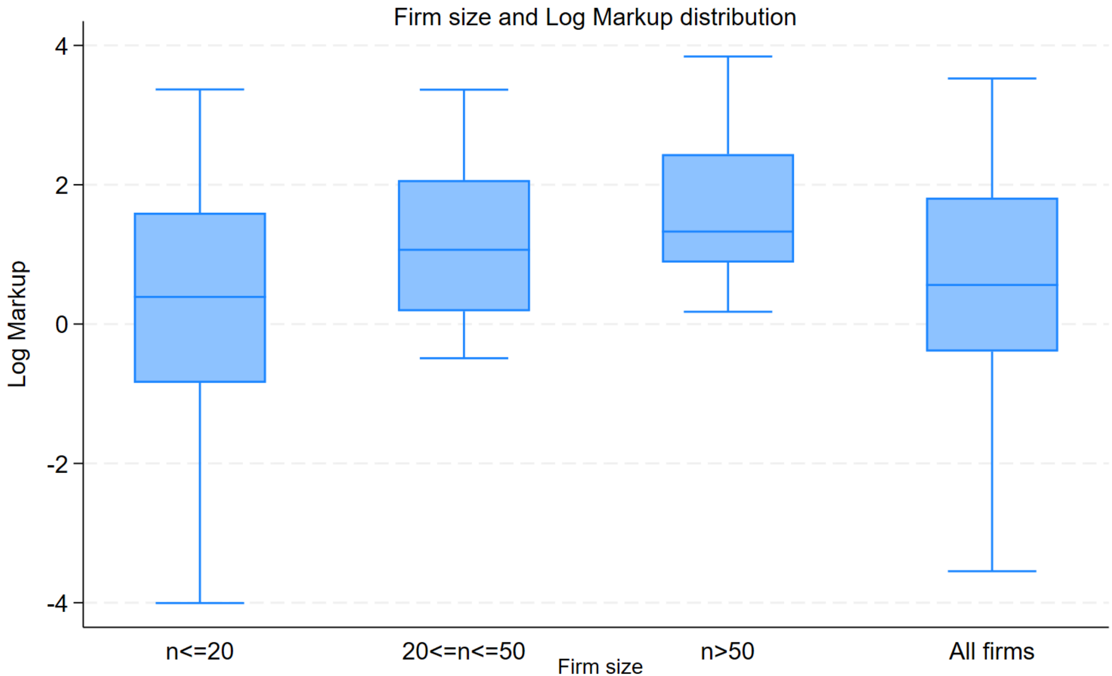
RESULTS

- Correlation between Markup and costs. $\nearrow$ in production costs $\Longrightarrow$ $\nearrow$ Markup. The average markups have gone up from 1.11 in 2000 to 1.31 in 2022.



Results

- Small firms have higher markup volatility but large firms are charging higher price under monopolistic competition



Results

Table. Statistics of Log-Markup in agri-food sectors

Statistics	Food	Beverage and tobacco products	Chemical
Mean	15.470	217.12	8.57
Standard deviation	1688.42	26494.5	351.39
Skewness	184.49	136.37	107.02
Kurtosis	37023.29	19558.27	13137.74
Interquartile Range (IQR)	2.18	0.98	1.96
p50	1.60	1.13	1.57
p1	0	0	0
p25	0.96	0.71	0.86
p75	3.14	1.68	2.81
p99	35.25	17.64	35.97

RESULTS

- High skewness values $\implies$ heavy right tail $\implies$ most firms have low markups, there are a few firms with extremely high markups driving the distribution
- High kurtosis $\implies$ distributions are very peaked $\implies$ high concentration around the mean
- Higher markup for agrifood products and chemicals, compared to Beverage & Tobacco products
- High variability in Markup for agrifood products and chemicals, compared to beverage and chemical products.

Results

- Rising temperature extremes decrease the cost of primary inputs used in the Canadian agri-food sector
- Mixed effect of climate shocks on firm productivity and markup depending on the month of the growing season
- A negative effect of temperature extremes on productivity especially at the start of the growing season (e.g., April)

Results

Climate variables	Log material inputs[1]	Log productivity[2]
HDD April	-	-
HDD May	-	+
HDD June	-	+
HDD July	-	-
HDD August	-	-
HDD September	-	+
GDD April	+	+
GDD May	-	-
GDD June	-	-
GDD July	+	+
GDD August	+	+
GDD September	+	+
Growing Precipitations April	-	+
Growing Precipitations May	+	+
Growing Precipitations June	-	-
Growing Precipitations July	+	+
Growing Precipitations August	-	-
Growing Precipitations September	+	+

(1) Estimations with all sectors combined. ; (2) Log-productivity under decreasing return to scales

RESULTS

	Log Markup		
Climate variables	**Food**	**Beverage and Tobacco**	**Chemicals**
HDD April	-	-	-
HDD May	-	-	-
HDD June	+	+	+
HDD July	-	+	-
HDD August	+	+	+
HDD September	-	+	-
GDD April	+	+	-
GDD May	+	+	-
GDD June	+	+	+
GDD July	-	-	-
GDD August	-	-	+
GDD September	+	-	-
Growing Precipitations April	-	-	-
Growing Precipitations May	+	-	-
Growing Precipitations June	+	+	+
Growing Precipitations July	-	-	+
Growing Precipitations August	-	-	-
Growing Precipitations September	-	-	+

* Log-productivity under decreasing return to scales.

Concluding remarks and policy implications

- Climate change is having profound impacts on production especially in agriculture.
- We found a negative effect of climate shocks on firm productivity at the start of the growing season
- **Implications**
  1. Extreme temperature shocks at the start of the growing season $\Longrightarrow$ disruption of the normal growth cycle of crops $\Longrightarrow$ lower farmers productivity
  2. Higher per unit costs + No influence on the market
  3. Monopolistic competing firms $\Longrightarrow$ source inputs at lower prices, firms reduce their production costs and boost profitability
- We found mixed effect on Markup depending on the month of the growing season

Concluding remarks and policy implications

- Small firms a more vulnerable to climate shocks
- Policy implications:
  1. Providing incentives (e.g., subsidies, technical support) for small firms (SMEs) to enter sectors prone to input shortages during shocks.
  2. Support to small firms with risk-sharing mechanisms, such as climate insurance, to stabilize costs and reduce markup volatility.

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