

# Food Policy in a Warming World

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# Three perspectives on India's export ban

**Indian Ministry of  
Commerce & Industry**  
May 13 statement

Spike in wheat prices  
threatens “**food security**  
of India”

**Farmer Ranbeer Singh  
Sirsa of Punjab**  
May 14 *New York Times*

“If the price wants to go  
up ... who are they trying  
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**Industry analyst Sonal  
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“These measures could  
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## Questions

- ① How do governments intervene in response to agricultural shocks?
- ② What are the aggregate and distributional consequences?

# This paper

## ① **Empirics:** new global data by country, crop, year (1980-2011)

- Domestic shocks lead to consumer aid, especially during elections
- Foreign shocks lead to producer aid, possibly offsetting consumer aid
- Persistent effects, including for longer-run changes

## ② **Theory:** model of agricultural policy and trade

- To rationalize observed policy responses
- Government considers prices and revenues

## ③ **Quantification:** how policy responses affect incidence of climate damages

- Policy responses shield domestic consumers by stabilizing prices

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- Policy responses shield domestic consumers by stabilizing prices

# Contributions

## ① Climate damages and trade with **endogenous government policy**

- Mendelsohn et al. 1994, Deschênes & Greenstone 2007, Lobell & Field 2007, Schlenker & Roberts 2009, Lobell et al. 2011, Ortiz-Bobea et al. 2021
- Costinot et al. 2016, Baldos et al. 2019, Gouel and Laborde 2021, Carleton et al. 2022, Hultgren et al. 2022, Rudik et al. 2022, Cruz & Rossi-Hansberg 2023, Nath 2023

## ② Trade policy and politics for **climate adaptation**

- Grossman & Helpman 1994, Goldberg & Maggi 1999, Fajgelbaum et al. 2020, Adão et al. 2023
- Johnson 1953, Putnam 1988, Bagwell & Staiger 1999, Grossman & Helpman 1995, Ossa 2014
- Johnson 1991, Anderson 2009, Anderson & Masters 2009, Anderson et al. 2013, Bates 2014

# Data and Measurement

## Shocks: extreme heat exposure

- Capture that extreme heat drives yield variability (Schlenker & Roberts 2009)
  - ERA-5 re-analysis data on temperatures
  - EarthStat data on geography of crop production (Monfreda et al. 2008)
  - ECOCROP data on crop-specific temperature sensitivity (Moscona & Sastry 2022)
- Exposure by country  $\ell$ , crop  $k$ , year  $t$ , aggregating over cells  $c$

$$\text{ExtremeHeat}_{\ell k t} = \sum_{c \in \ell} \frac{\text{Area}_{ck}}{\sum_{c' \in \ell} \text{Area}_{c'k}} \cdot \text{DegreeDays}_{ct}(T_k^{\max})$$

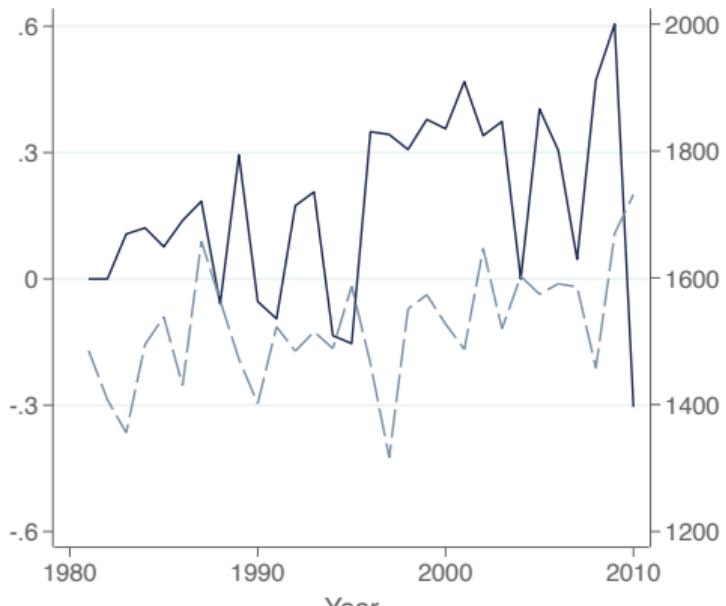
## Policy: nominal rate of assistance

- “Distortions to Agricultural Incentives” project (Anderson & Valenzuela 2008)
  - 80 products, 82 countries, 85% of global production (1955-2011)
  - Wedge between domestic and international prices
  - “Pro-consumer” if  $NRA_{\ell kt} < 0$
- Captures multiple dimensions of policy
  - Quantity instruments, input-market interventions, temporary measures
  - But some subjectivity in measurement

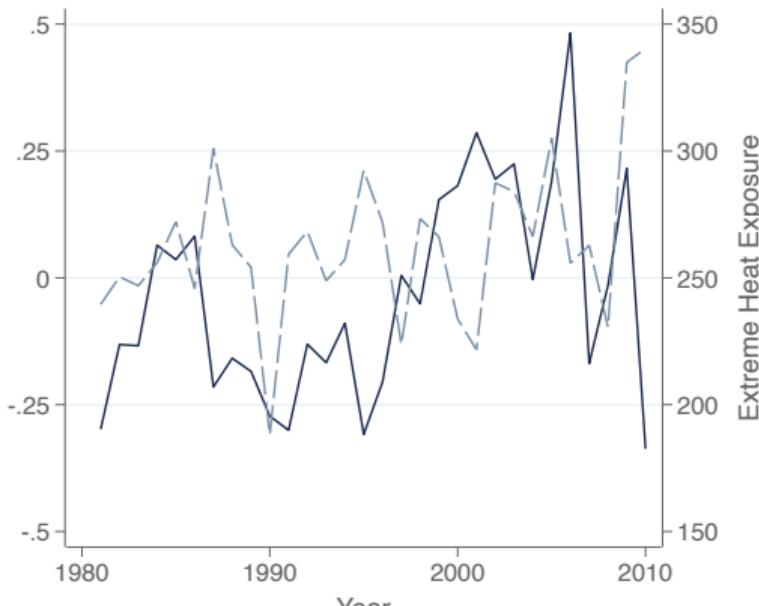
Alternatives

## Example: staples in India

**Wheat**



**Rice**



— NRA —— Extreme Heat Exposure

— NRA —— Extreme Heat Exposure

NRA variation

Shock variation

Yield effects

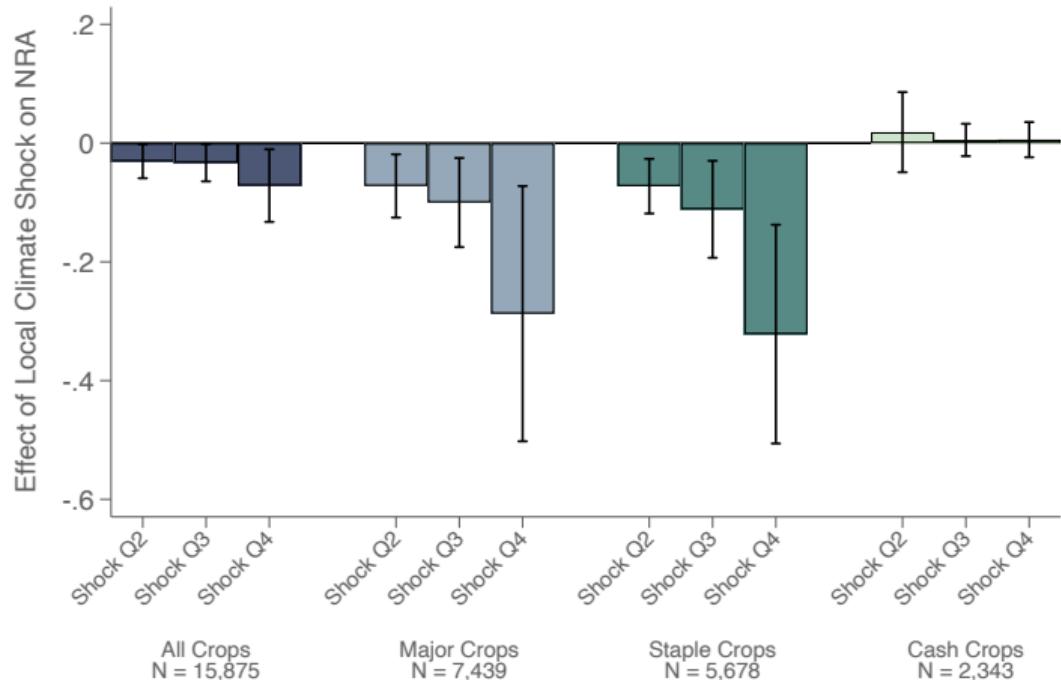
## Empirical Results

# 1. How does extreme heat affect trade policy?

$$\text{NRA}_{\ell kt} = g(\text{ExtremeHeat}_{\ell kt}) + \gamma_{\ell t} + \delta_{kt} + \mu_{\ell k} + \varepsilon_{\ell kt}$$

- Country  $\ell$ , crop  $k$ , year  $t$ , quartile dummies  $g(\cdot)$
- Fixed effects by country-year, crop-year, country-crop
- **Identification:** some crops get worse shocks due to physiology, geography

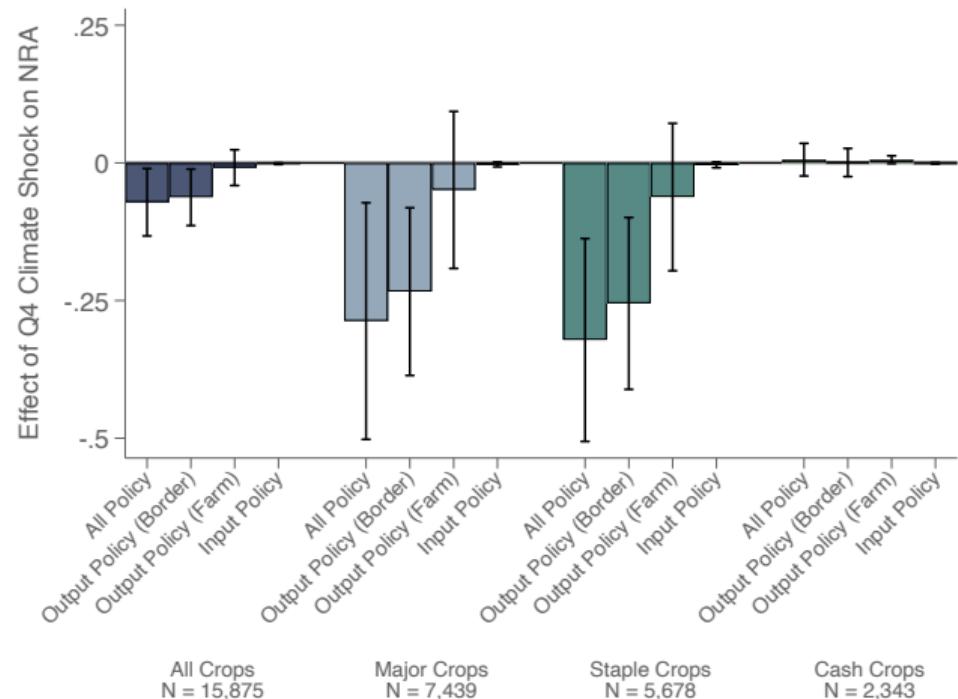
# Extreme heat induces pro-consumer policy



$$\text{NRA}_{\ell kt} = g(\text{ExtremeHeat}_{\ell kt}) + \gamma_{\ell t} + \delta_{kt} + \mu_{\ell k} + \varepsilon_{\ell kt}$$

