Food Policy in a Warming World

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November 8, 2024

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*

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Questions

1. **How do governments intervene in response to agricultural climate 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 policy response to climate shocks
   - Government considers constituent welfare and fiscal revenue

3. **Quantification:** how policy responses affect incidence of climate damages
   - Policy responses shield domestic consumers by fully stabilizing prices

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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 ℓ, crop k, year t, aggregating over cells c

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

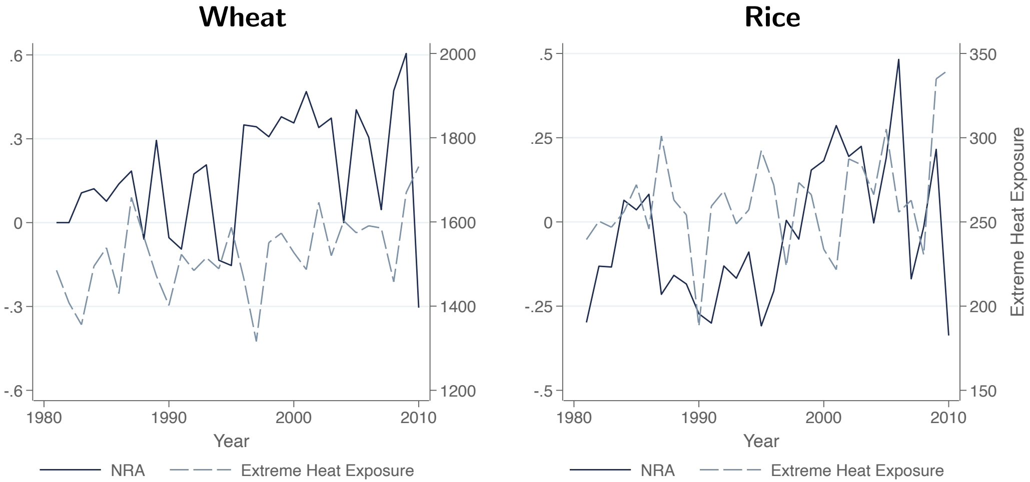
Policy: nominal rate of assistance

- "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



NRA variation | Shock variation | Yield effects

Empirical Results

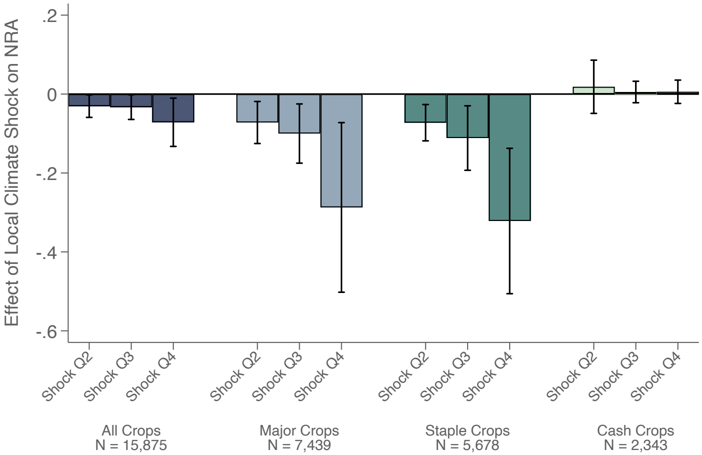
1. How does extreme heat affect trade policy?

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

- Country ℓ, 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

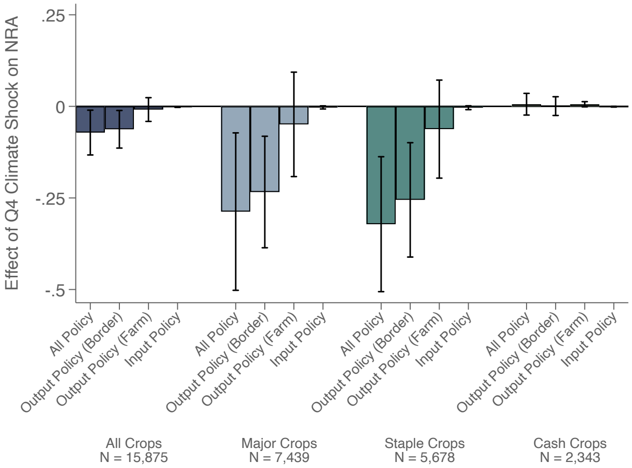
Extreme heat induces pro-consumer policy



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

Country level

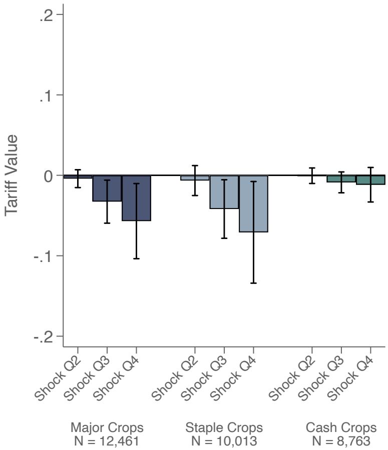
Effects concentrated in border policies



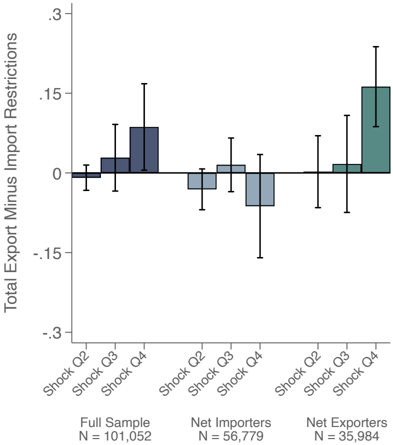
$$\text{NRA}^{\text{type}}_{\ell kt} = g(\text{ExtremeHeat}_{\ell kt}) + \gamma_{\ell t} + \delta_{kt} + \mu_{\ell k} + \varepsilon_{\ell kt}$$

