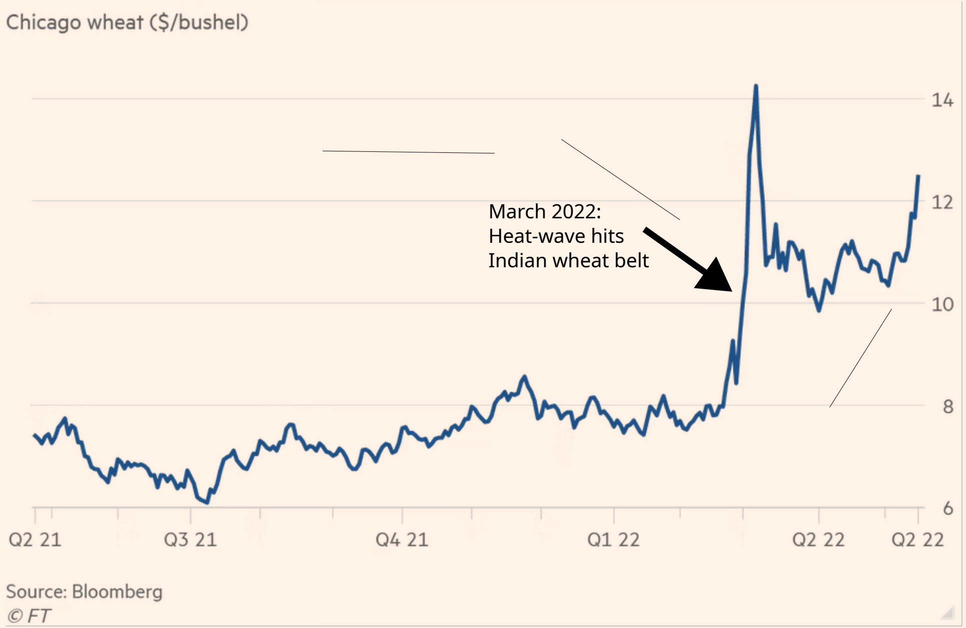
Food Policy in a Warming World

Allan Hsiao
Princeton University

Jacob Moscona
Harvard University

Karthik Sastry
Princeton University

March 4, 2024


Chicago wheat ($/bushel)
14
12
10
8
6
March 2022:
Heat-wave hits
Indian wheat belt
Q2 21
Q3 21
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Q1 22
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Source: Bloomberg
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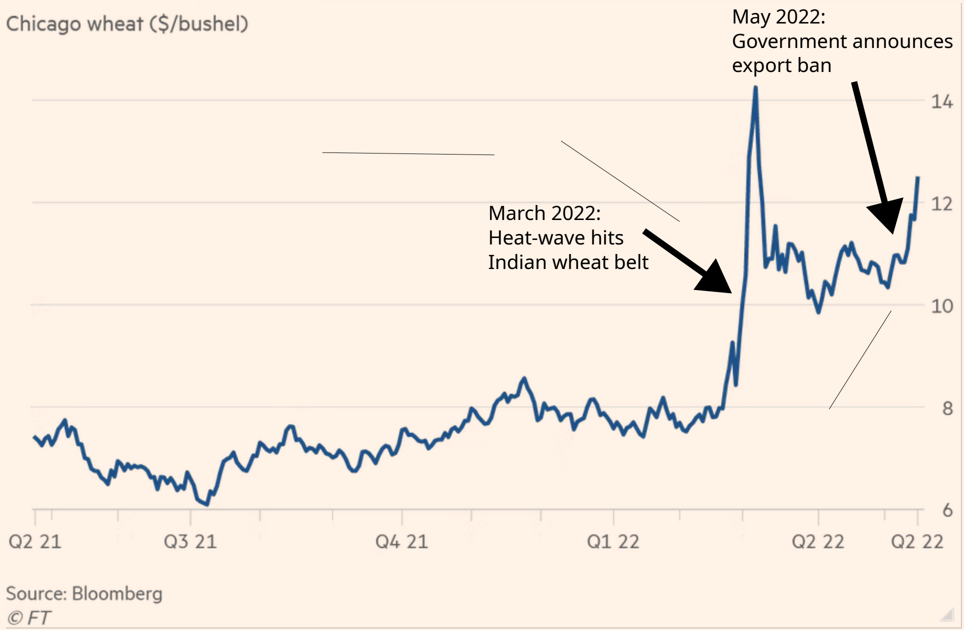
Chicago wheat ($/bushel)
May 2022:
Government announces
export ban
March 2022:
Heat-wave hits
Indian wheat belt
14
12
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Q2 21
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Three perspectives on the export ban

Indian Ministry of Commerce & Industry
May 13 statement

Spike in wheat prices threatens "food security of India"

(domestic consumers)

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

"If the price wants to go up ... who are they trying to protect, at the cost of farmers?"

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Industry analyst Sonal Verna
May 17 *CNN Business*

"These measures could end up exacerbating food price pressures globally."