Country level

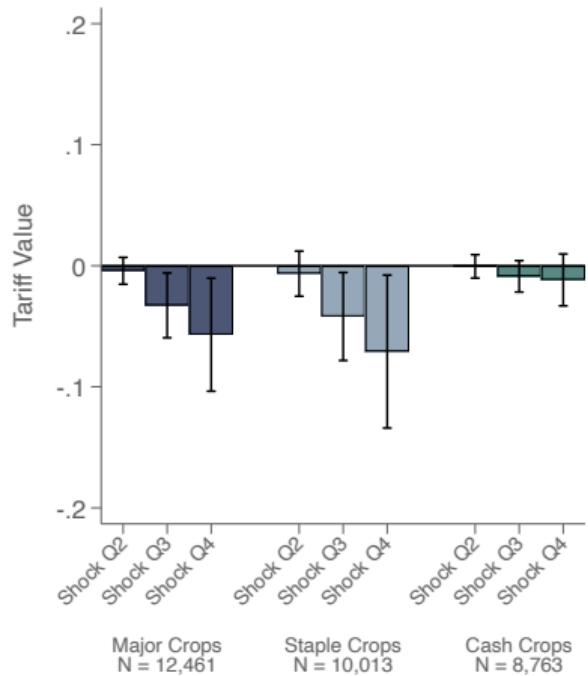
## Effects concentrated in border policies



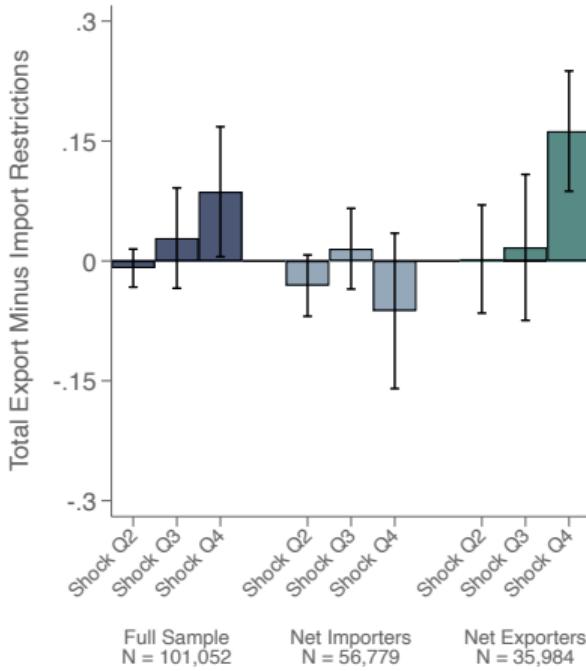
$$\text{NRA}_{\ell kt}^{\text{type}} = g(\text{ExtremeHeat}_{\ell kt}) + \gamma_{\ell t} + \delta_{kt} + \mu_{\ell k} + \varepsilon_{\ell kt}$$

With lower import tariffs and more export restrictions

### TRAINs import tariffs



### GTA export restrictions



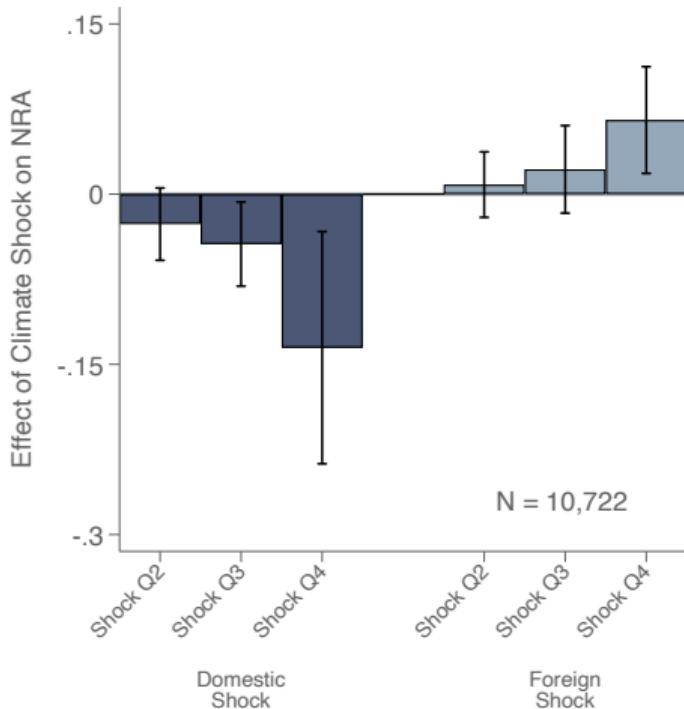
$$\text{Policy}_{\ell k t} = g(\text{ExtremeHeat}_{\ell k t}) + \gamma_{\ell t} + \delta_{k t} + \mu_{\ell k} + \varepsilon_{\ell k t}$$

## 2. How do foreign shocks affect trade policy?

$$\text{NRA}_{\ell kt} = g(\text{ExtremeHeat}_{\ell kt}) + h(\text{ForeignExtremeHeat}_{\ell kt}) + \gamma_{\ell t} + \delta_{kt} + \mu_{\ell k} + \varepsilon_{\ell kt}$$

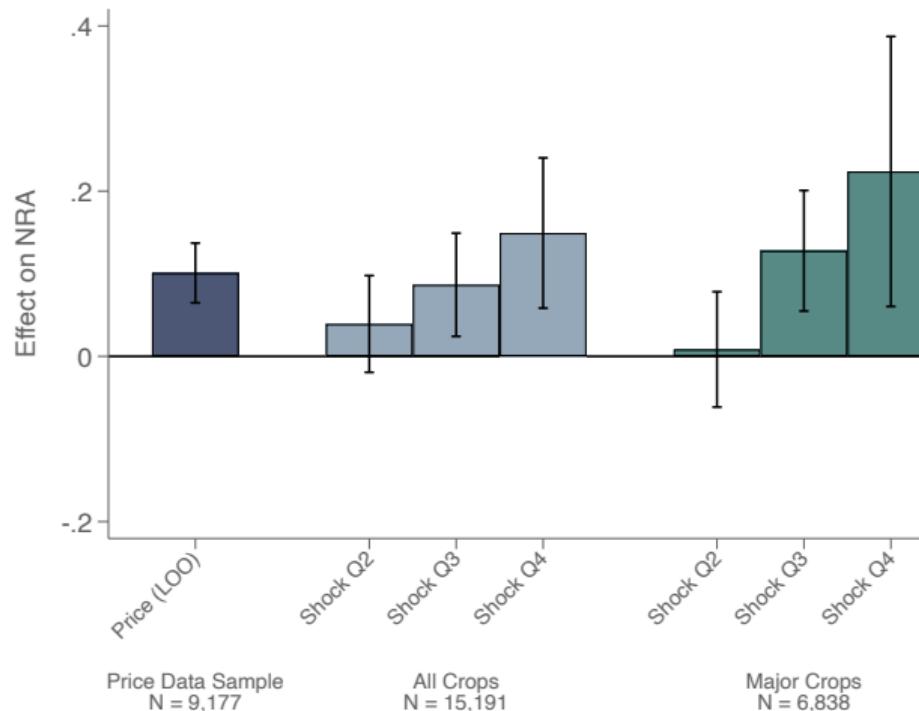
- Country  $\ell$ , crop  $k$ , year  $t$ , quartile dummies  $g(\cdot)$  and  $h(\cdot)$  International prices
- Fixed effects by country-year, crop-year, country-crop
- ForeignExtremeHeat: trade partner shocks, weighted by pre-period trade shares

# Foreign shocks induce pro-producer policy



$$\text{NRA}_{\ell kt} = g(\text{ExtremeHeat}_{\ell kt}) + h(\text{ForeignExtremeHeat}_{\ell kt}) + \gamma_{\ell t} + \delta_{kt} + \mu_{\ell k} + \varepsilon_{\ell kt}$$

## Global shocks also induce pro-producer policy



$$\text{NRA}_{\ell kt} = \textcolor{orange}{g}(\text{ExtremeHeat}_{\ell kt}) + \textcolor{brown}{h}(\text{GlobalShock}_{kt}) + \gamma_{\ell t} + \mu_{\ell k} + \varepsilon_{\ell kt}$$

### 3. How does extreme heat affect longer-run policy?

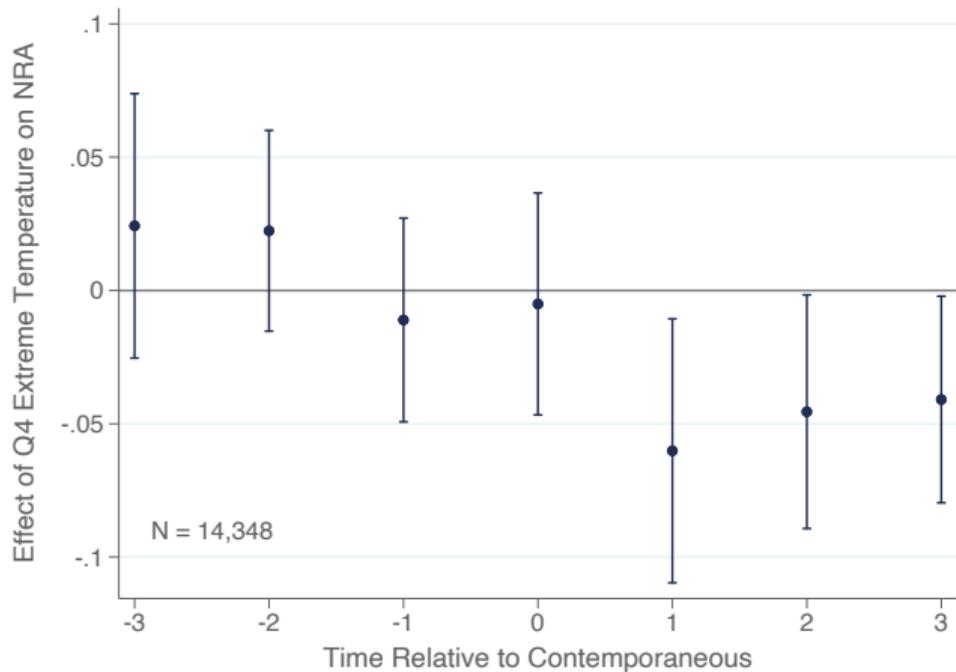
- Longer-run policy: country  $\ell$ , crop  $k$ , years  $t + s$

$$\text{NRA}_{\ell k t} = \sum_{s=-3}^3 \text{ExtremeHeat}_{\ell k t+s}^{Q4} + \gamma_{\ell t} + \delta_{k t} + \mu_{\ell k} + \varepsilon_{\ell k t}$$

- Longer-run shocks: country  $\ell$ , crop  $k$ , decade  $\bar{t}$

$$\text{NRA}_{\ell k \bar{t}} = \beta \text{YearsHeat}_{\ell k \bar{t}}^{Q4} + \alpha \text{YearsForeignHeat}_{\ell k \bar{t}}^{Q4} + \gamma_{\ell \bar{t}} + \delta_{k \bar{t}} + \mu_{\ell k} + \varepsilon_{\ell k \bar{t}}$$

## Annual shocks have persistent effects



$$\text{NRA}_{\ell k t} = \sum_{s=-3}^3 \text{ExtremeHeat}_{\ell k t+s}^{Q4} + \gamma_{\ell t} + \delta_{k t} + \mu_{\ell k} + \varepsilon_{\ell k t}$$

