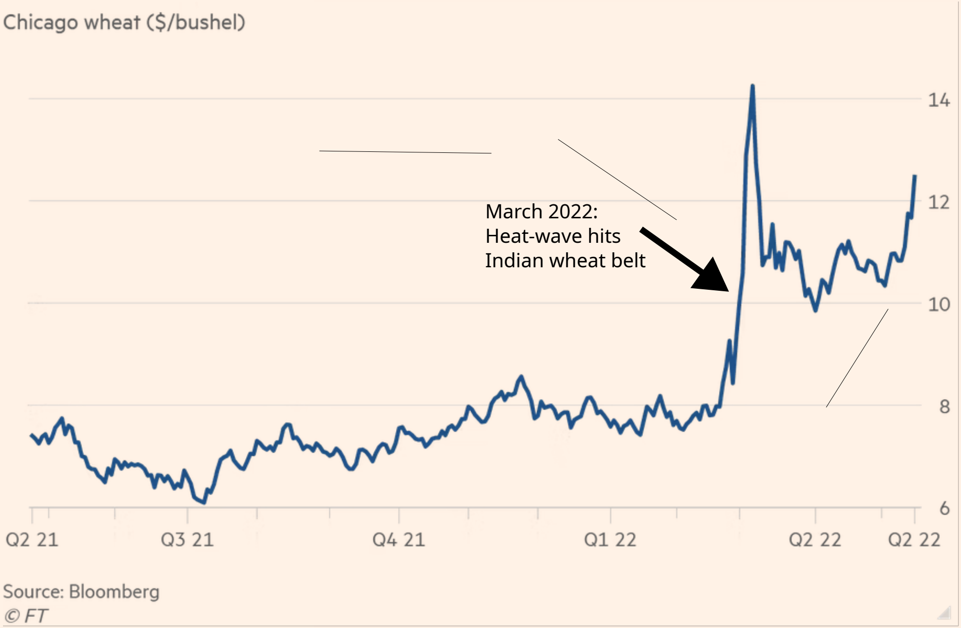
Food Policy in a Warming World

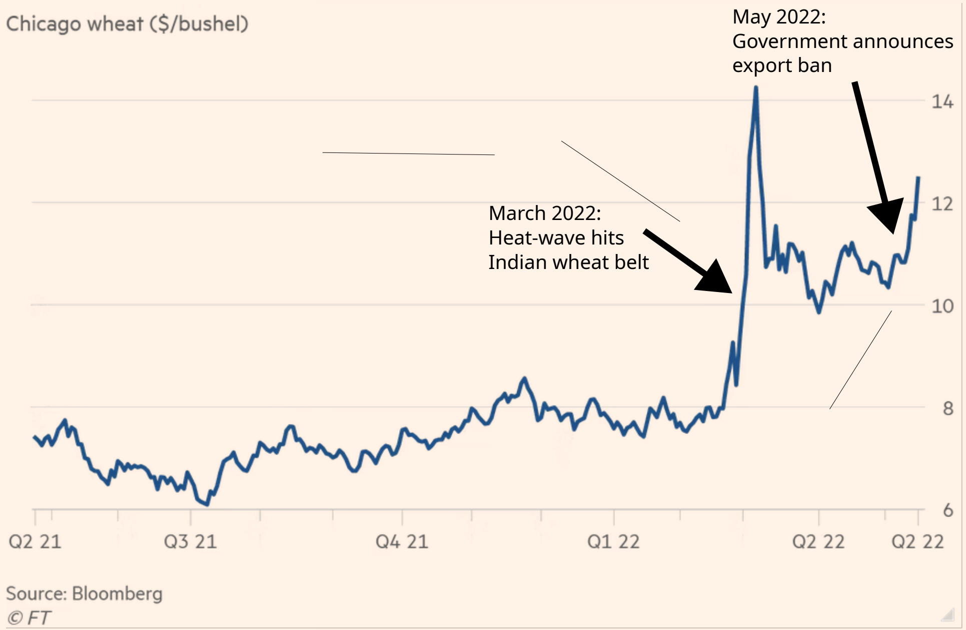
Allan Hsiao
Princeton University

Jacob Moscona
Harvard University

Karthik Sastry
Princeton University

February 28, 2024


Chicago wheat ($/bushel)
March 2022:
Heat-wave hits
Indian wheat belt
14
12
10
8
6
Q2 21
Q3 21
Q4 21
Q1 22
Q2 22
Q2 22
Source: Bloomberg
© FT