With lower import tariffs and more export restrictions

TRAINS import tariffs



GTA export restrictions



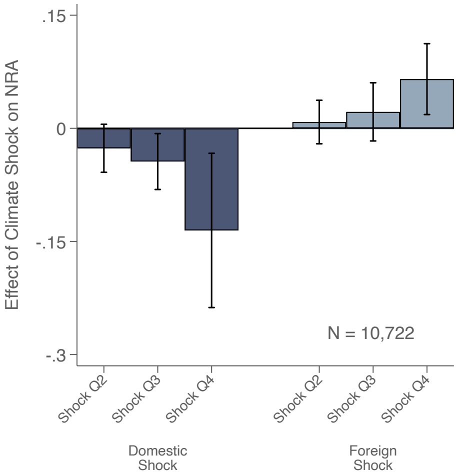
$$\text{Policy}_{\ell kt} = g(\text{ExtremeHeat}_{\ell kt}) + \gamma_{\ell t} + \delta_{kt} + \mu_{\ell k} + \varepsilon_{\ell kt}$$

2. How do foreign adverse shocks affect trade policy?

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

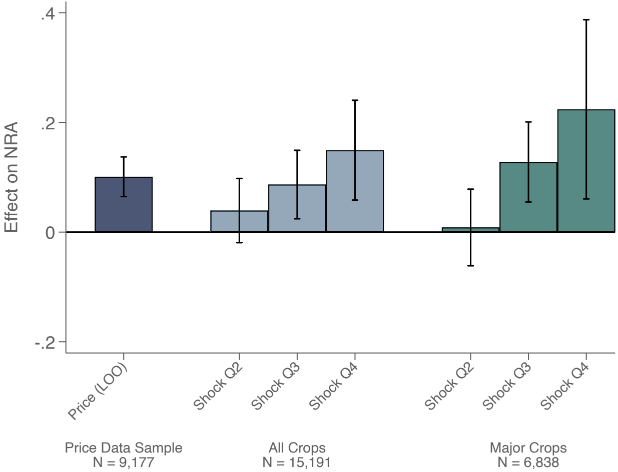
- Country ℓ, crop k, year t, quartile dummies $g(\cdot)$ and $h(\cdot)$ International prices
- Fixed effects by country-year, crop-year, country-crop
- ForeignExtremeHeat: trade partner shocks, weighted by pre-period import shares

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



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

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

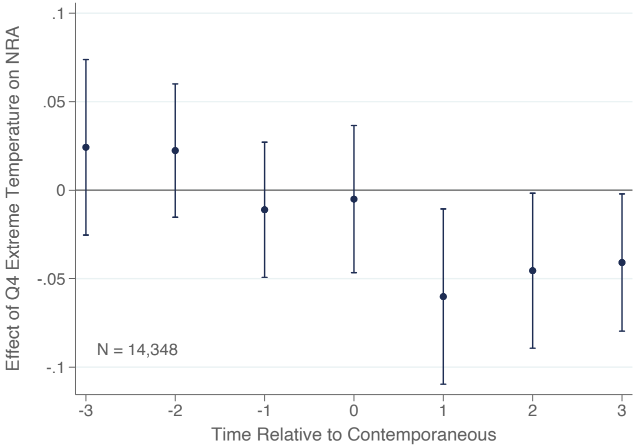
- Longer-run policy: country ℓ, crop k, years $t+s$

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

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

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

Annual shocks have persistent effects



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

Decadal shocks have similar effects

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

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

4. Does political economy drive policy effects?

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

- Country ℓ, crop k, year t, $g(\cdot)$ and $h(\cdot)$ quartile dummies — Other heterogeneity
- Fixed effects by country-year, crop-year, country-crop
- 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	

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

Theory

Model

- Terms-of-trade manipulation (Johnson 1951)
- Redistributive motives (Grossman & Helpman 1994; Bates 2014)

- Market clearing $q = y + m$

$$\underbrace{q = Q_0 p^{-\epsilon_d}}_{\text{Demand}} \qquad \underbrace{y = Y_0 e^{-\omega} p^{\epsilon_s}}_{\text{Domestic supply, shock } \omega} \qquad \underbrace{m = M_0 p^{\epsilon_m}}_{\text{Foreign net supply}}$$

- Tax wedge α 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

Response to shocks depends on constituent vs. revenue focus

The government is **constituent-focused** if

$$\epsilon_s(\lambda^C - \lambda^G) + \epsilon_d(\lambda^P - \lambda^G) > 0$$

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

Proposition: Food Policy and Climate Shocks

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

Intuition for both cases

- **Revenue focus:** high import share $\Rightarrow$ more profitable to tax imports
- **Constituent 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 climate shocks on policy and production
    - Policy responds to shocks in the empirically observed way
    - Calibrate $\epsilon_d = 2.82$, $\epsilon_s = 2.46$ from Costinot, Donaldson, and Smith (2016)

$$
\begin{array}{lr@{\;}l}
\text{demand} & \log q_{\ell k} &= \log q^0_{\ell k} - \epsilon_d \log[(1+\alpha_{\ell k})p_k] \\
\text{supply} & \log y_{\ell k} &= \log y^0_{\ell k} + \epsilon_s \log[(1+\alpha_{\ell k})p_k] - f(\text{ExtremeHeat}_{\ell k}) \\
\text{NRA} & \alpha_{\ell k} &= \alpha^0_{\ell k} - g(\text{ExtremeHeat}_{\ell k}) + h(\text{ForeignExtremeHeat}_{\ell k})
\end{array}
$$

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

How does trade policy affect global adaptation to climate shocks?