## Decadal shocks have similar effects

	All Policy	Output Policy	Output Policy (Border)	Output Policy (Farm)
Years of Extreme Heat (Local)	-0.0252** (0.0110)	-0.0251** (0.0111)	-0.0204** (0.00897)	-0.00468 (0.00471)
Years of Extreme Heat (Foreign)	0.0179* (0.00969)	0.0180* (0.00968)	0.0131*** (0.00463)	0.00491 (0.00727)
Observations	1,951	1,951	1,951	1,951

$$NRA_{\ell k \bar{t}} = \beta \text{YearsHeat}_{\ell k \bar{t}}^{Q4} + \alpha \text{YearsForeignHeat}_{\ell k \bar{t}}^{Q4} + \gamma_{\ell \bar{t}} + \delta_{k \bar{t}} + \mu_{\ell k} + \varepsilon_{\ell k \bar{t}}$$

## 4. Does political economy drive policy effects?

$$\text{NRA}_{\ell kt} = g(\text{Heat}_{\ell kt} \times \text{No Election}_{\ell kt}) + h(\text{Heat}_{\ell kt} \times \text{Election}_{\ell t}) + \gamma_{\ell t} + \delta_{kt} + \mu_{\ell k} + \varepsilon_{\ell kt}$$

- Country  $\ell$ , crop  $k$ , year  $t$ ,  $g(\cdot)$  and  $h(\cdot)$  quartile dummies Other heterogeneity
- Fixed effects by country-year, crop-year, country-crop
- $\text{Election}_{\ell t}$ : election year or one year before (Database for Political Institutions)
- Elections erode fiscal responsibility  $\Rightarrow$  negative interaction coefficients Debt burden
  - Political cycles, e.g. Alesina & Roubini 1992, Akhmedov & Zhuravskaya 2004

## Stronger effects before elections

	Full sample		Major crops	
	Estim	SE	Estim	SE
Q2 Extreme Heat × No Election	-0.0249	(0.0299)	-0.0541	(0.0375)
Q3 Extreme Heat × No Election	-0.0114	(0.0387)	-0.0853	(0.0661)
Q4 Extreme Heat × No Election	-0.0996	(0.0698)	-0.155	(0.0974)
Q2 Extreme Heat × Election	-0.0234	(0.0196)	-0.0908***	(0.0280)
Q3 Extreme Heat × Election	-0.0576**	(0.0258)	-0.0991**	(0.0377)
Q4 Extreme Heat × Election	-0.145**	(0.0695)	-0.340**	(0.163)
Observations	10,711		5,580	

$$\text{NRA}_{\ell kt} = g(\text{Heat}_{\ell kt} \times \text{No Election}_{\ell kt}) + h(\text{Heat}_{\ell kt} \times \text{Election}_{\ell t}) + \gamma_{\ell t} + \delta_{kt} + \mu_{\ell k} + \varepsilon_{\ell kt}$$

# Theory

# Model

- Prices: redistributive motives (Grossman & Helpman 1994; Bates 2014)
- Revenue: terms-of-trade manipulation (Johnson 1951)
- Market clearing  $q = y + m$

$$\underbrace{q = Q_0 p^{-\epsilon_d}}_{\text{Demand}}$$

$$\underbrace{y = Y_0 e^{-\omega} p^{\epsilon_s}}_{\text{Domestic supply, shock } \omega}$$

$$\underbrace{m = M_0 p^{\epsilon_m}}_{\text{Foreign net supply}}$$

- Tax wedge  $\alpha$  between domestic price  $p^*$  and international price  $\frac{p^*}{1+\alpha}$
- Government maximizes weighted sum of surplus

$$\max_{\alpha \in [-1, \infty)} \left\{ \lambda^C CS + \lambda^P PS + \lambda^G G \right\}$$

Microfoundations  
Optimal Policy

# Policy responses depend on price vs. revenue concerns

The government is **price-focused** if

$$\frac{\epsilon_s \lambda^C + \epsilon_d \lambda^P}{\epsilon_s + \epsilon_d} > \lambda^G$$

**revenue-focused** if the opposite holds strictly, and **neutral** at equality.

## Proposition: Food Policy and Climate Shocks

- ① Under price focus, adverse shock  $\rightarrow$  consumer assistance (lower  $\alpha$ )
- ② Under revenue focus, adverse shock  $\rightarrow$  producer assistance (higher  $\alpha$ )
- ③ In the neutral case, policy is invariant to shock  $\omega$ .

## Intuition for both cases

- **Revenue focus:** high import share  $\Rightarrow$  more profitable to tax imports
- **Price focus:** high import share  $\Rightarrow$  best time to subsidize imports
  - Smaller losses for domestic producers, bigger gains for domestic consumers
  - Note political economy effects
- Corollary: opposite policy responses to foreign production shocks
  - Domestic and foreign shocks have opposite effects on import share
  - Distinguish this model from others (e.g., pure price stabilization)
  - Note opposite shock effects

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# Counterfactuals

# Quantitative model

- Many countries + **estimated impacts** of heat shocks on production and policy
  - Goals: equilibrium welfare impacts, characterize incidence, isolate policy effects

demand       $\log q_{\ell k} = \log q_{\ell k}^0 - \epsilon_d \log[(1 + \alpha_{\ell k}) p_k]$

supply       $\log y_{\ell k} = \log y_{\ell k}^0 + \epsilon_s \log[(1 + \alpha_{\ell k}) p_k] - f(\text{ExtremeHeat}_{\ell k})$

NRA       $\alpha_{\ell k} = \alpha_{\ell k}^0 - g(\text{ExtremeHeat}_{\ell k}) + h(\text{ForeignExtremeHeat}_{\ell k})$

equilibrium       $\sum_{\ell} q_{\ell k} = \sum_{\ell} y_{\ell k} \quad \forall k$

# How does trade policy affect global adaptation to climate shocks?

- ① “Baseline” of minimum observed heat (1991-2011)
  - In-sample shocks as observed heat (1991-2011)
  - Out-of-sample shocks as projected heat (2090-2100 from GFDL-ESM4)
- ② Apply shocks to 1991-2011 data, then compute
  - Equilibrium prices, quantities, trade, and welfare
- ③ Compare outcomes to baseline
  - Under responsive vs. fixed trade policy

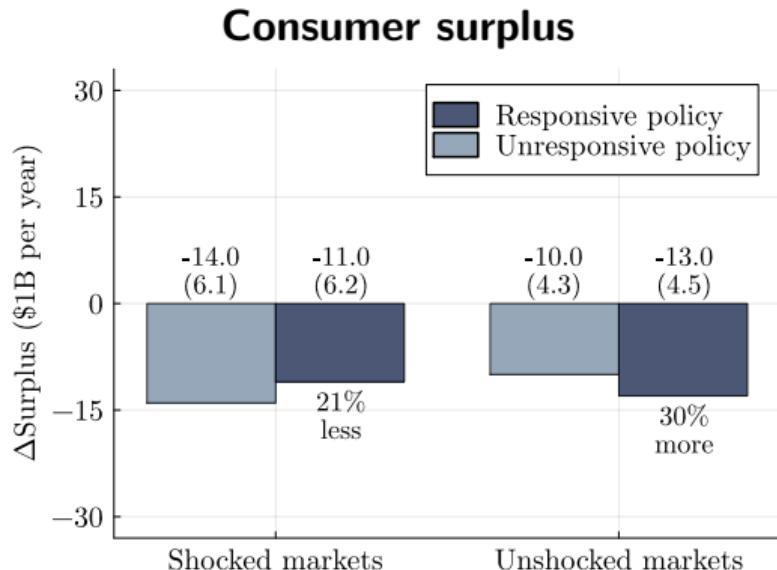
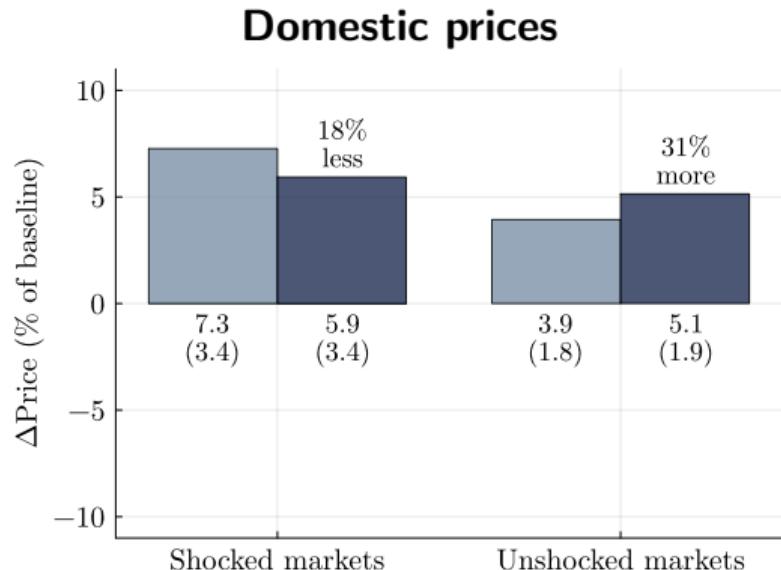
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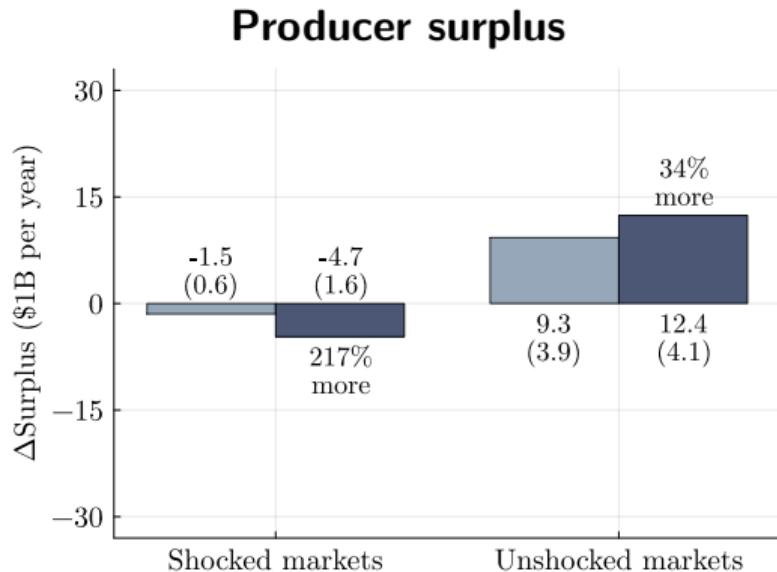
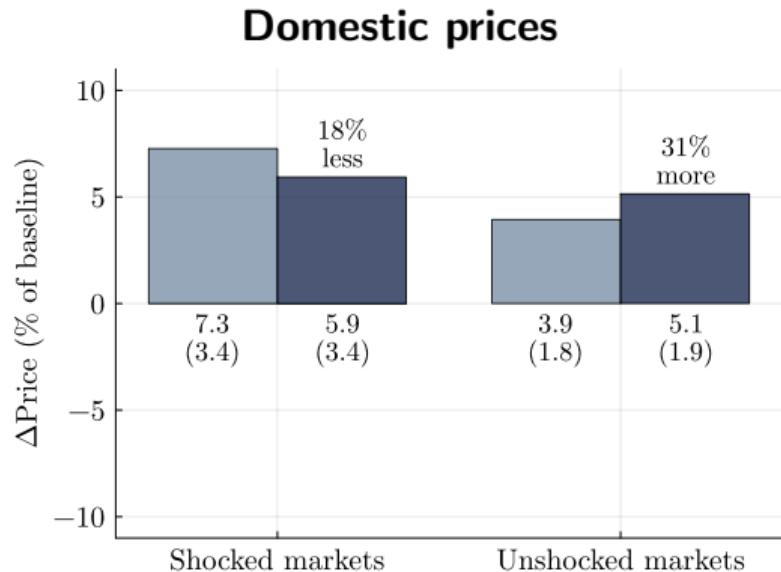
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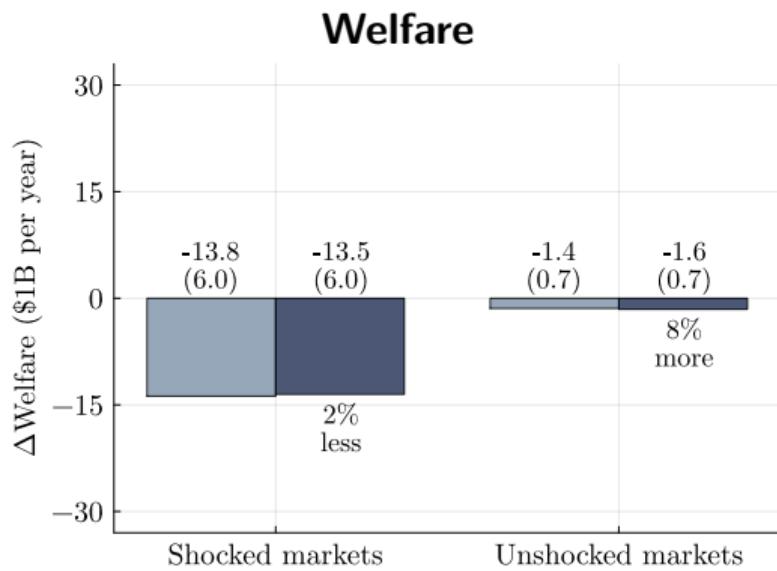
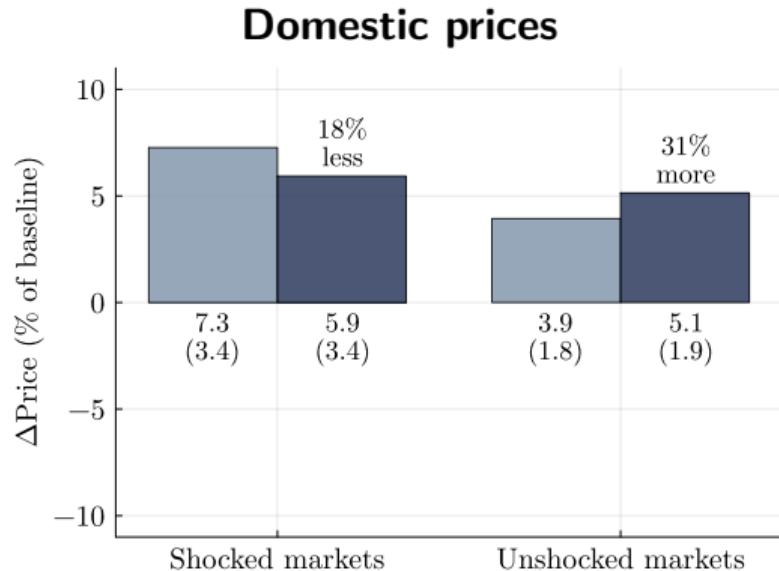
# In shocked markets, policy responses stabilize prices