Chicago wheat ($/bushel)
May 2022:
Government announces export ban
March 2022:
Heat-wave hits Indian wheat belt
14
12
10
8
6
Q2 21
Q3 21
Q4 21
Q1 22
Q2 22
Q2 22
Source: Bloomberg
© FT

Three perspectives on the export ban

Indian Ministry of Commerce & Industry
May 13 statement

Goal is to combat "sudden spike in the global prices of wheat" which threatens "food security of India"

Three perspectives on the export ban

Indian Ministry of Commerce & Industry
May 13 statement

Goal is to combat "sudden spike in the global prices of wheat" which threatens "food security of India"

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

"If the price wants to go up, let it settle at the international price. Who are they trying to protect now, at the cost of farmers?"

Three perspectives on the export ban

Indian Ministry of Commerce & Industry
May 13 statement

Goal is to combat "sudden spike in the global prices of wheat" which threatens "food security of India"

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

"If the price wants to go up, let it settle at the international price. Who are they trying to protect now, at the cost of farmers?"

Industry analyst Sonal Verna
May 17 *CNN Business*

"These measures could end up exacerbating food price pressures globally. [The effects will] be felt disproportionately by low-income developing countries."

Question

- Trade can facilitate climate adaptation
  - But trade policy responds to shocks
- For India, extreme heat $\rightarrow$ policy $\rightarrow$ distributional effects
  - Both within and across countries
- **How does trade policy affect global adaptation to climate shocks?**

This paper

1. **Theory:** model of agricultural policy, trade, production, climate
   - Ambiguous effects of climate shocks on policy
   - Government weighs constituent welfare against fiscal revenue
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 $\rightarrow$ climate damages
   - Heatwaves in a more volatile world
   - Damages for 2100 in a warmer world

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 shocks

$$\underbrace{Q(p^*)}_{\text{consumption}} = \underbrace{Y(p^*,\omega)}_{\text{production}} + \underbrace{M(\alpha,p^*,\omega')}_{\text{imports}}$$

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

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

Trade policy in response to shocks

1. Revenue focus: $\lambda^G \gg \lambda^C, \lambda^P$
    - α^* increases in ω, decreases in ω'
    - Shock $\uparrow$, imports $\uparrow$, subsidy cost $\uparrow$, tax benefit $\uparrow$ (terms-of-trade)
2. Constituent focus: $\lambda^C \gg \lambda^G$ or $\lambda^P \gg \lambda^G$
    - α^* decreases in ω, increases in ω'
    - Import subsidy helps (C, P'), hurts (P, C')
    - Shock $\uparrow$, imports $\uparrow$, hurt $P \downarrow$, hurt $C' \uparrow$

Data and measurement

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

- Agricultural policy, production, trade
  - Nominal rate of assistance (World Bank)
  - Production, exports, imports (FAO)