1. "Baseline" of minimum observed heat (1991-2010)
   - In-sample shocks as observed heat (1991-2010)
   - Out-of-sample shocks as projected heat (2090-2100 from GFDL-ESM4)
2. Apply shocks to 1991-2010 data, then compute
   - Trade policy, equilibrium prices, production, and consumption
3. Compare changes in prices, surplus, and welfare relative to baseline
   - Under responsive vs. fixed trade policy

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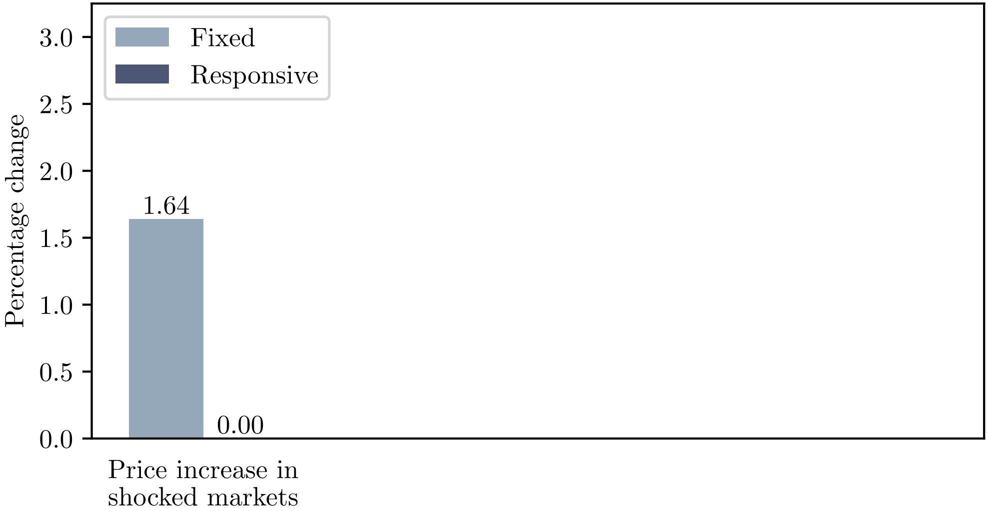
Stabilizing domestic prices offloads losses to rest of the world



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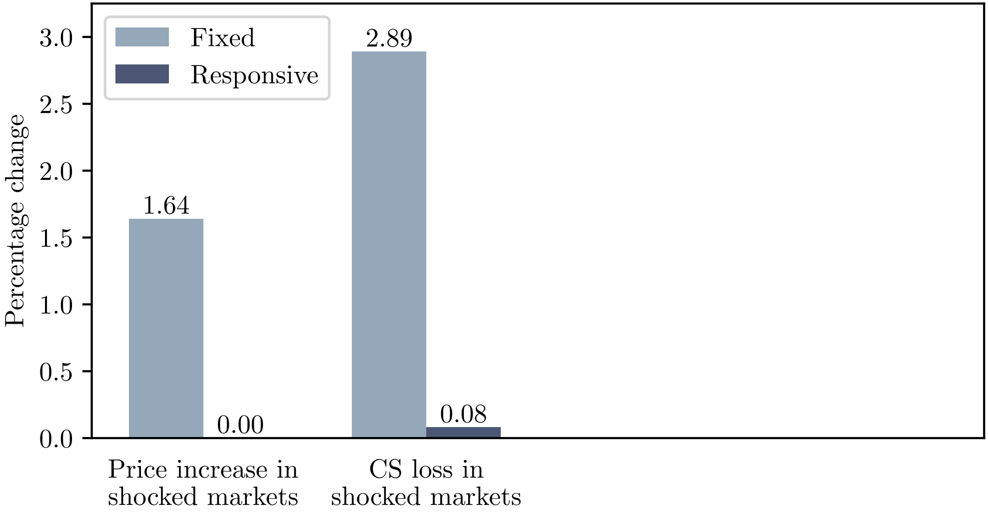