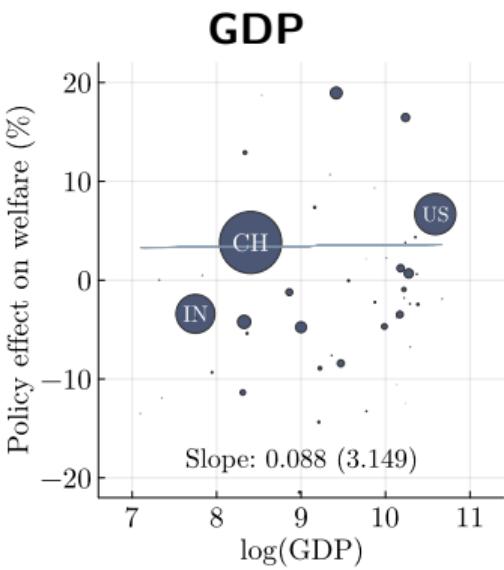
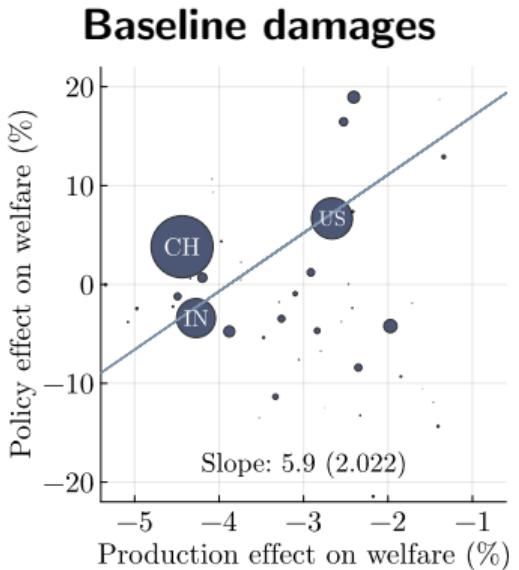
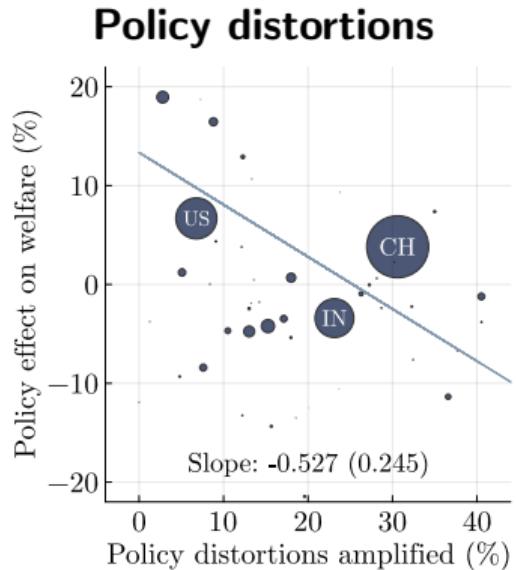
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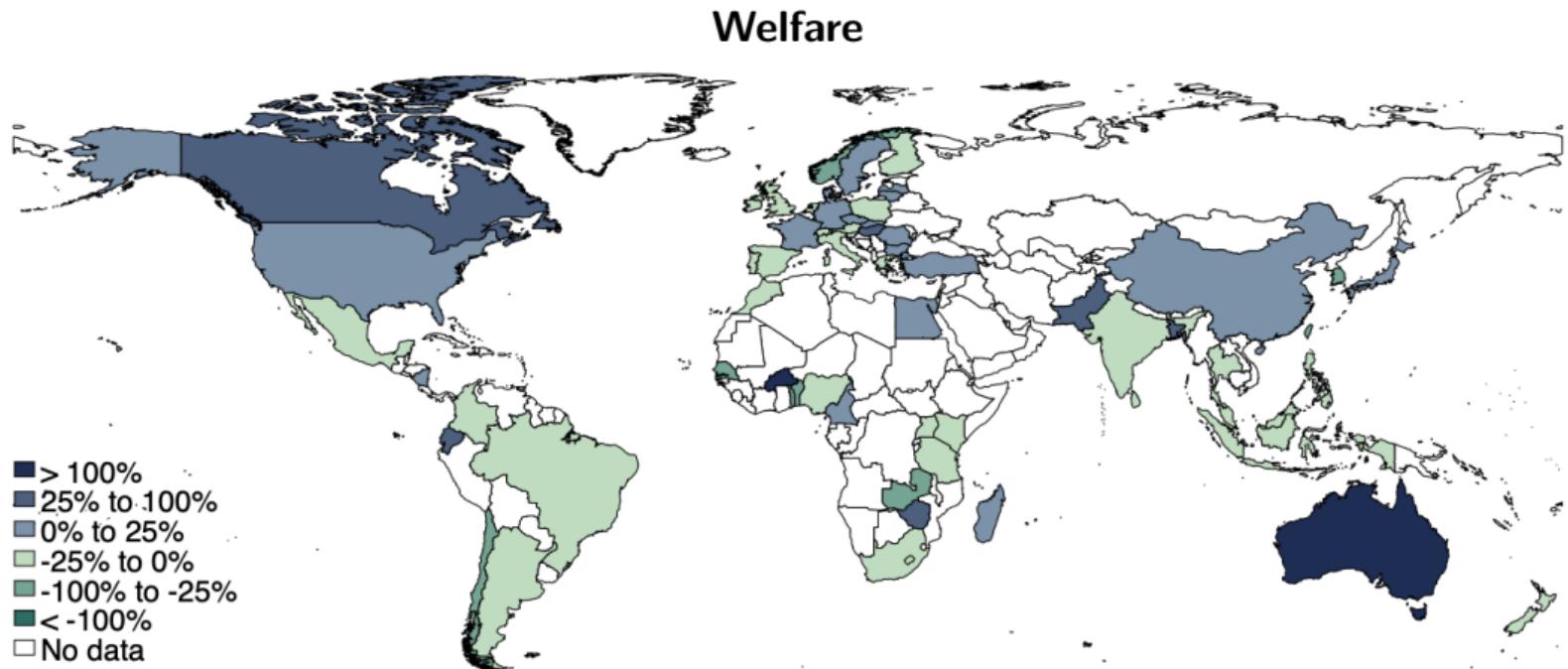
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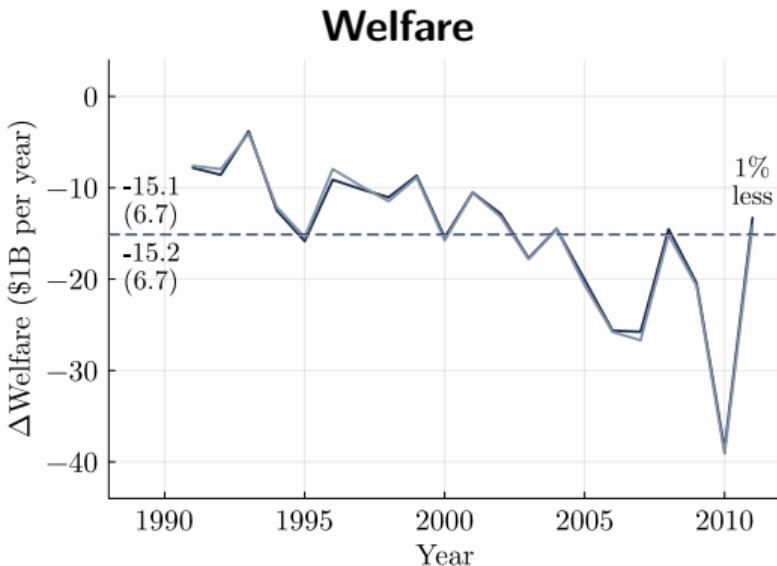
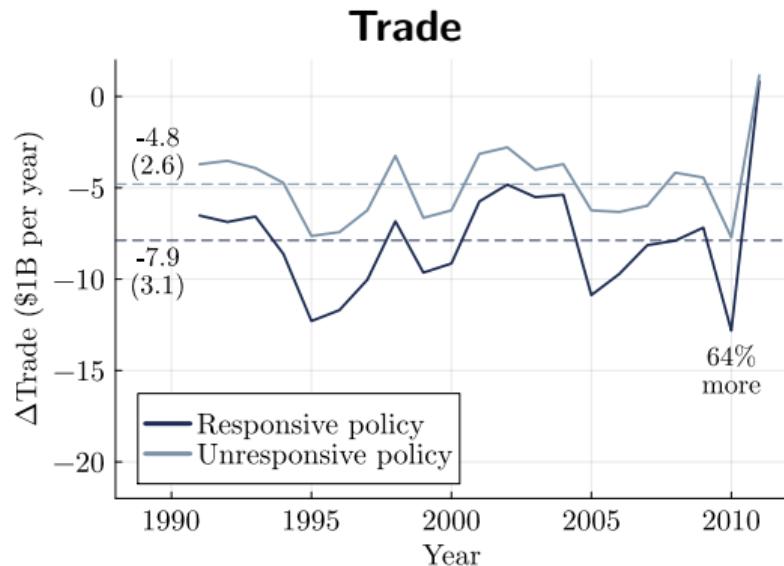
# Across countries, policy responses affect pre-existing distortions