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Question

- Trade can facilitate climate adaptation
  - But trade policy responds to shocks
  - With important distributional consequences

- **How does trade policy affect global adaptation to climate shocks?**

This paper

1. **Theory:** model of agricultural policy and trade
    - Ambiguous effects of climate shocks on policy

2. **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

3. **Quantification:** empirical estimates $\rightarrow$ aggregate damages
    - In-sample observed heat shocks, 1991-2010
    - Out-of-sample projected heat shocks, 2090-2100

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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

Theory

Trade policy with production shocks

$$\underbrace{S(p^*,\omega)}_{\text{production}} = \underbrace{D(p^*)}_{\text{consumption}} + \underbrace{X(\alpha,p^*,\omega')}_{\text{exports}}$$

$$\alpha^* = \arg\max\left\{\lambda^C CS(p^*) + \lambda^P PS(p^*,\omega) + \lambda^G G(\alpha,p^*,\omega')\right\}$$

1. Domestic/foreign redistribution (terms-of-trade)
2. Consumer/producer redistribution

Policy response to production shocks

1. Neutral case: $\lambda^C = \lambda^P = \lambda^G$
   - Shocks do not affect policy
2. Revenue focus: $\lambda^G \gg \lambda^C, \lambda^P$
   - Domestic shocks induce producer support (foreign shocks opposite)
   - Exports $\downarrow$, terms-of-trade effect $\downarrow$
3. Constituent focus: $\lambda^C \gg \lambda^G$ or $\lambda^P \gg \lambda^G$
   - Domestic shocks induce consumer support (foreign shocks opposite)
   - Consumer focus: best time to help
   - Producer focus: high prices also help foreign

Data and measurement

Panel data for 80 crops, 81 countries (1980-2011)

- Annual climate shocks
  - Extreme temperatures (ERA-5)
  - Crop-specific temperature sensitivity (EcoCrop)
  - Geography of agricultural production (Earthstat)

- Annual agricultural activity
  - Policy (World Bank)
  - Production, exports, imports (FAO)

Shocks: extreme heat exposure

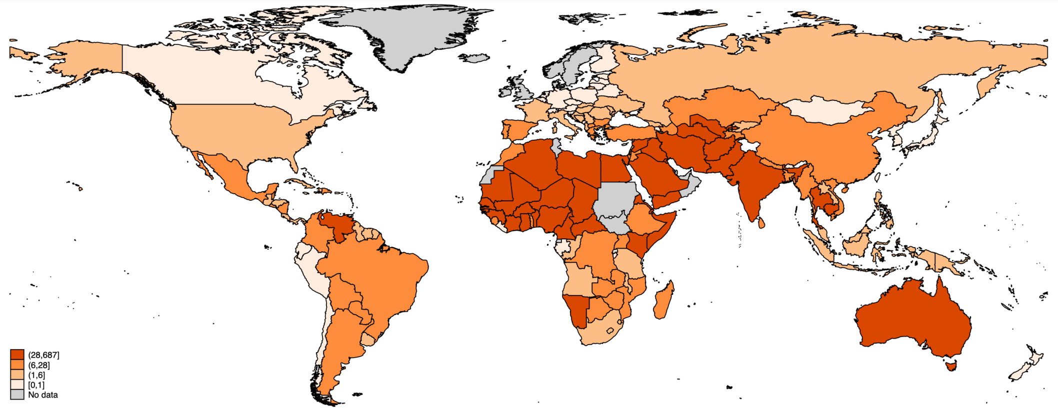
$$\text{ExtremeHeat}_{\ell kt} = \sum_{c \in \ell} \text{PercentArea}_{ck} \cdot \text{DegreeDays}_{ct}(T_k^{\text{max}})$$

$$\text{ForeignExtremeHeat}_{\ell kt} = \sum_{\ell' \neq \ell} \text{ImportShare}_{\ell' k}^{\ell} \cdot \text{ExtremeHeat}_{\ell' kt}$$

- Global variation in weather, plant physiology, and crop geography
  - Extreme heat degree days by country ℓ, crop k, year t, cell c

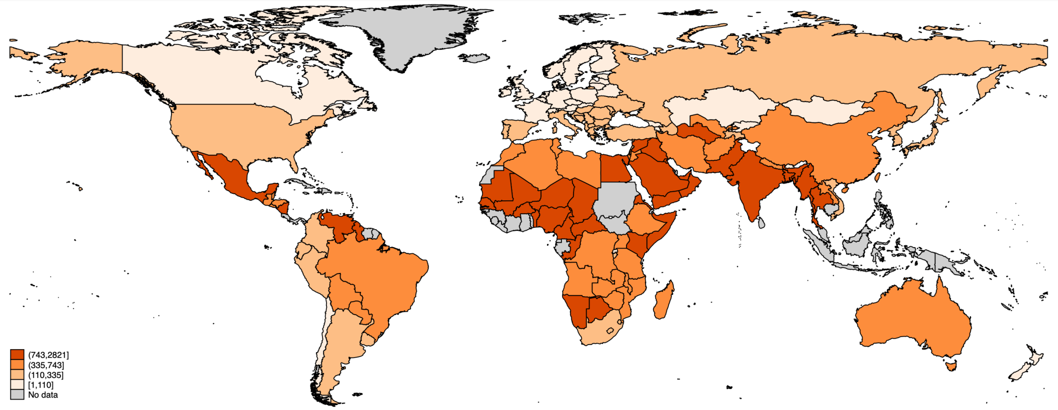
Extreme heat exposure

Maize (2001-2010 average)