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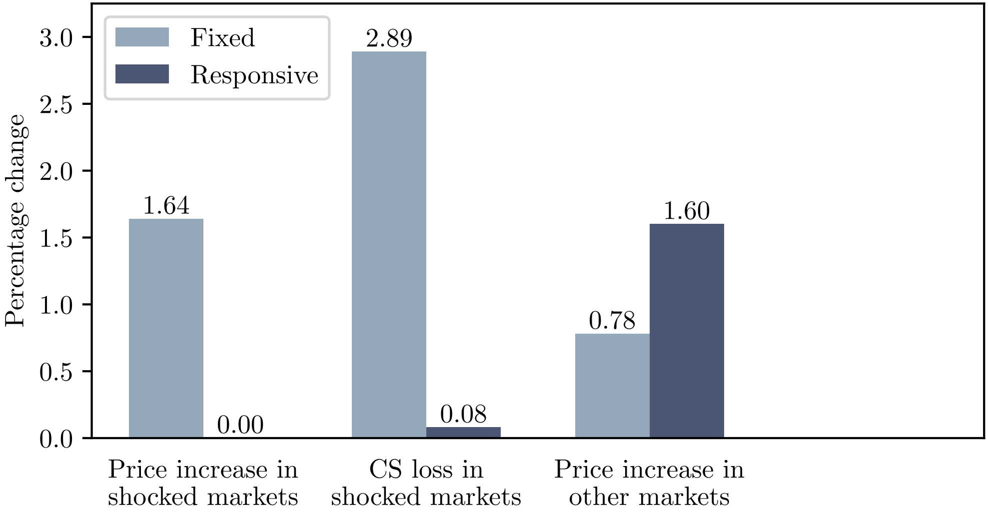

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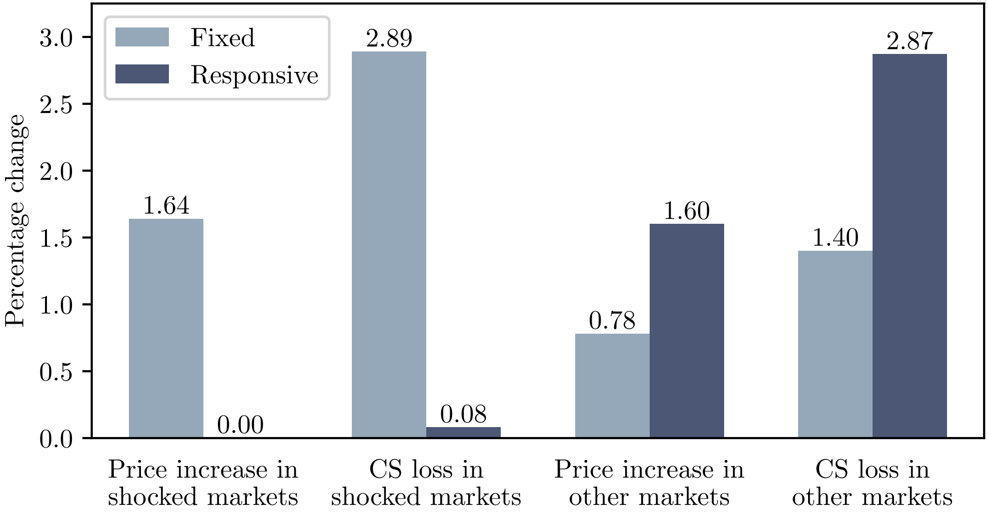
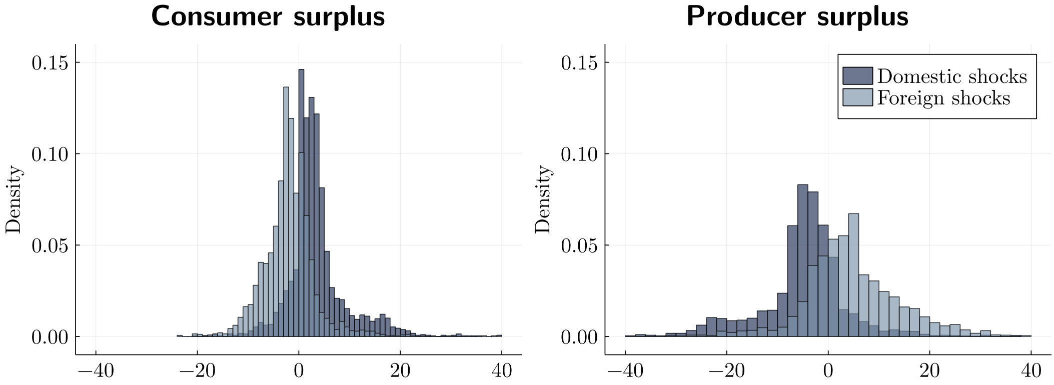


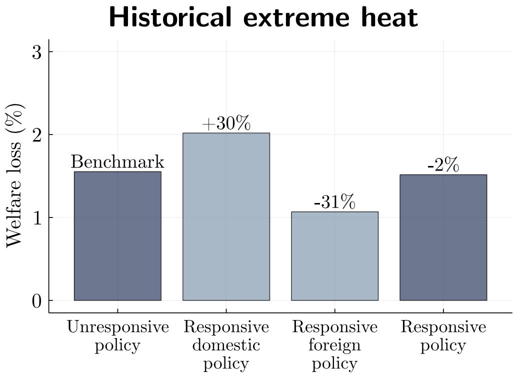
Shocked countries protect consumers at expense of producers



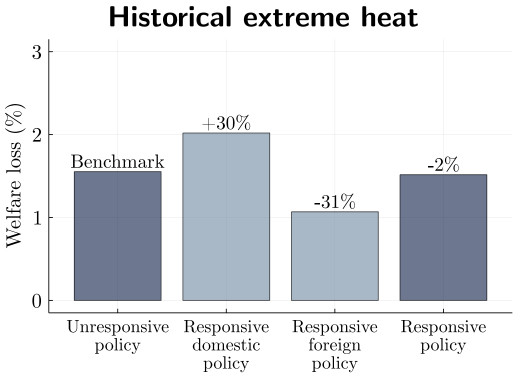
$\Delta\mathcal{C}^R - \Delta\mathcal{C}^U$: Consumer surplus effects under responsive vs. unresponsive policy (%)