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

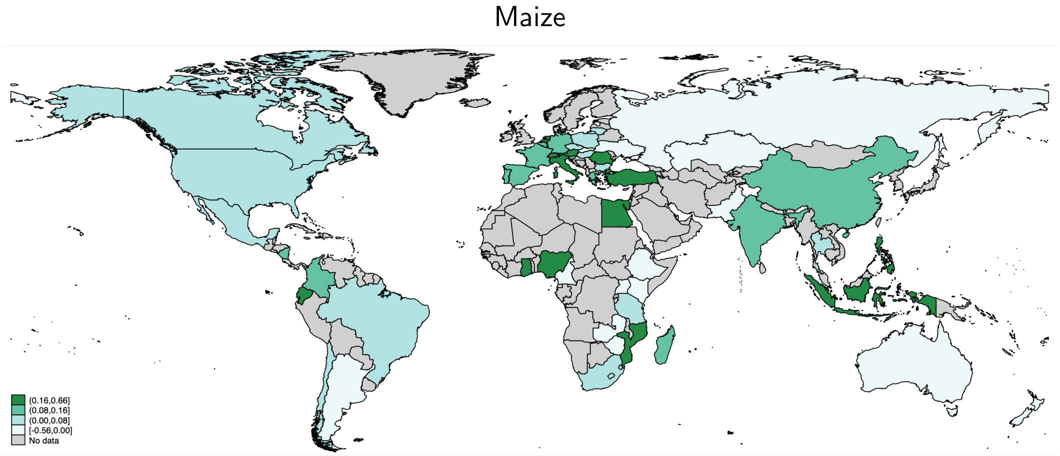
Policy: nominal rate of assistance

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

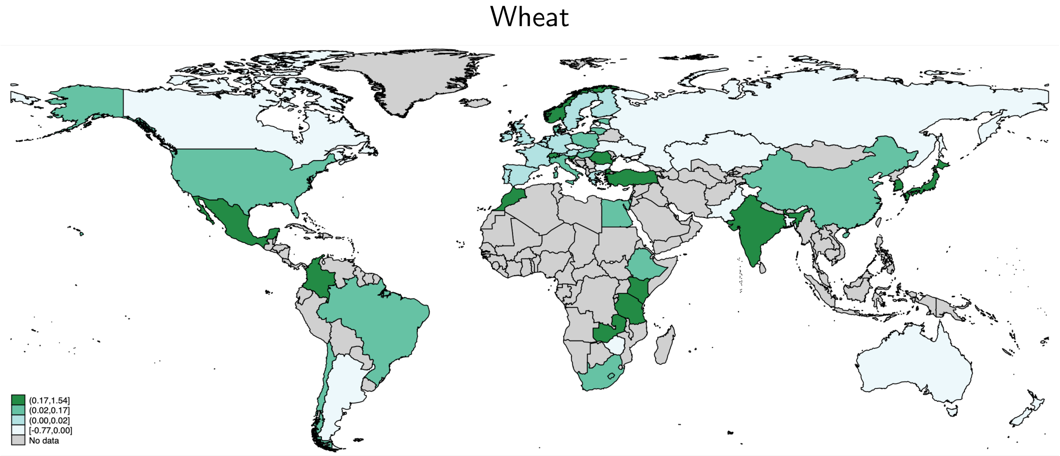
- Domestic vs. world price by country ℓ, crop k, year t
  - "Distortions to Agricultural Incentives" (Anderson & Valenzuela 2008)
  - Unbalanced panel of 82 countries, 80 crops, 85% of production (1955-2011)
  - Pro-consumer if $NRA_{\ell kt} < 0$

- Captures multiple dimensions of policy
  - Quantity instruments, input-market interventions
  - Exchange-rate manipulation, temporary support, export bans
  - Robustness: tariff measures from TRAINS