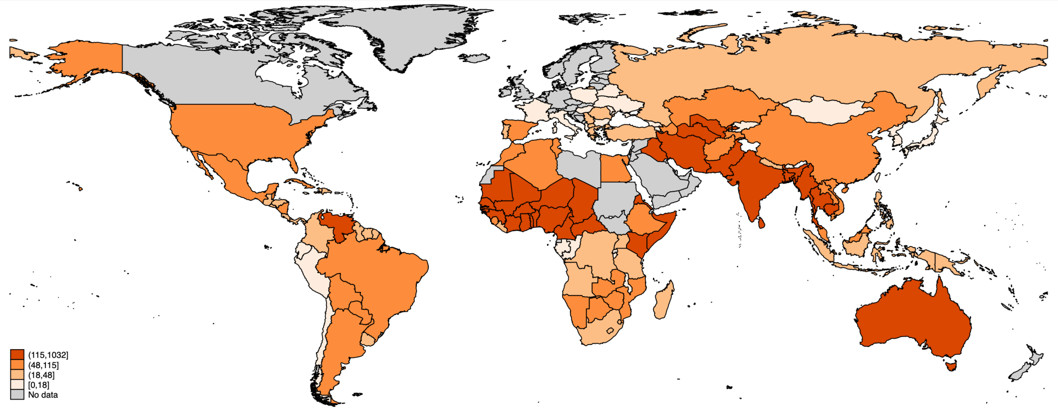
Extreme heat exposure

Wheat (2001-2010 average)



Extreme heat exposure

Rice (2001-2010 average)



Policy: nominal rate of assistance

$$\text{NRA}_{\ell kt} = \frac{P^d_{\ell kt} - P^w_{kt}}{P^w_{kt}}$$

- Domestic vs. world price by country ℓ, crop k, year t
  - "Distortions to Agricultural Incentives" (Anderson & Valenzuela 2008)
  - Unbalanced panel covering 85% of global production (1955-2011)
  - Pro-consumer if $NRA_{\ell kt} < 0$
- Captures multiple dimensions of policy
  - Quantity instruments, input-market interventions, temporary measures
  - Robustness: tariff measures from TRAINS

Nominal rate of assistance

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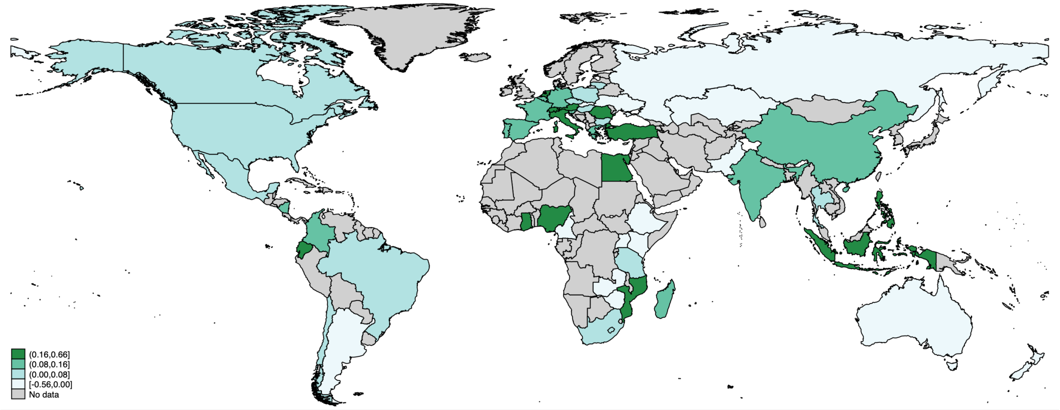

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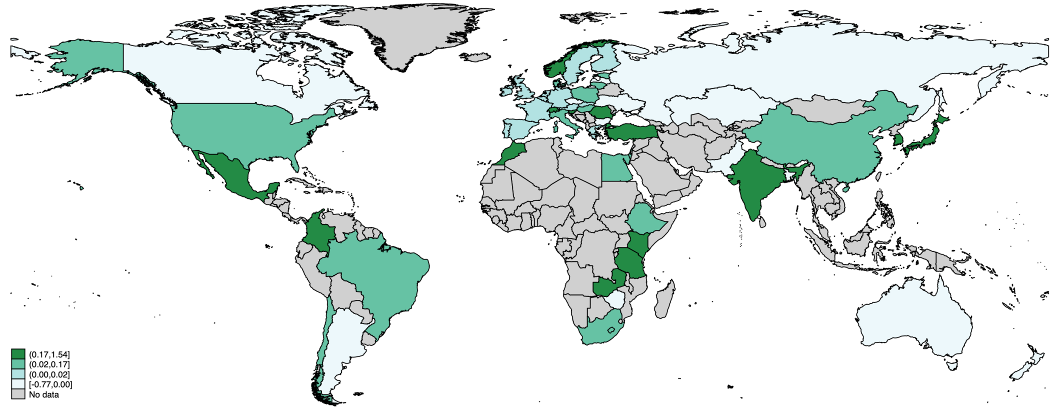