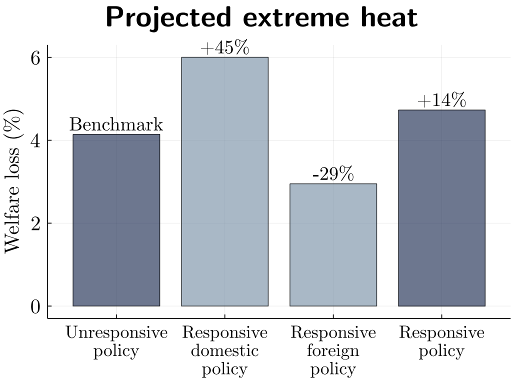
$\Delta\mathcal{P}^R - \Delta\mathcal{P}^U$: Producer surplus effects under responsive vs. unresponsive policy (%)

Aggregate effects net out in sample



Aggregate effects net out in sample but are negative for climate change





In projections, policy changes amplify pre-existing distortions

		Historical	Projected
		Increases $\lvert\alpha\rvert$	Increases $\lvert\alpha\rvert$
Baseline distortion is:	Positive ($\alpha > 0$)	18%	33%
	Negative ($\alpha \leq 0$)	23%	58%

- Responsive policy can increase (or decrease) trade barriers and deadweight loss

Heterogeneity

1. In policy responses
   - To domestic and foreign shocks
   - By region, income, and agricultural share
2. In climate shocks
   - Pre-existing distortions
   - Spatial correlation
3. In welfare impacts

Conclusion

Summary

- **Endogenous agricultural policy** complicates global adaptation
  - Domestic climate shocks induce pro-consumer policy
  - Redistributes 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

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

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

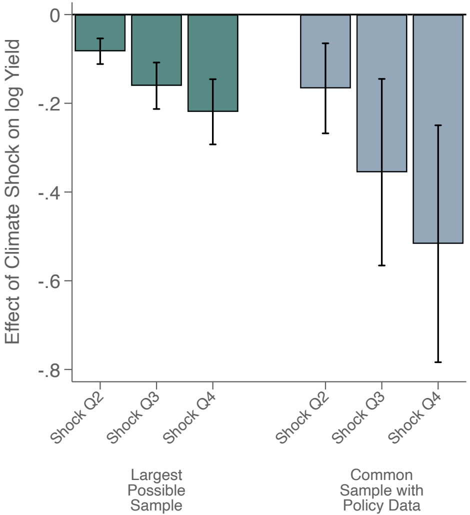
Corollary

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

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

Result 0: extreme heat lowers yields Back

$$\log(\text{yield}_{\ell kt}) = \underbrace{f(\text{ExtremeHeat}_{\ell kt})}_{\text{Four quantiles}} + \gamma_{\ell t} + \delta_{kt} + \mu_{\ell k} + \varepsilon_{\ell kt}$$



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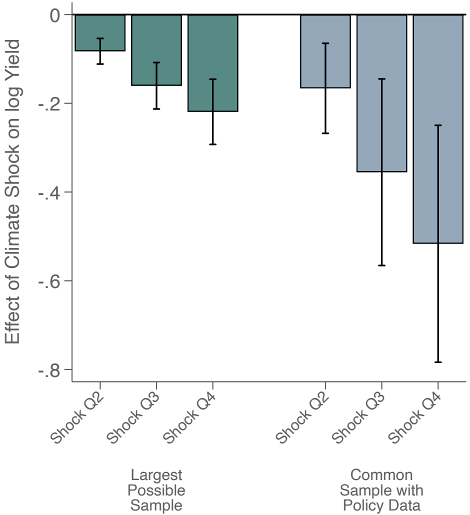


Weaker effects with high debt stress

Back

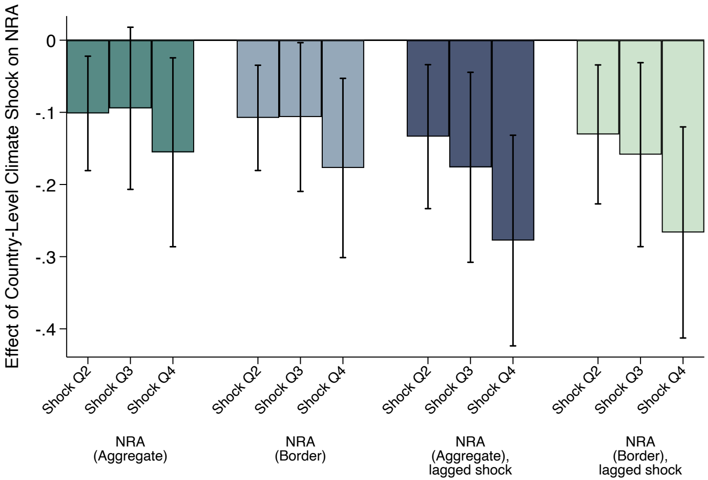
	(1)	(2)	(3)	(4)
	Dependent Variable is NRA			
	Full Sample		Major Crops	
Q2 Extreme Heat Exposure	-0.0403	-0.0768	-0.151**	-0.0925*
	(0.0343)	(0.0515)	(0.0728)	(0.0548)
Q3 Extreme Heat Exposure	-0.0620	-0.122*	-0.323**	-0.142**
	(0.0514)	(0.0683)	(0.123)	(0.0623)
Q4 Extreme Heat Exposure	-0.163**	-0.399***	-0.614***	-0.434***
	(0.0712)	(0.146)	(0.180)	(0.150)
Q2 Extreme Heat Exposure x Central Government Debt	0.0366	-0.00497	0.0784	-0.00673
	(0.0510)	(0.0739)	(0.105)	(0.104)
Q3 Extreme Heat Exposure x Central Government Debt	0.110	0.0648	0.314*	0.0646
	(0.103)	(0.101)	(0.179)	(0.0977)
Q4 Extreme Heat Exposure x Central Government Debt	0.261**	0.327***	0.675***	0.370**
	(0.129)	(0.119)	(0.248)	(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