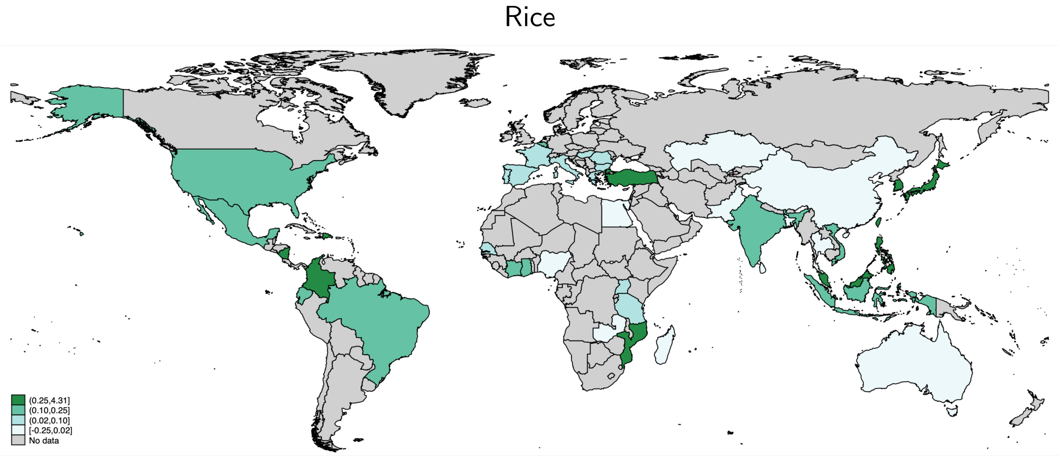
Average nominal rate of assistance (2001-2010)



Average nominal rate of assistance (2001-2010)



Average nominal rate of assistance (2001-2010)



Shocks: extreme heat exposure

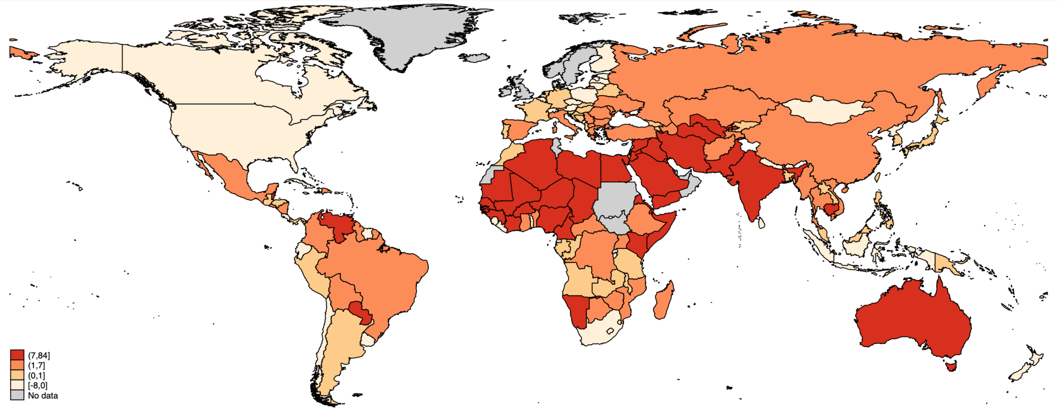
$$\text{ExtremeHeat}_{\ell kt} = \sum_{c \in \ell} \frac{\text{Area}_{ck}}{\sum_{c' \in \ell} \text{Area}_{c'k}} \cdot \text{DegreeDays}_{ct}(T_k^{\text{max}})$$

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

- Growing degree days by country ℓ, crop k, year t, cell c
  - Variation in weather, plant physiology, and crop geography

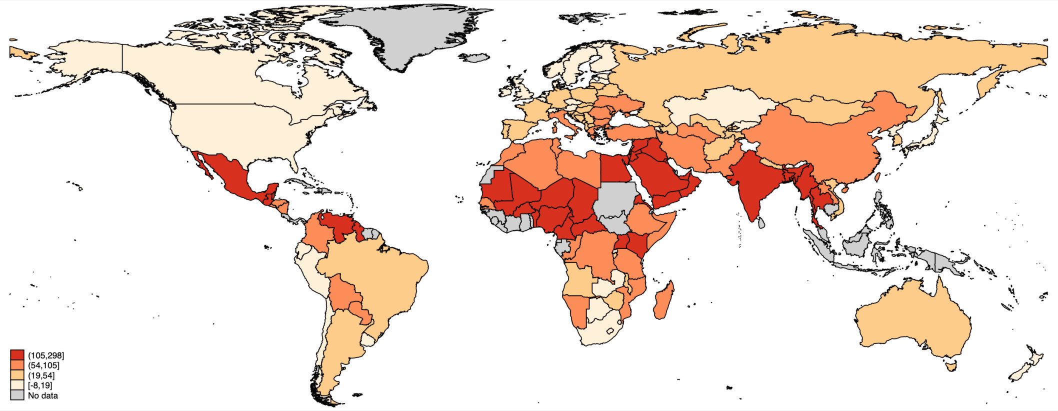
Change in extreme heat exposure (1980-2010)