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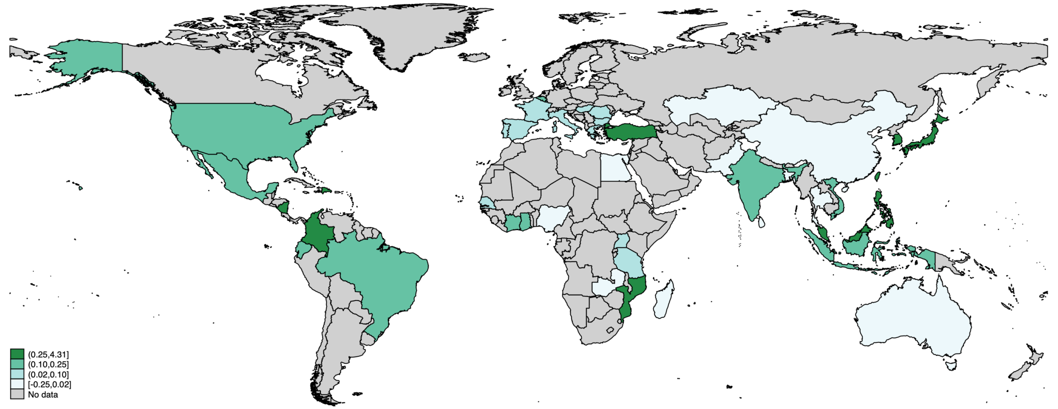
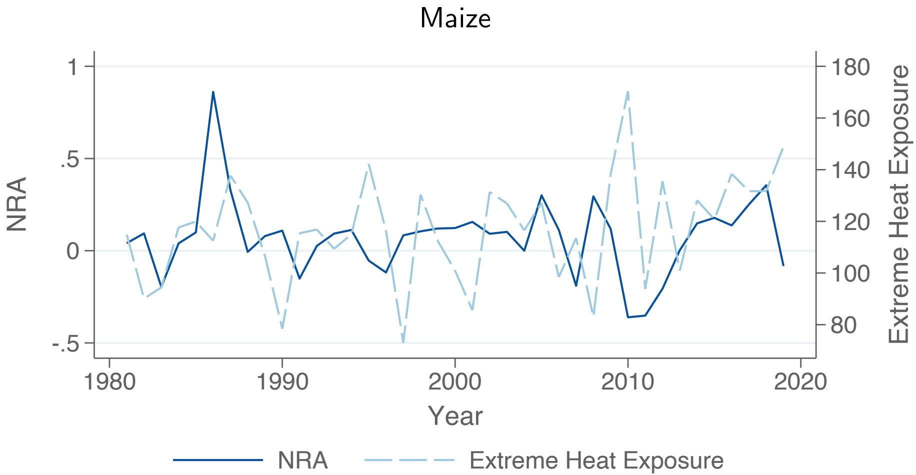


Staples in India



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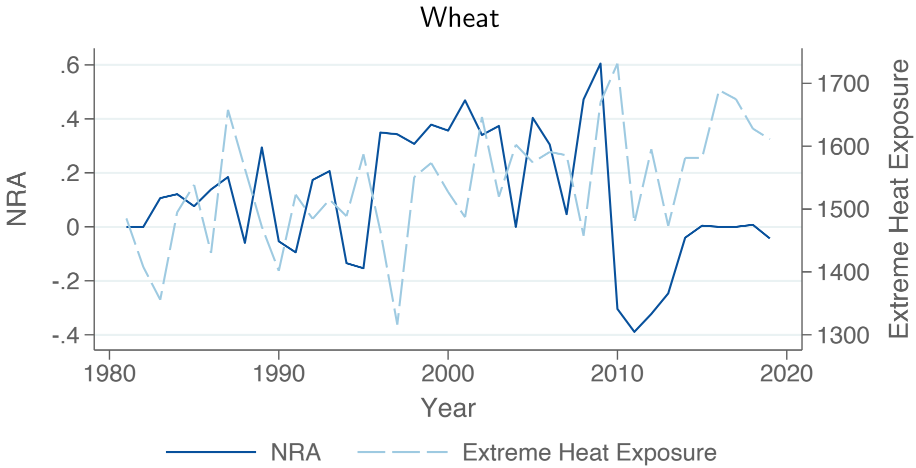