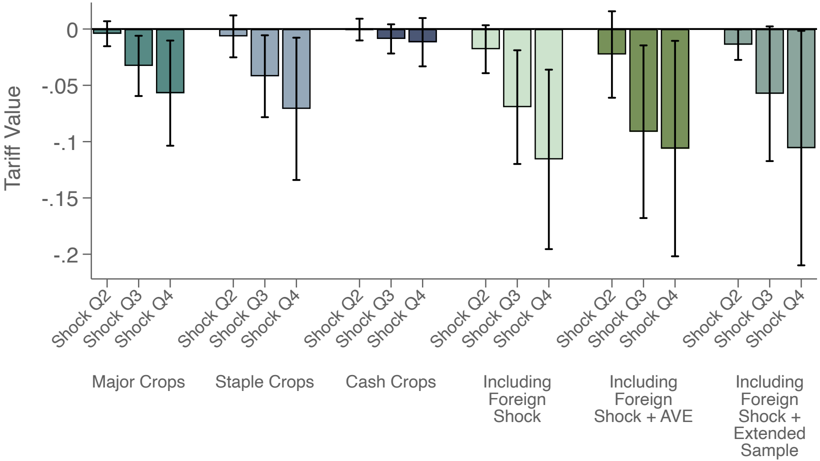
1. United Nations' Trade Analysis Information System (TRAINS) database
   - Crop-level tariff measure for each country-year
   - Reported at the HS code level and linked to crops by hand
2. Global Trade Alert (GTA) database
   - Sector-specific policy interventions broken down by HS code and policy type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

Extreme heat induces pro-consumer policy: country level

Back

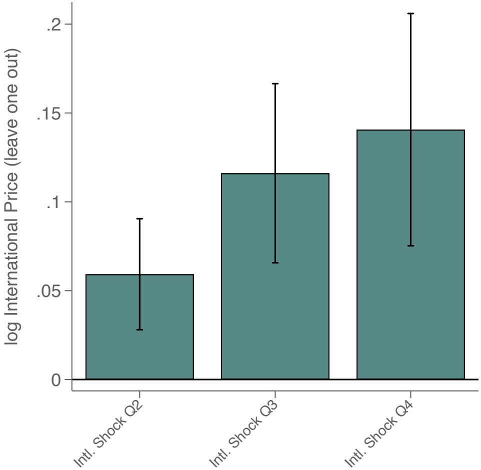


Alternative measurement: border tariffs (TRAINS) Back

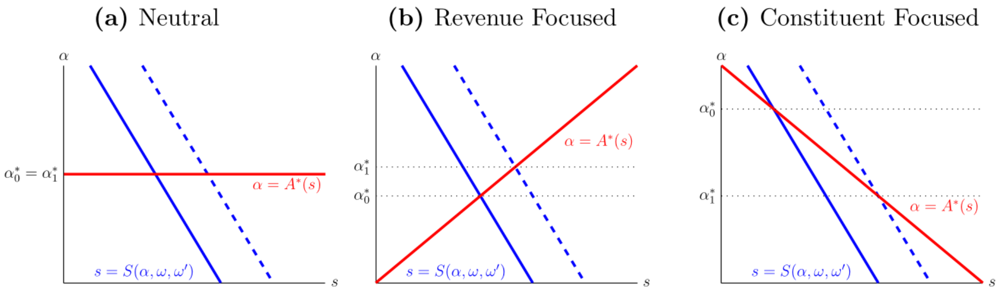


$\Longrightarrow$ Extreme heat leads to lower tariffs

Foreign shocks affect international prices Back



Graphical proof and key intuition

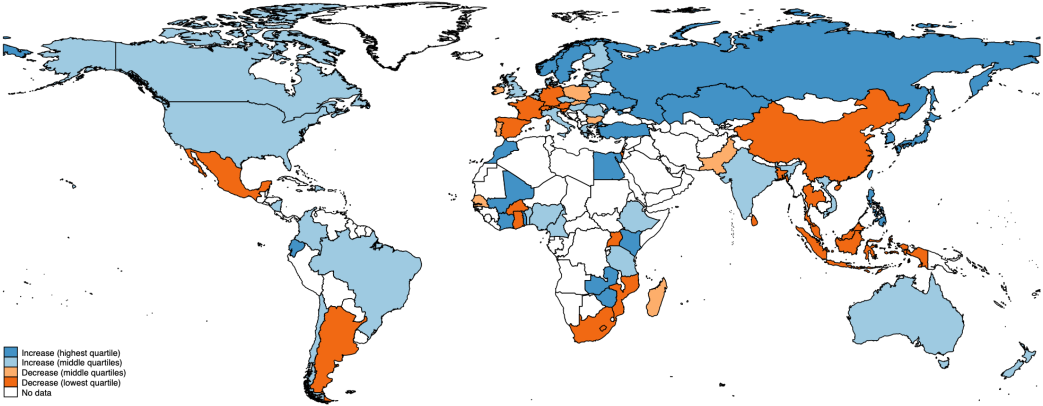


- Shocks increase import share s for any level of policy
- Revenue focus: high $s \Rightarrow$ more profitable to tax imports
- Constituent focus: high $s \Rightarrow$ best time to subsidize consumers, because losses are shifted onto foreign producers