Maize



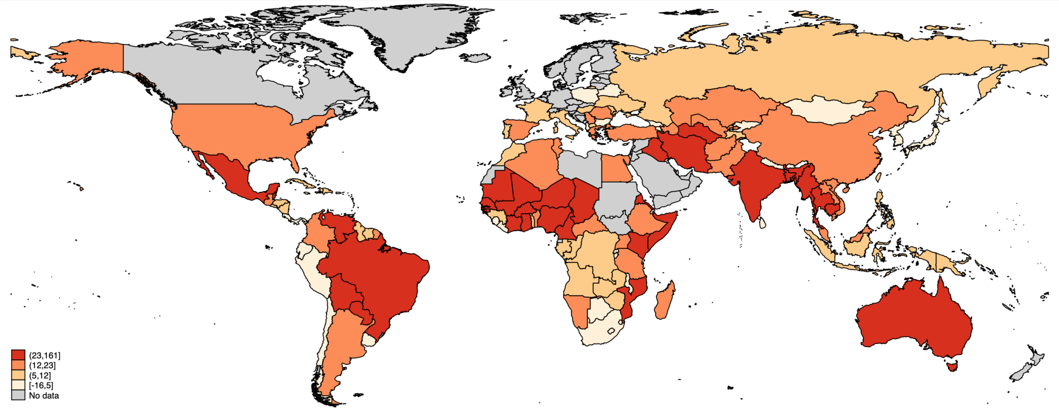
Change in extreme heat exposure (1980-2010)

Wheat



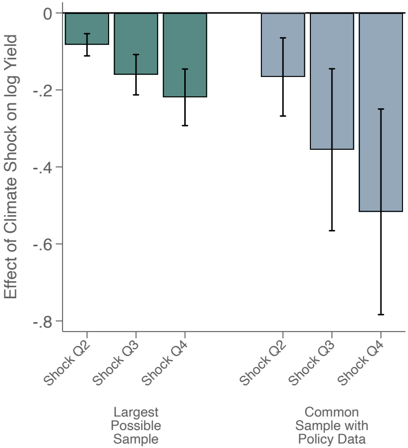
Change in extreme heat exposure (1980-2010)

Rice



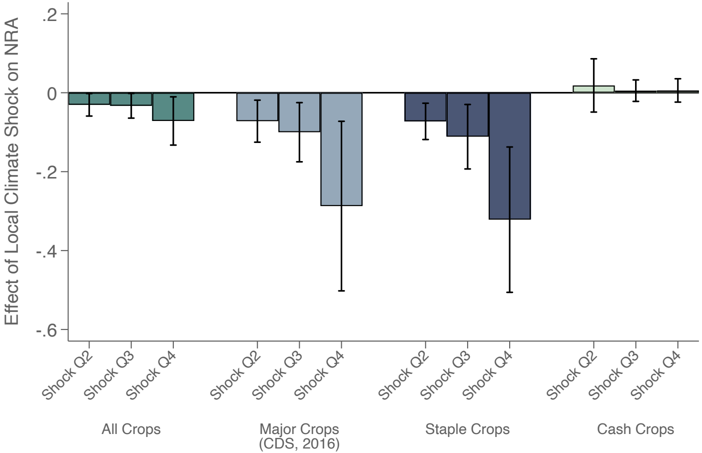
Empirical results

Extreme heat lowers yields (quartile effects)