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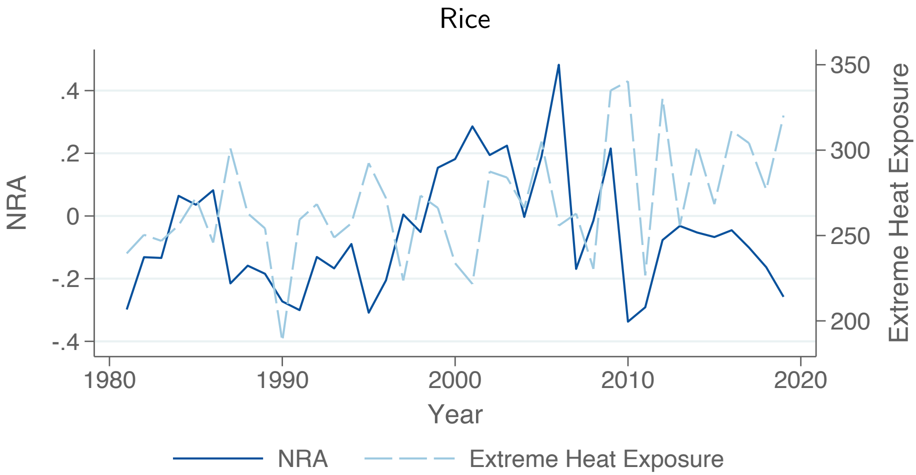
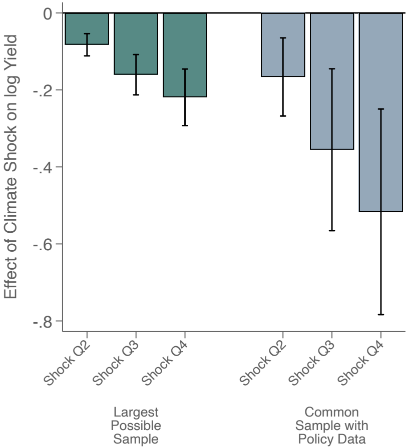


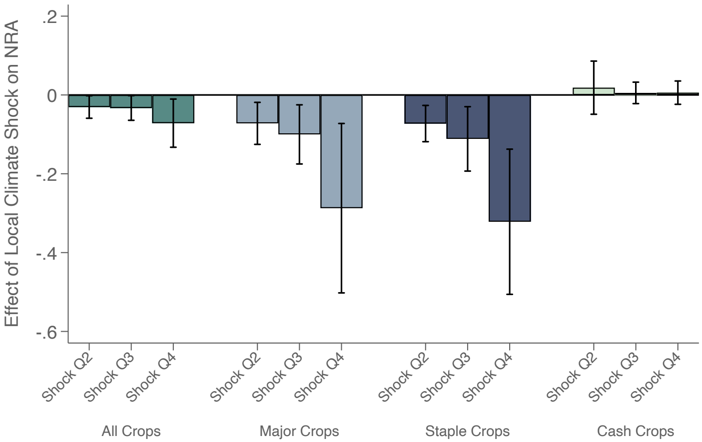
Empirical results

Extreme heat lowers yields (quartile effects)



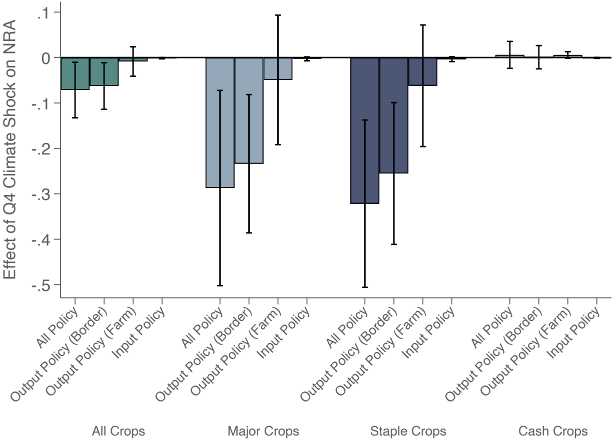
$$\log(\text{yield}_{\ell kt}) = f(\text{ExtremeHeat}_{\ell kt}) + \gamma_{\ell t} + \delta_{kt} + \mu_{\ell k} + \varepsilon_{\ell kt}$$

Result 1: Domestic shocks induce pro-consumer policy



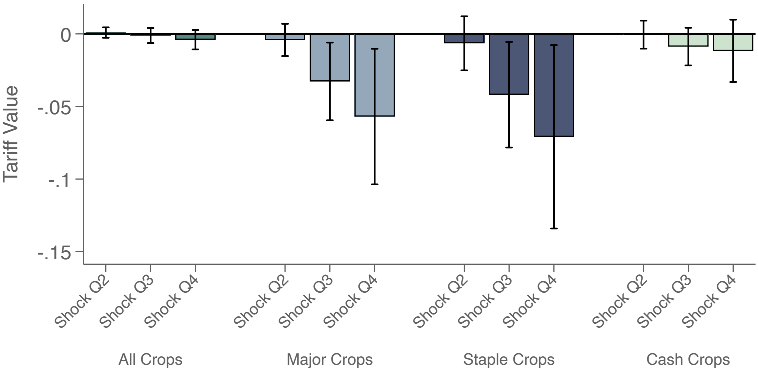
$$\text{NRA}_{\ell kt} = g(\text{ExtremeHeat}_{\ell kt}) + \gamma_{\ell t} + \delta_{kt} + \mu_{\ell k} + \varepsilon_{\ell kt}$$