By country: % difference, responsive vs. unresponsive policy

Back

Observed 1991-2010



Optimal trade policy

Back

Proposition

The optimal trade policy satisfies:

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

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

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

Positive vs. negative

Microfoundations (I) Back

- Households $i \in \{1, \ldots, N\}$, 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

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

- 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) Back

Lemma

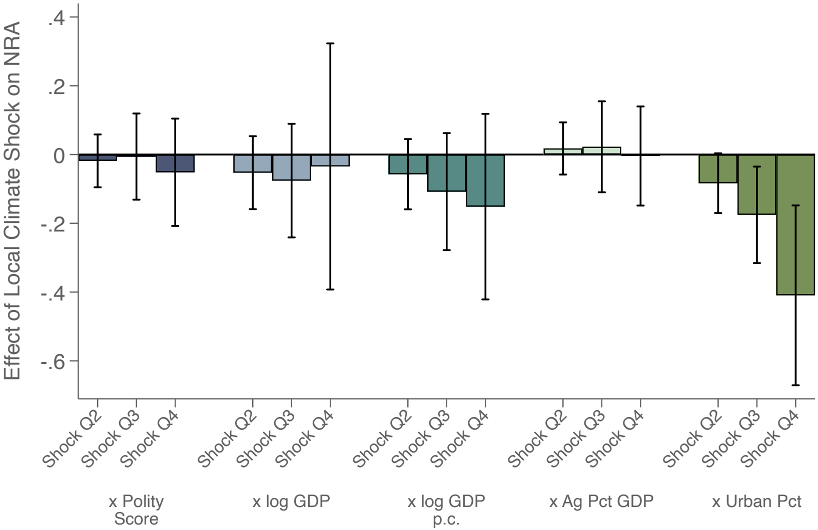
The competitive equilibrium in this economy coincides with the "supply and demand" representation described in the main model, where $Q_0 = \sum_i^N \mu_i$ *and* $Y_0(\omega) = f(\omega) \sum_i^N \psi_i$. *The government's preferences coincide with those in the main model, with*

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

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* $\lambda^C = \lambda^P = \lambda^G = 1$.