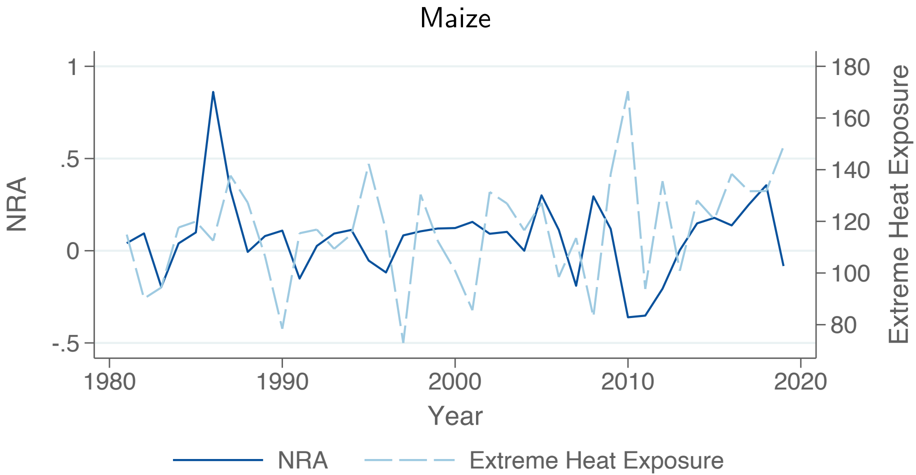
$$\log(\text{yield}_{\ell kt}) = f(\text{ExtremeHeat}_{\ell kt}) + \gamma_{\ell t} + \delta_{kt} + \mu_{\ell k} + \varepsilon_{\ell kt}$$

Result 1: domestic shocks induce pro-consumer policy

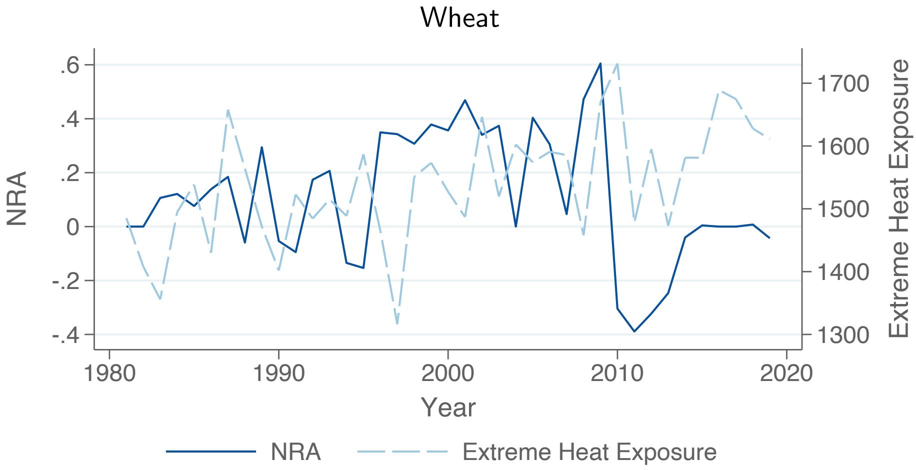


$$\text{NRA}_{\ell kt} = g(\text{ExtremeHeat}_{\ell kt}) + \gamma_{\ell t} + \delta_{kt} + \mu_{\ell k} + \varepsilon_{\ell kt}$$