Through border policies



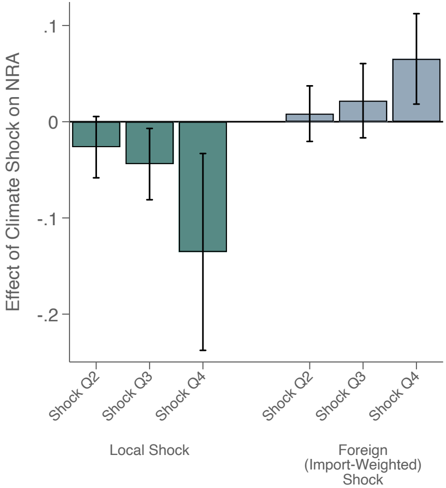
$$\text{NRA}^{\text{component}}_{\ell kt} = g(\text{ExtremeHeat}_{\ell kt}) + \gamma_{\ell t} + \delta_{kt} + \mu_{\ell k} + \varepsilon_{\ell kt}$$

And direct tariff measures (TRAINS)



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

Result 2: Foreign shocks induce pro-producer policy



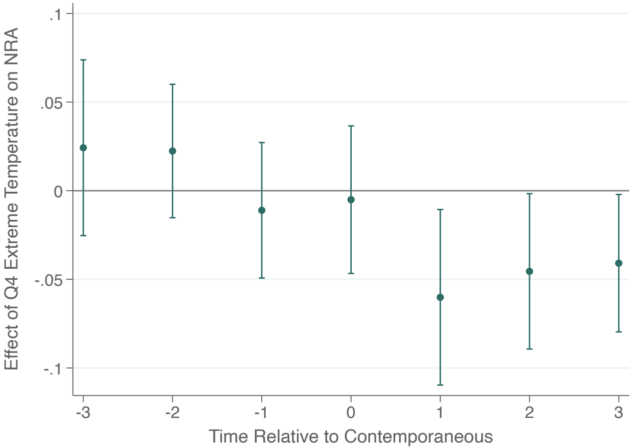
$$\text{NRA}_{\ell kt} = g(\text{ExtremeHeat}_{\ell kt}) + h(\text{ForeignExtremeHeat}_{\ell kt}) + \gamma_{\ell t} + \delta_{kt} + \mu_{\ell k} + \varepsilon_{\ell kt}$$

Isolated shocks amplified, common shocks offset

- Isolated: country A shocked, country B not
  - Country A helps consumers A (and producers B)
  - Country B helps producers B (and consumers A)

- Common: countries A and B shocked
  - Country A reacts to shocks A and shocks B
  - These reactions are partially offsetting

Result 3: Annual shocks have persistent effects



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

Decadal shocks have similar effects

	Full sample	Major crops	Staple crops	Cash crops
Years of Extreme Heat (Local)	-0.0252**	-0.0620**	-0.0758**	-0.0311
	(0.0110)	(0.0259)	(0.0266)	(0.0400)
Years of Extreme Heat (Foreign)	0.0179*	0.0254*	0.0237	0.0272
	(0.00969)	(0.0123)	(0.0127)	(0.0185)
Observations	1,951	905	771	215

Result 4: Stronger effects before elections

	Full sample		Major crops	
	Estim	SE	Estim	SE
Q2 Extreme Heat × No Election	-0.0429*	(0.0222)	-0.0724	(0.0445)
Q3 Extreme Heat × No Election	-0.0138	(0.0236)	-0.0788	(0.0654)
Q4 Extreme Heat × No Election	-0.0172	(0.0374)	-0.0948	(0.101)
Q2 Extreme Heat × Election	-0.0120	(0.0172)	-0.0689**	(0.0315)
Q3 Extreme Heat × Election	-0.0363	(0.0230)	-0.110**	(0.0543)
Q4 Extreme Heat × Election	-0.108**	(0.0490)	-0.382**	(0.149)
Observations	15,860		7,432	

Weaker effects under debt stress

	Full sample		Major crops	
	Estim	SE	Estim	SE
Q2 Extreme Heat	-0.0403	(0.0343)	-0.151**	(0.0728)
Q3 Extreme Heat	-0.0620	(0.0514)	-0.323**	(0.123)
Q4 Extreme Heat	-0.163**	(0.0712)	-0.614***	(0.180)
Q2 Extreme Heat × Central Gov Debt	0.0366	(0.0510)	0.0784	(0.105)
Q3 Extreme Heat × Central Gov Debt	0.110	(0.103)	0.314*	(0.179)
Q4 Extreme Heat × Central Gov Debt	0.261**	(0.129)	0.675***	(0.248)
Observations	13,544		6,260	

Quantitative analysis

Extreme heat effects at global scale

- **How does trade policy affect global adaptation to climate shocks?**
  - If policy responds to shocks in the empirically observed way