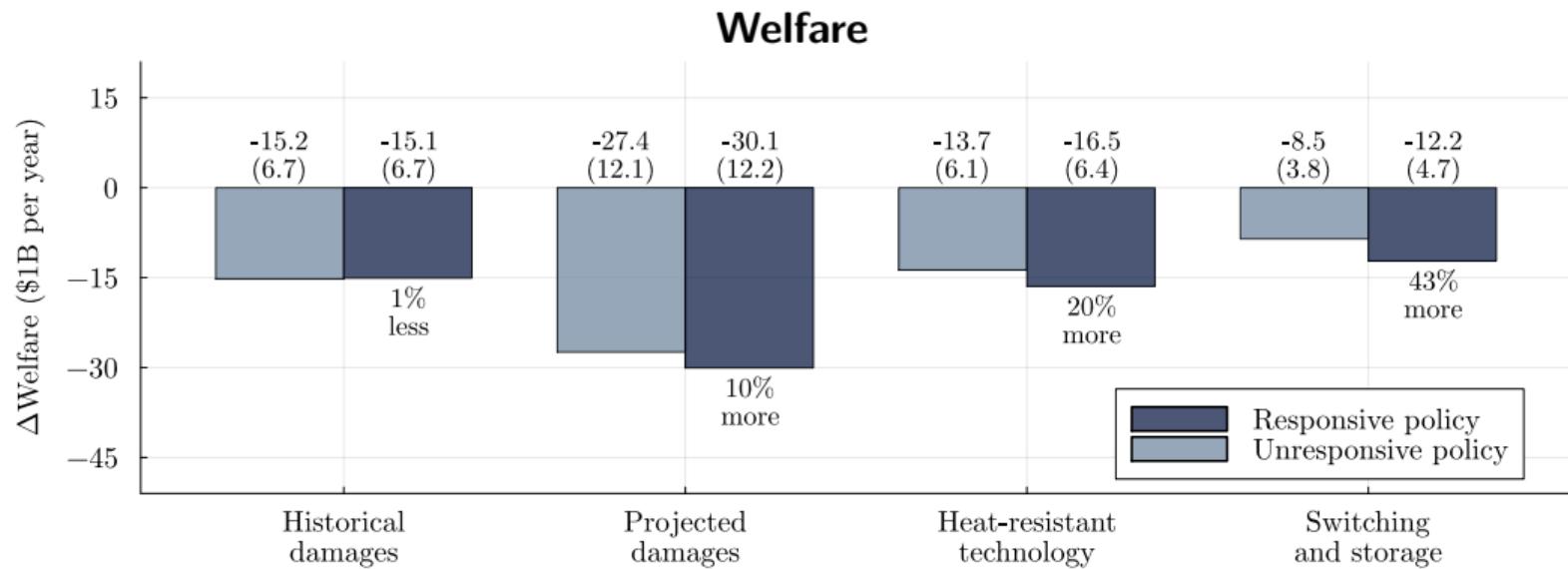
# Across countries, policy responses affect pre-existing distortions



# Over time, policy responses reduce trade



# In projections, policy responses worsen climate damages



# Conclusion

# Summary

- **Endogenous agricultural policy** complicates global adaptation
  - Domestic climate shocks induce pro-consumer policy
  - Redistributions losses and can intensify pre-existing distortions
- Broader implications
  - For global trade liberalization
  - And other adaptation mechanisms

# Appendix

# Crops

Major	Staple	Cash
maize	maize	cocoa
soy	soy	coffee
rice	rice	cotton
wheat	wheat	palm
potato	potato	sugar
tomato	tomato	tobacco
banana	onion	
cotton		
palm		
sugar		

# Sign of optimal trade policy

Back

$$\alpha^* = \frac{1}{\epsilon_m} \left( \frac{\lambda^G ((1-s)\epsilon_s + \epsilon_d) + \epsilon_m (\lambda^P(1-s) + \lambda^G s - \lambda^C)}{\lambda^G ((1-s)\epsilon_s + \epsilon_d) - (\lambda^P(1-s) + \lambda^G s - \lambda^C)} \right)$$

where  $s = m/q \leq 1$  is the import share.

## Corollary

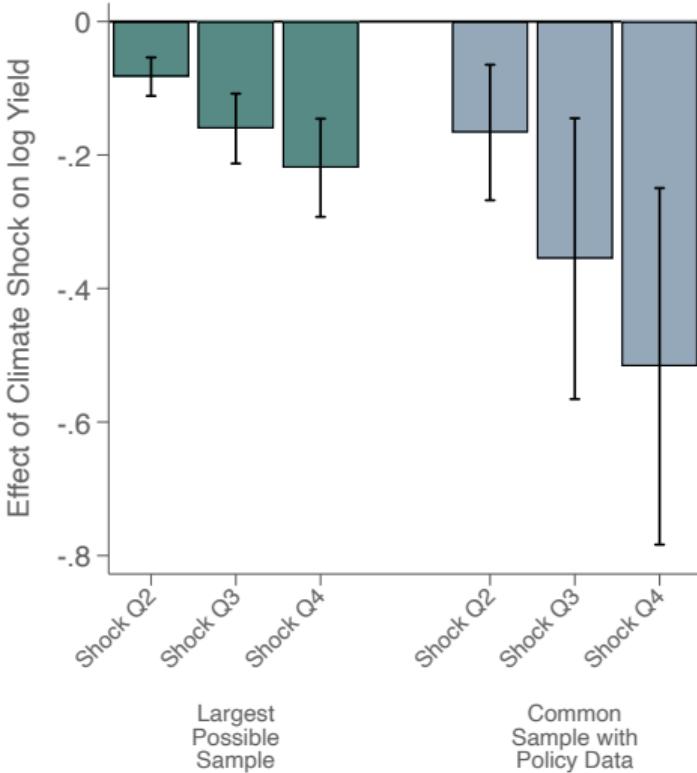
*The government supports producers ( $\alpha > 0$ ) if and only if*

$$\lambda^C < \lambda^P(1-s) + \lambda^G s + \frac{\lambda^G}{\epsilon_m} ((1-s)\epsilon_s + \epsilon_d) \quad (1)$$

# Result 0: extreme heat lowers yields

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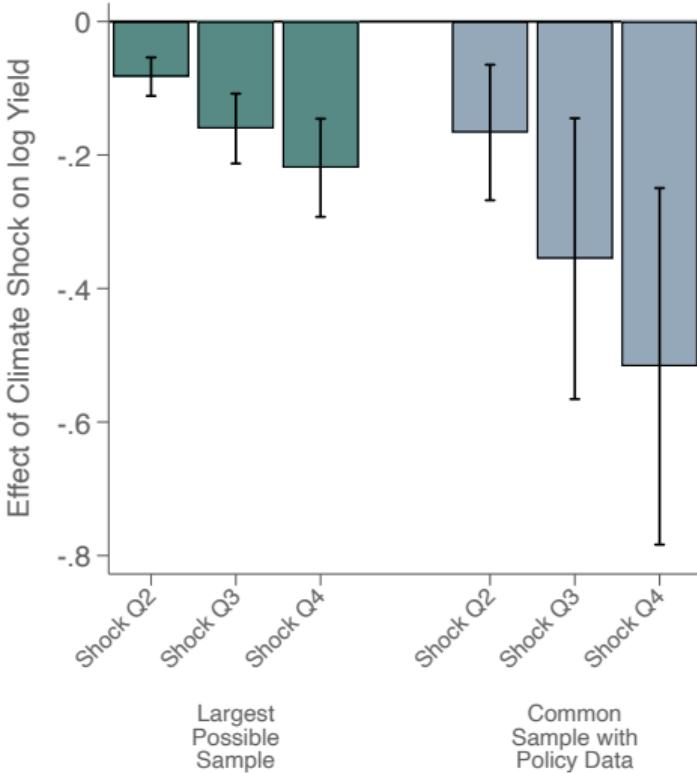
$$\log(\text{yield}_{\ellkt}) = \underbrace{f(\text{ExtremeHeat}_{\ellkt})}_{\text{Four quantiles}} + \gamma_{\ellt} + \delta_{kt} + \mu_{\ellk} + \varepsilon_{\ellkt}$$



# Result 0: extreme heat lowers yields

[Back](#)

$$\log(\text{yield}_{\ellkt}) = \underbrace{f(\text{ExtremeHeat}_{\ellkt})}_{\text{Four quantiles}} + \gamma_{\ellt} + \delta_{kt} + \mu_{\ellk} + \varepsilon_{\ellkt}$$



# Weaker effects with high debt stress

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	(1)	(2)	(3)	(4)
	Dependent Variable is NRA			
	Full Sample	Major Crops		
Q2 Extreme Heat Exposure	-0.0403 (0.0343)	-0.0768 (0.0515)	-0.151** (0.0728)	-0.0925* (0.0548)
Q3 Extreme Heat Exposure	-0.0620 (0.0514)	-0.122* (0.0683)	-0.323** (0.123)	-0.142** (0.0623)
Q4 Extreme Heat Exposure	-0.163** (0.0712)	-0.399*** (0.146)	-0.614*** (0.180)	-0.434*** (0.150)
Q2 Extreme Heat Exposure x Central Government Debt	0.0366 (0.0510)	-0.00497 (0.0739)	0.0784 (0.105)	-0.00673 (0.104)
Q3 Extreme Heat Exposure x Central Government Debt	0.110 (0.103)	0.0648 (0.101)	0.314* (0.179)	0.0646 (0.0977)
Q4 Extreme Heat Exposure x Central Government Debt	0.261** (0.129)	0.327*** (0.119)	0.675*** (0.248)	0.370** (0.147)
Country x Year Fixed Effects	Yes	Yes	Yes	Yes
Crop x Year Fixed Effects	Yes	Yes	Yes	Yes
Country x Crop Fixed Effects	Yes	Yes	Yes	Yes
Country x Crop Fixed Effects x Central Government Debt	No	No	Yes	No
Interactions with change in debt	No	No	No	Yes
Observations	13,544	6,260	6,260	6,020
R-squared	0.861	0.862	0.840	0.867