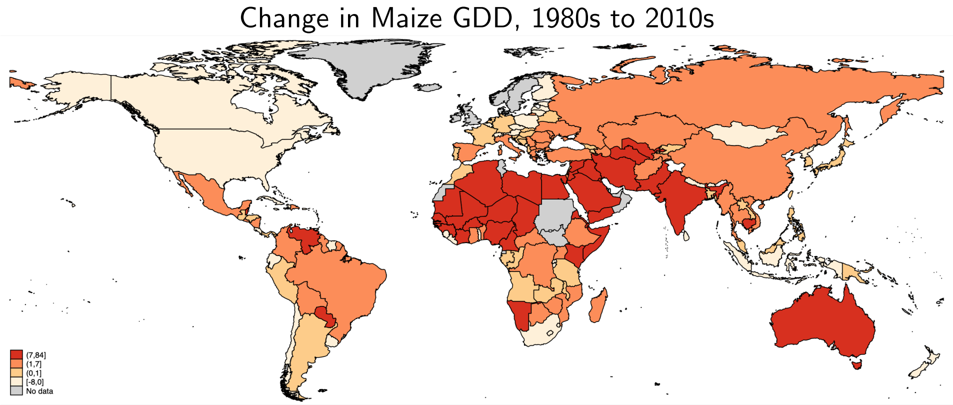
Additional Heterogeneity

Back



The global variation in temperature shocks

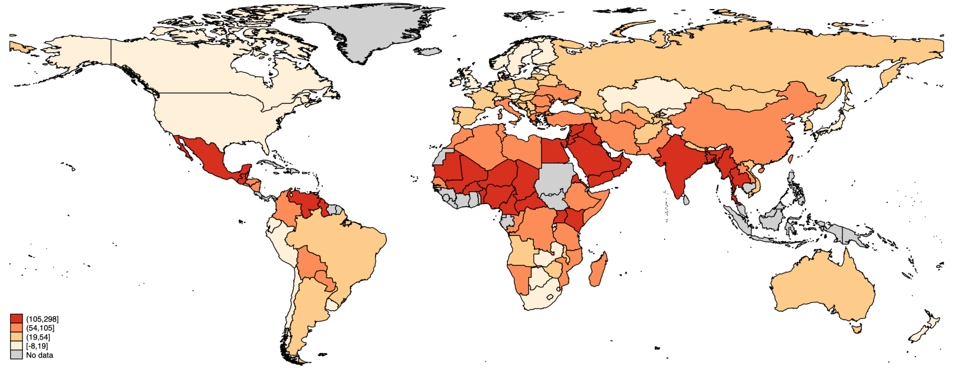
Back



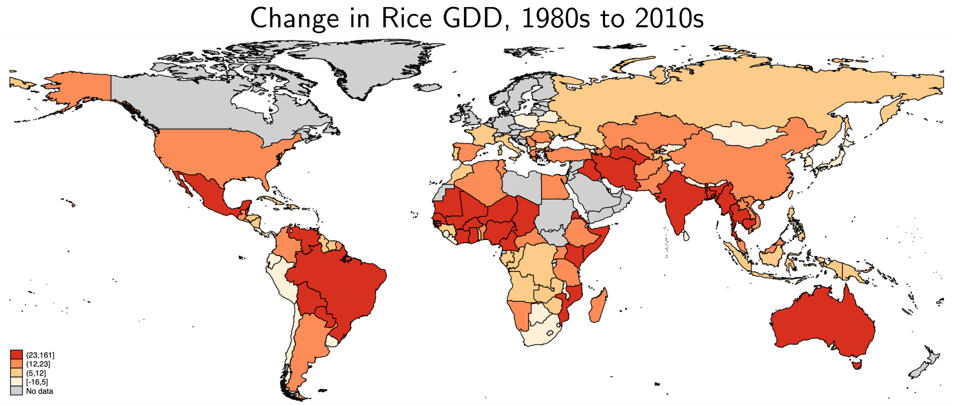
The global variation in temperature shocks

Back

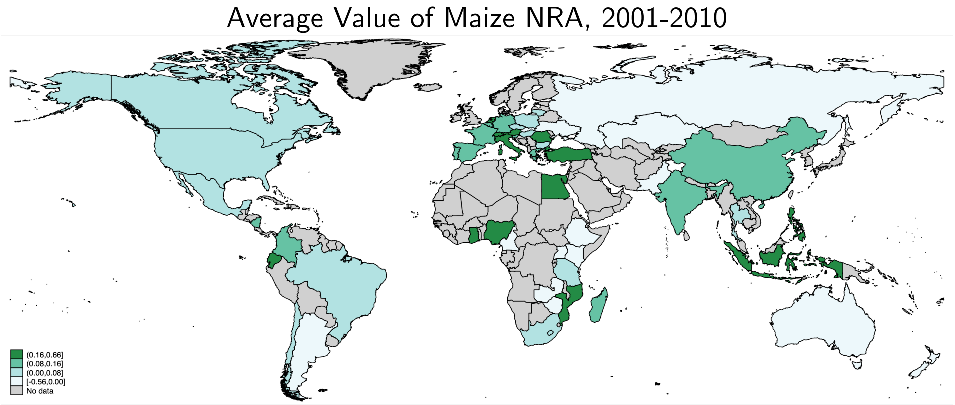
Change in Wheat GDD, 1980s to 2010s



The global variation in temperature shocks Back

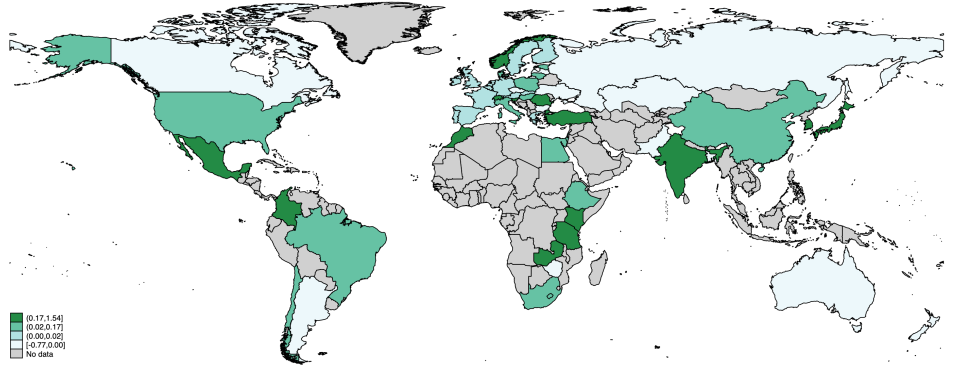


The global variation in NRA Back



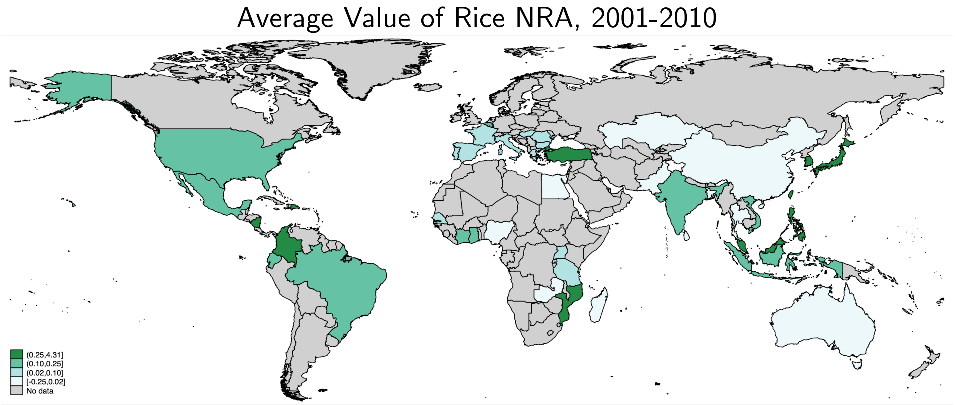
The global variation in NRA Back

Average Value of Wheat NRA, 2001-2010



The global variation in NRA

Back



Effect on policy persists for several years Back

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