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

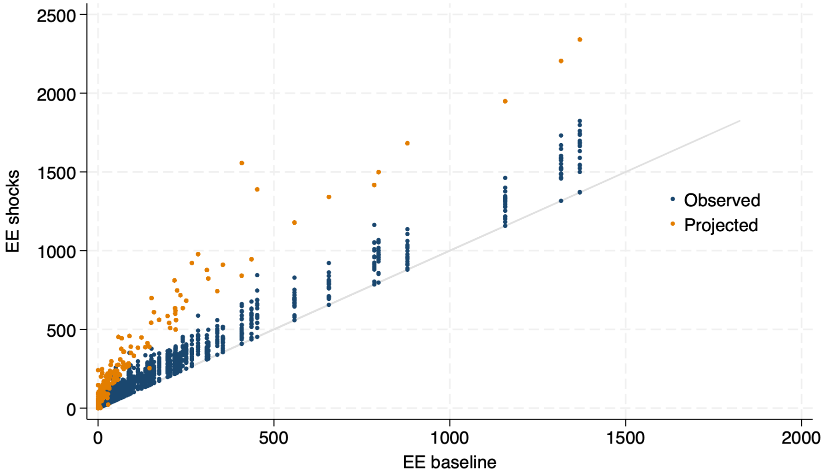
$$
\text{equilibrium} \qquad Q_k(p^*_k) = Y_k(p^*_k)
$$

Simulating climate shocks

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

Projected shocks are larger

Domestic extreme heat



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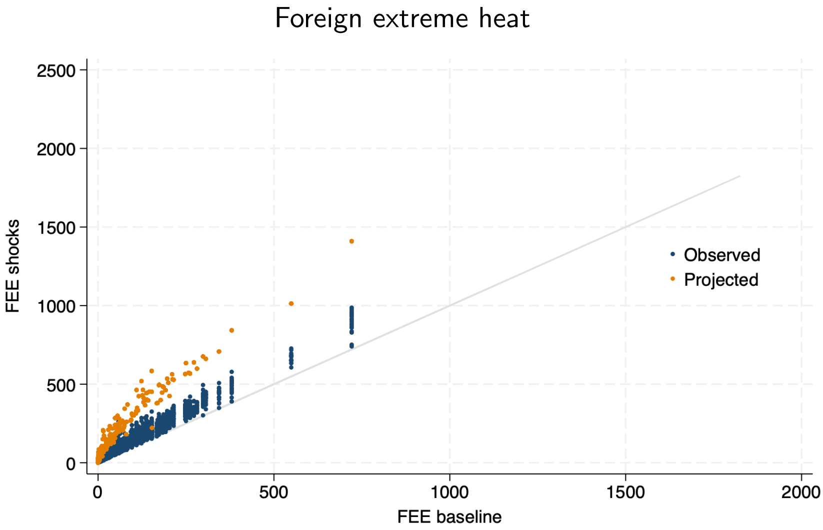

Results

1. Clear trade-off between consumer and producer surplus
    - Consumer aid hurts producers
    - With global spillovers through world prices

2. (Utilitarian) welfare effects depend on baseline trade policy
    - Endogenous policy can improve or worsen existing distortions

In-sample shocks: observed 1991-2010

Shock	CS (%Δ)		PS (%Δ)		W (%Δ)		%
	Fixed Policy	Endog Policy	Fixed Policy	Endog Policy	Fixed Policy	Endog Policy	
Domestic + foreign	-1.94	-1.23	-4.08	-4.88	-2.14	-0.93	10
Domestic	-1.72	0.82	-4.08	-7.06	-5.02	-5.02	14
Foreign	-1.44	-4.87	1.12	4.21	-0.72	0.05	19
None	-0.80	-0.79	0.76	0.74	-0.32	-0.44	56
Total	-1.25	-1.29	-0.78	-0.91	-1.55	-1.30	100

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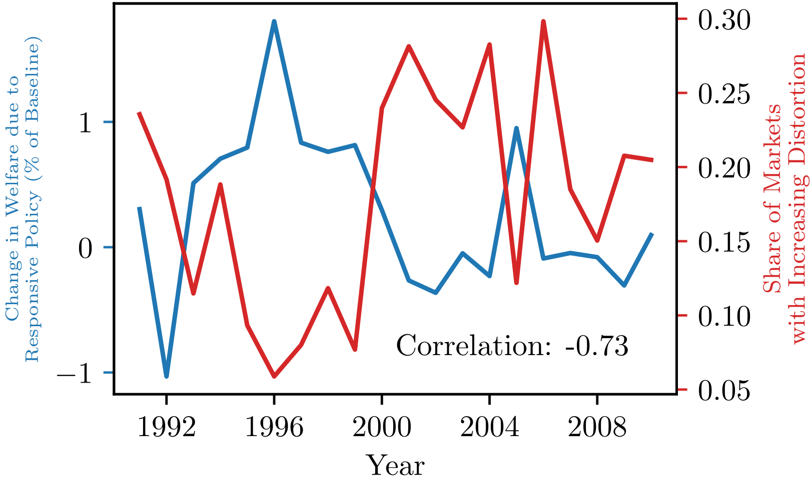
Policy change relative to baseline