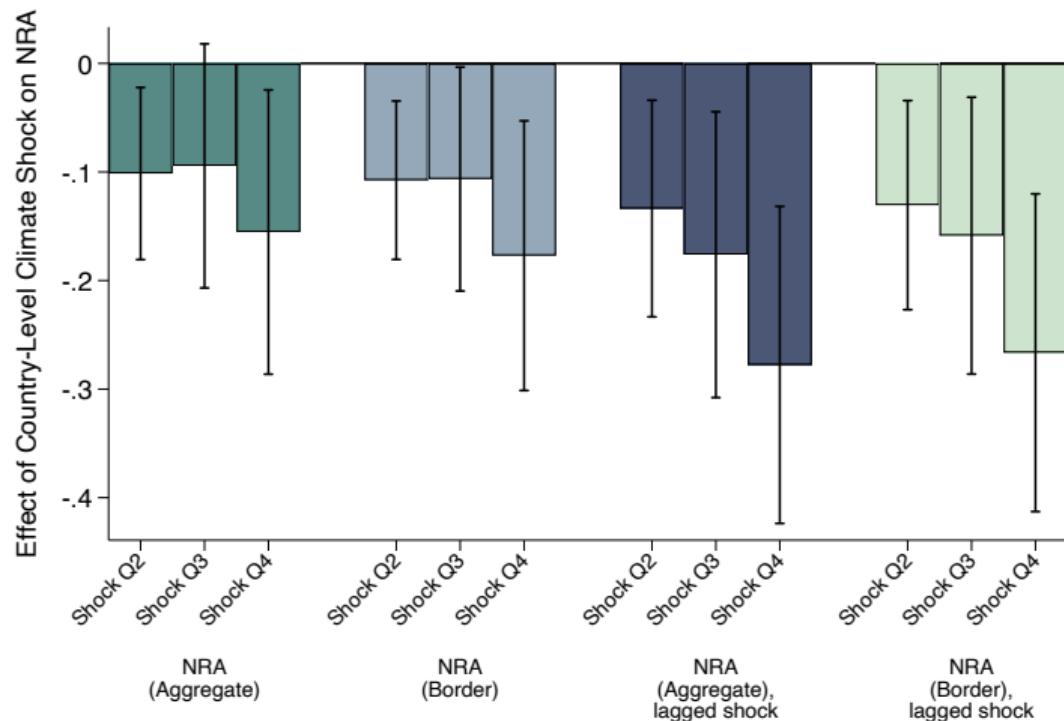
# Measuring policy: Direct measurement

Back

- ① United Nations' Trade Analysis Information System (TRAINS) database
  - Crop-level tariff measure for each country-year
  - Reported at the HS code level and linked to crops by hand
- ② Global Trade Alert (GTA) database
  - Sector-specific policy interventions broken down by HS code and policy type
  - Compute the total number of export-restricting and import-restricting policies
  - Shorter sample period: 2008-present

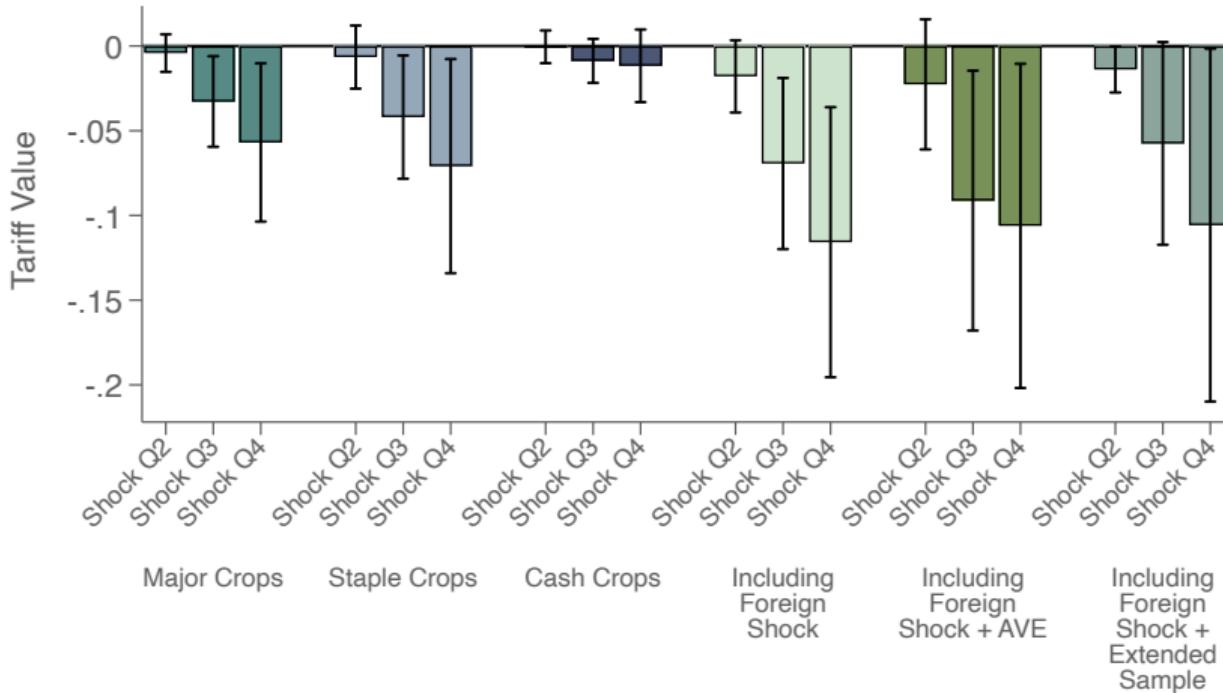
# Extreme heat induces pro-consumer policy: country level

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# Alternative measurement: border tariffs (TRAINs)

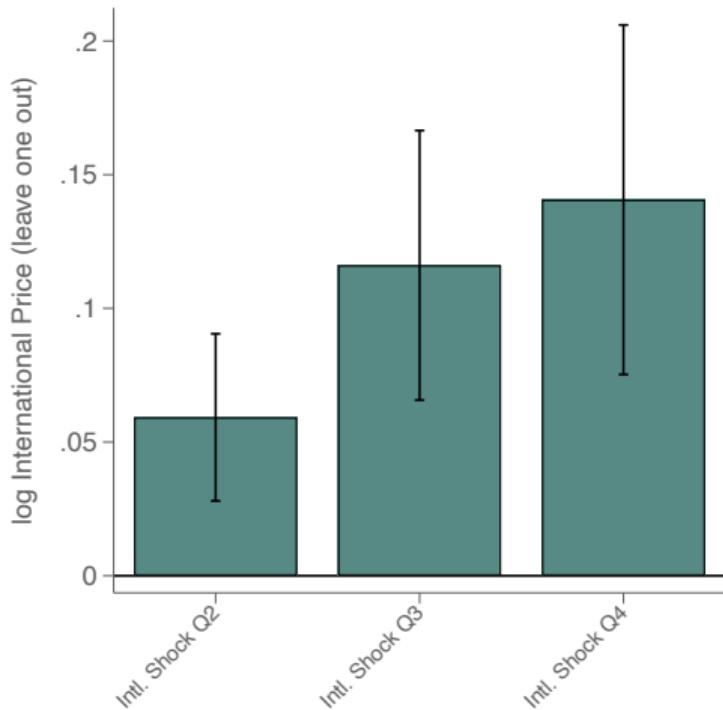
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⇒ Extreme heat leads to lower tariffs

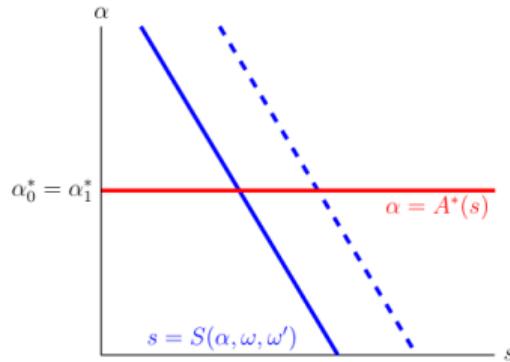
# Foreign shocks affect international prices

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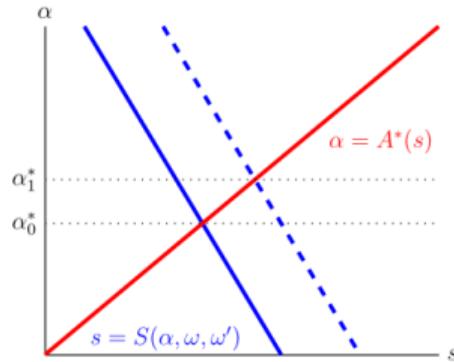


# Graphical proof and key intuition

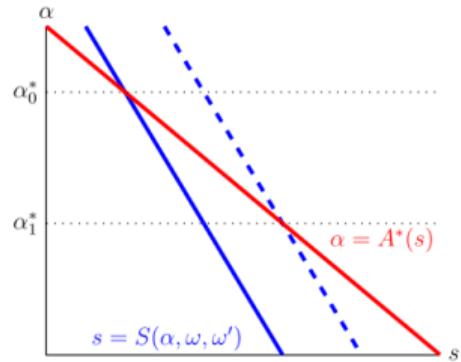
(a) Neutral



(b) Revenue Focused



(c) Constituent Focused

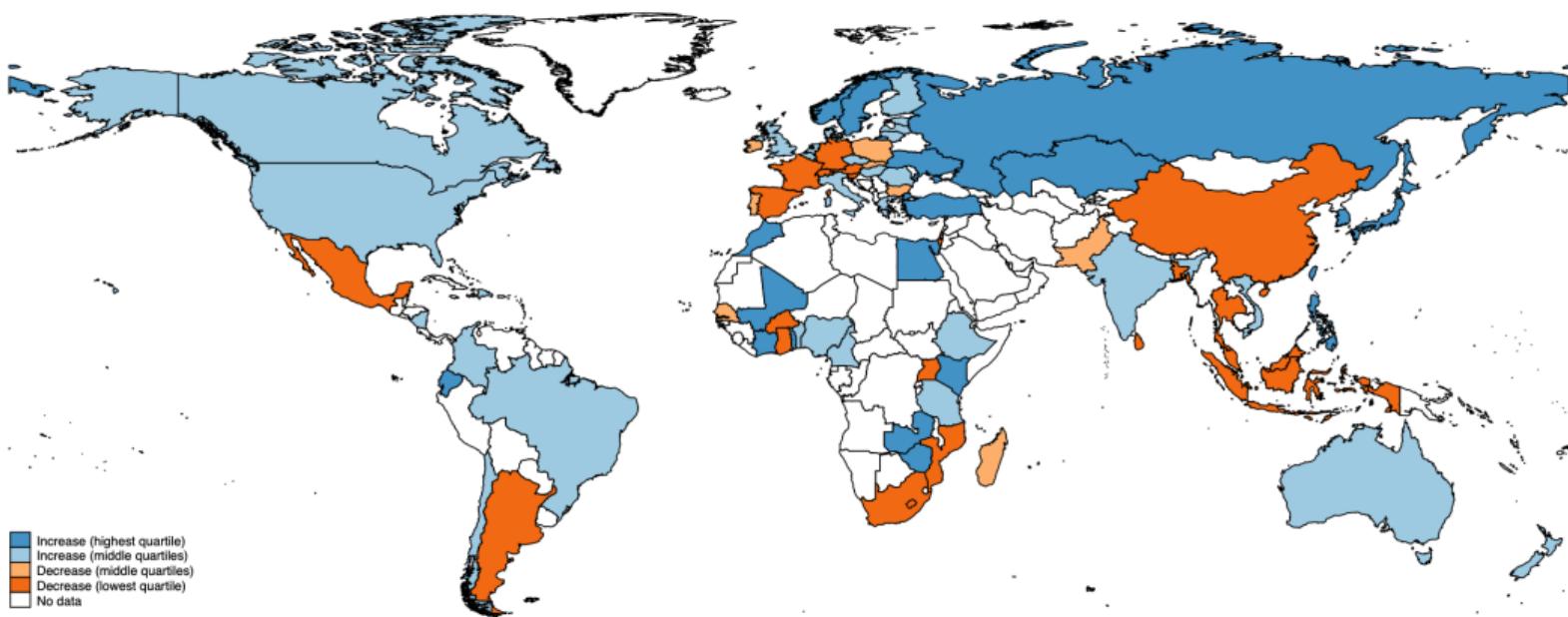


- Shocks increase import share  $s$  for any level of policy
- Revenue focus: high  $s \Rightarrow$  more profitable to tax imports
- Constituent focus: high  $s \Rightarrow$  best time to subsidize consumers, because losses are shifted onto foreign producers

# By country: % difference, responsive vs. unresponsive policy

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Observed 1991-2010



# Optimal trade policy

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## Proposition

*The optimal trade policy satisfies:*

$$\alpha^* = \frac{1}{\epsilon_m} \left( \frac{\lambda^G ((1-s)\epsilon_s + \epsilon_d) + \epsilon_m (\lambda^P(1-s) + \lambda^G s - \lambda^C)}{\lambda^G ((1-s)\epsilon_s + \epsilon_d) - (\lambda^P(1-s) + \lambda^G s - \lambda^C)} \right)$$

where  $s = m/q \leq 1$  is the import share.

- Policy can assist producers ( $\alpha > 0$ ) or consumers ( $\alpha < 0$ )
- If utilitarian ( $\lambda$ s equal), then  $\alpha^* = \frac{1}{\epsilon_m}$  (Ramsey rule )
- Otherwise *distributional considerations matter*

Positive vs. negative

# Microfoundations (I)

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- Households  $i \in \{1, \dots, N\}$ , consume agricultural good and money, operates farms
- Payoff in terms of agricultural consumption  $q_i \in \mathbb{R}_+$ , money consumption  $m_i \in \mathbb{R}$ , and production  $y_i \in \mathbb{R}_+$  is

$$\mathcal{U}_i = \mu_i^{\frac{1}{\epsilon_d}} \frac{q_i^{1-\frac{1}{\epsilon_d}}}{1 - \frac{1}{\epsilon_d}} - f(\omega)^{-\frac{1}{\epsilon_s}} \psi_i^{-\frac{1}{\epsilon_s}} \frac{y_i^{1+\frac{1}{\epsilon_s}}}{1 + \frac{1}{\epsilon_s}} + m_i, \quad (2)$$

- Budget constraint  $px_i + m_i \leq py_i + T_i$
- Transfer rule  $T_i = \xi_i \mathcal{G}$
- Government objective  $\mathcal{W} = \sum_{i=1}^N \lambda_i \mathcal{U}_i$ , with  $\sum_i \lambda_i = 1$ .

## Microfoundations (II)

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### Lemma

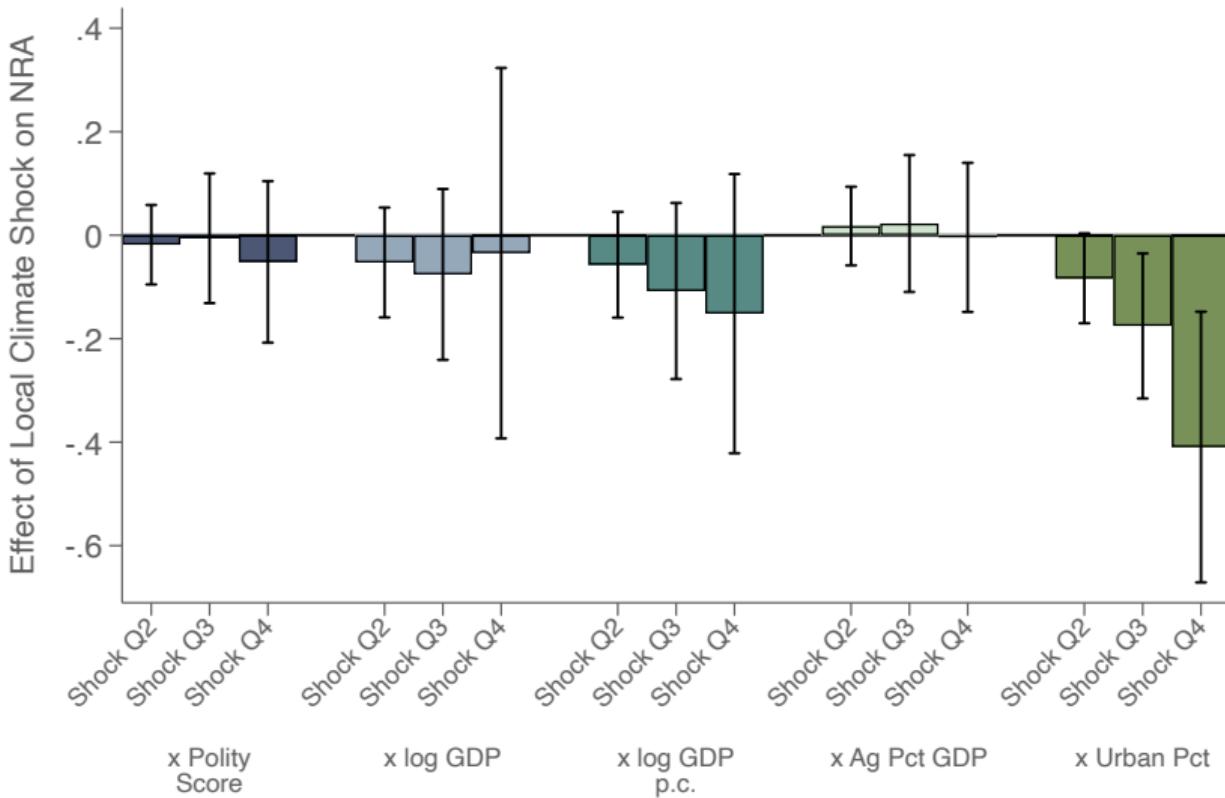
The competitive equilibrium in this economy coincides with the “supply and demand” representation described in the main model, where  $Q_0 = \sum_i^N \mu_i$  and  $Y_0(\omega) = f(\omega) \sum_i^N \psi_i$ . The government’s preferences coincide with those in the main model, with

$$\lambda^C = \sum_{i=1}^N \tilde{\mu}_i \lambda_i, \quad \lambda^P = \sum_{i=1}^N \tilde{\psi}_i \lambda_i, \quad \lambda^G = \sum_{i=1}^N \xi_i \lambda_i \quad (3)$$

and where  $\tilde{\mu}_i = \mu_i / (\sum_{j=1}^N \mu_j)$  is household  $i$ ’s share of domestic consumption and  $\tilde{\psi}_i = \psi_i / (\sum_{j=1}^N \psi_j)$  is household  $i$ ’s share of domestic production. If the social welfare function is utilitarian, such that  $\lambda_i = 1$  for all  $i$ , then  $\lambda^C = \lambda^P = \lambda^G = 1$ .

# Additional Heterogeneity

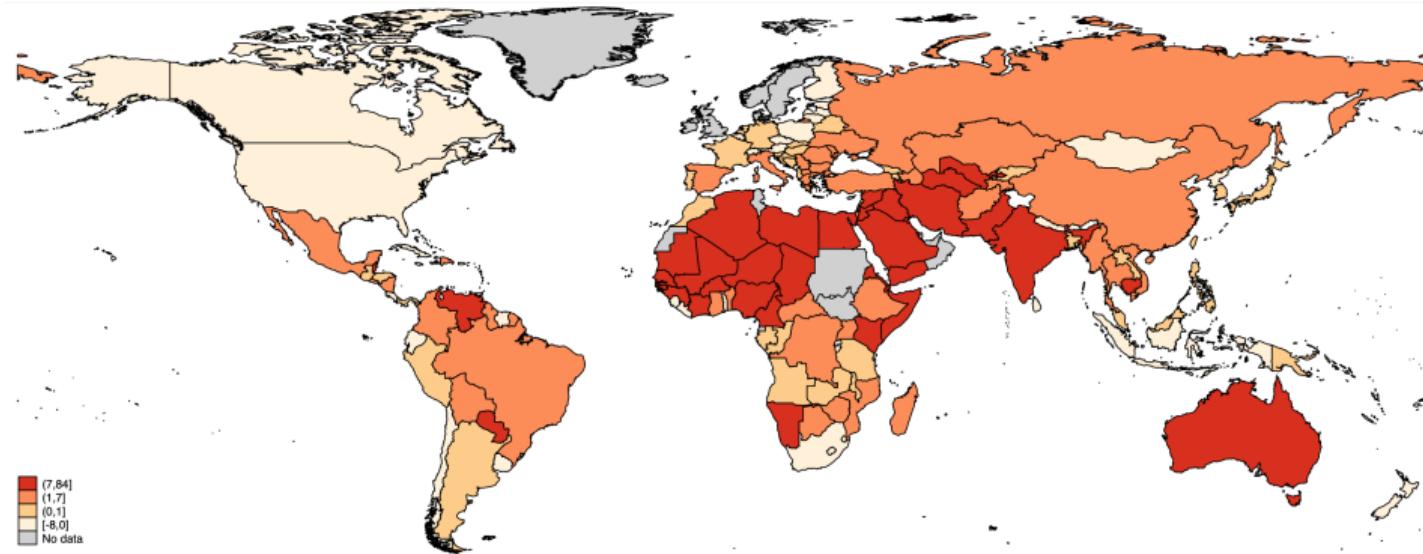
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# The global variation in temperature shocks

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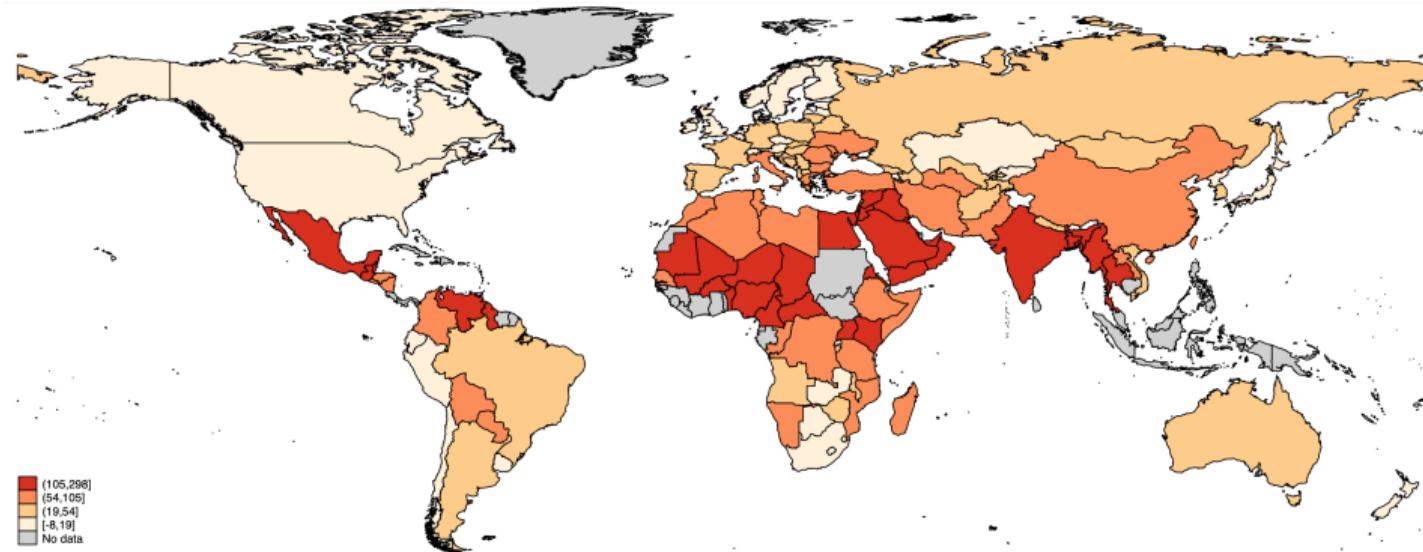
Change in Maize GDD, 1980s to 2010s