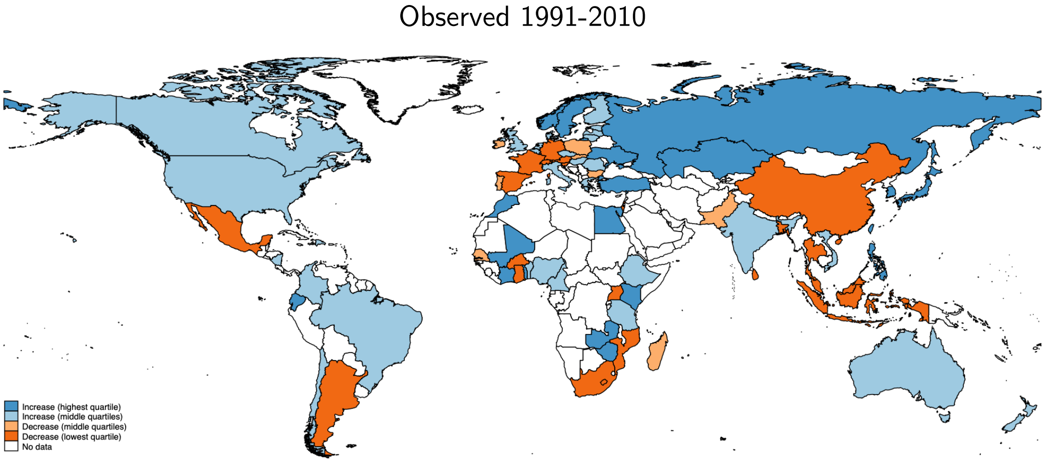
Observed 1991-2010

(% of sample) Baseline	Policy change: Toward consumers	Policy change: Toward producers
Consumer aid	9	24
Producer aid	45	23

Welfare by year



Welfare by country



Out-of-sample shocks: projected 2090-2100

Shock	CS (%Δ)		PS (%Δ)		W (%Δ)		%
	Fixed Policy	Endog Policy	Fixed Policy	Endog Policy	Fixed Policy	Endog Policy	
Domestic + foreign	-3.19	-3.29	-2.48	-2.05	-4.99	-4.96	64
Domestic	-2.52	4.11	-3.25	-8.16	-8.08	-18.99	11
Foreign	-2.68	-7.64	2.27	7.77	-1.52	0.66	15
None	-1.50	-2.04	1.42	1.99	-1.41	-1.38	9
Total	-2.85	-2.72	-1.54	-1.15	-4.58	-5.77	100

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Domestic	-2.52	4.11	-3.25	-8.16	-8.08	-18.99	11
Foreign	-2.68	-7.64	2.27	7.77	-1.52	0.66	15
None	-1.50	-2.04	1.42	1.99	-1.41	-1.38	9
Total	-2.85	-2.72	-1.54	-1.15	-4.58	-5.77	100

Out-of-sample shocks: projected 2090-2100

Shock	CS (%Δ)		PS (%Δ)		W (%Δ)		%
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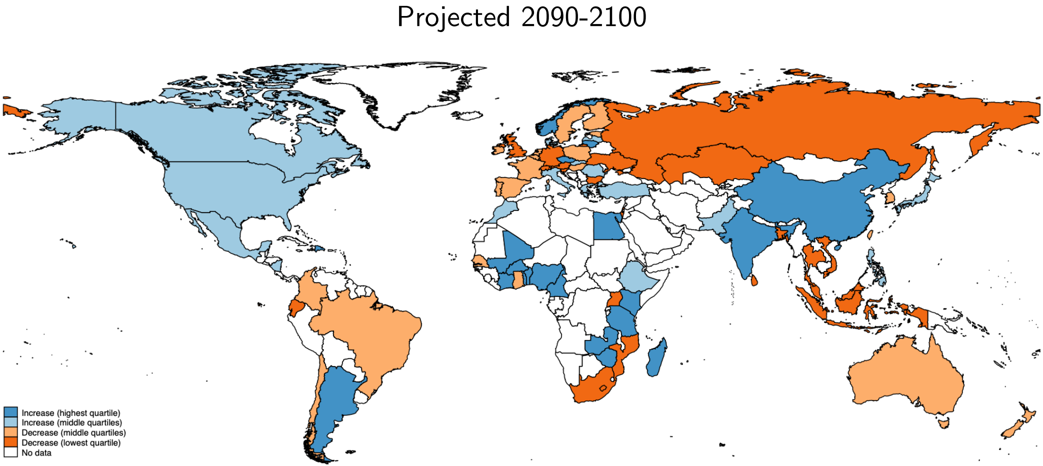
Policy change relative to baseline

Projected 2090-2100

(% of sample)	Policy change	
Baseline	Toward consumers	Toward producers
Consumer aid	16	9
Producer aid	38	36

Welfare by country



Summary

- Extreme heat prompts pro-consumer trade policy
- Endogenous trade policy complicates global adaptation
    - With distributional consequences within and across countries

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		