# The global variation in temperature shocks

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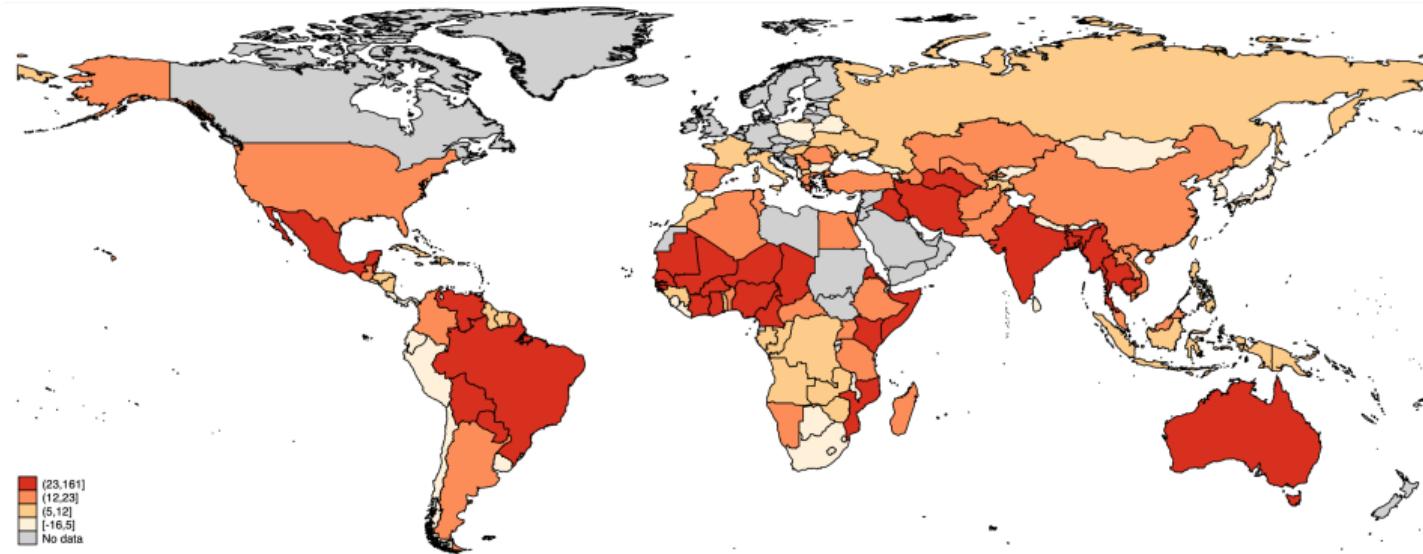
Change in Wheat GDD, 1980s to 2010s



# The global variation in temperature shocks

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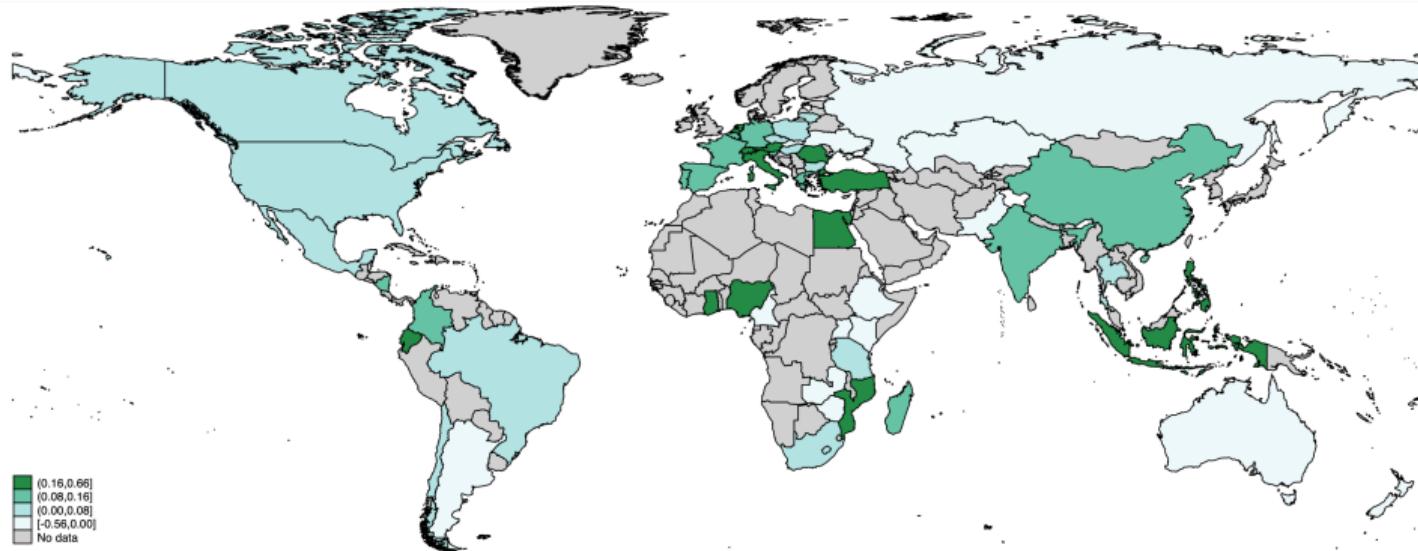
Change in Rice GDD, 1980s to 2010s



# The global variation in NRA

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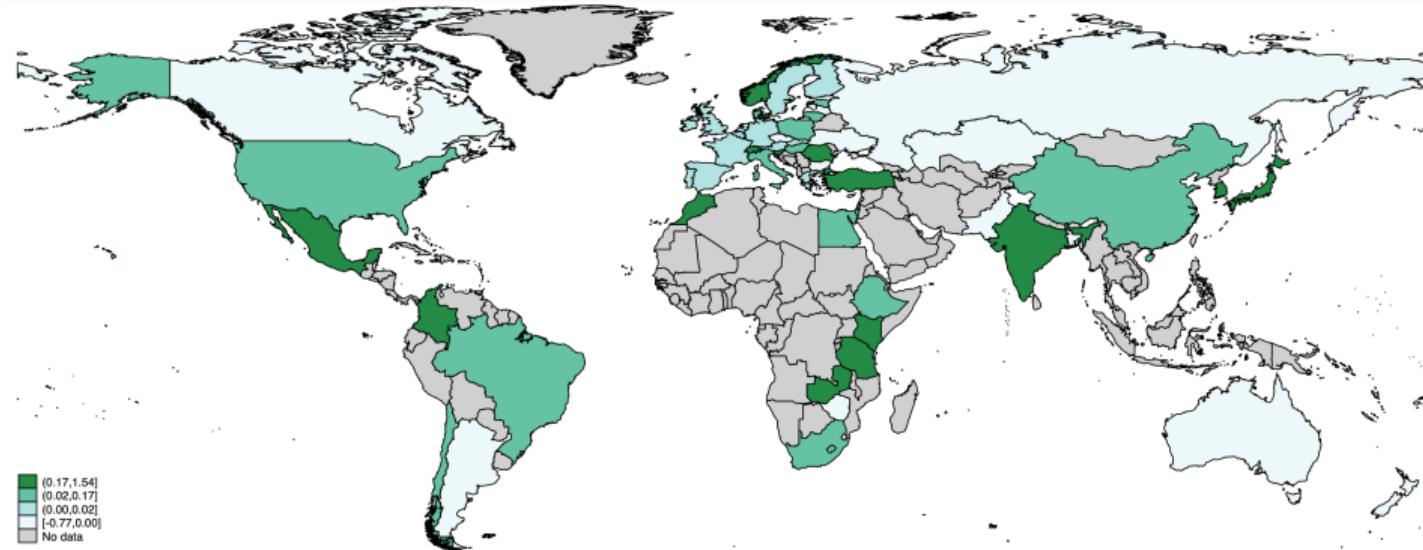
Average Value of Maize NRA, 2001-2010



# The global variation in NRA

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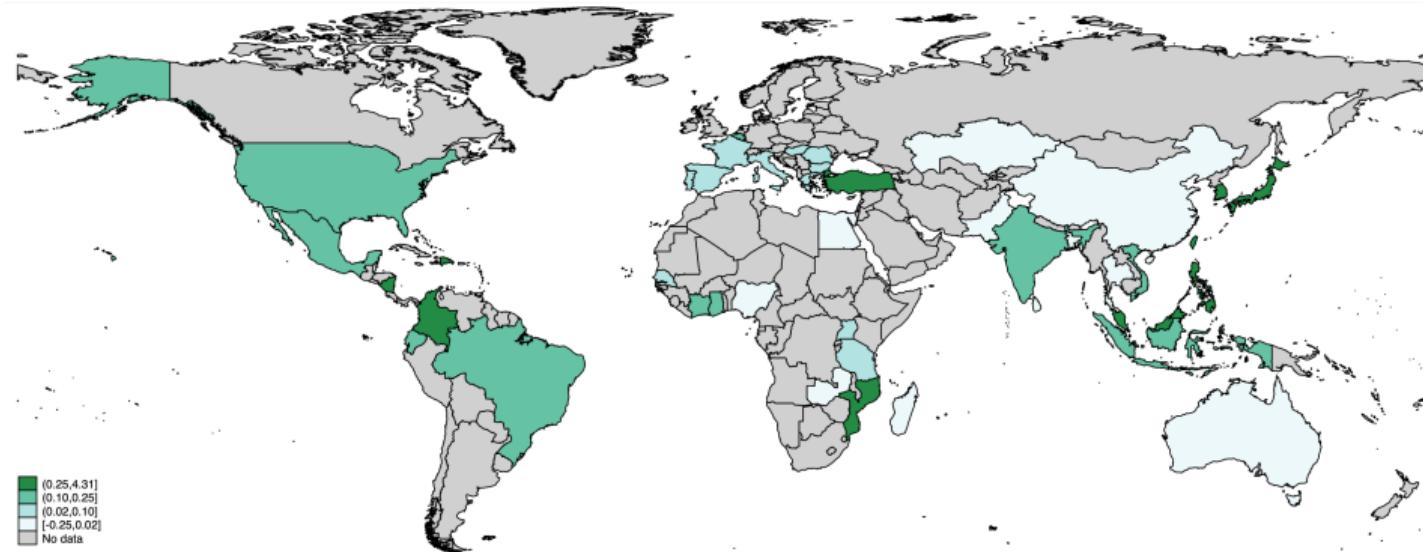
Average Value of Wheat NRA, 2001-2010



# The global variation in NRA

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Average Value of Rice NRA, 2001-2010



# Effect on policy persists for several years

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$$\text{NRA}_{\ell kt} = \sum_{s=-3}^3 g(\text{ExtremeHeat}_{\ell kt+s}) + \gamma_{\ell t} + \delta_{kt} + \mu_{\ell k} + \varepsilon_{\ell kt}$$