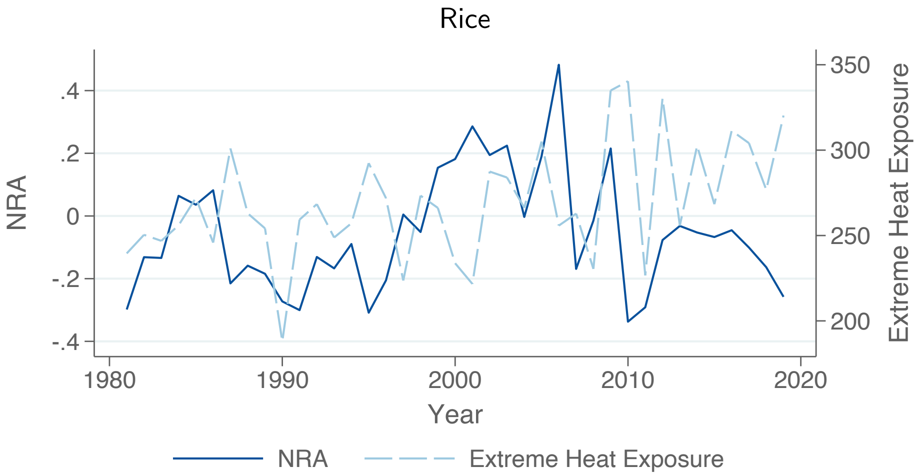
Example: staples in India



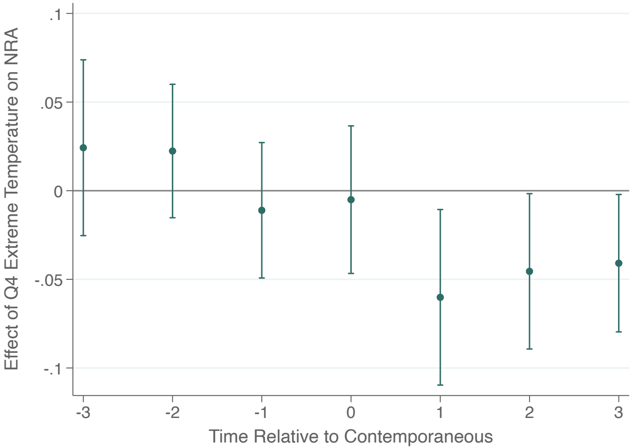
Example: staples in India



Example: staples in India

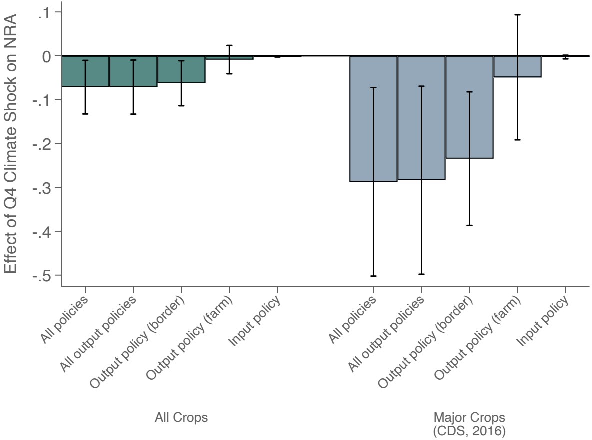


The effects are persistent



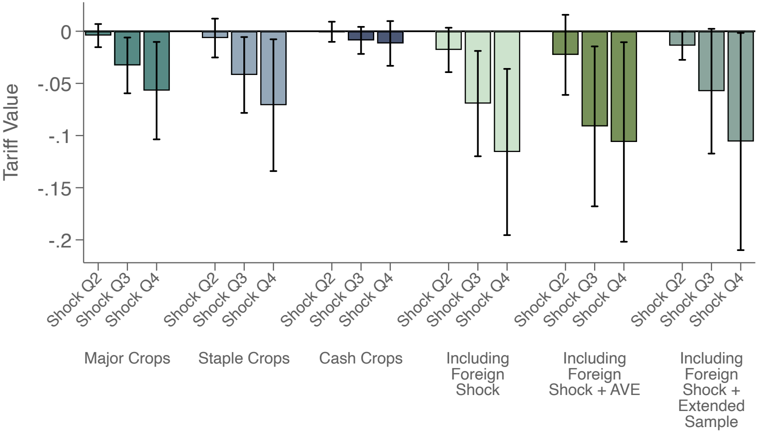
$$\text{NRA}_{\ell kt} = \sum_{s=-3}^{3} g(\text{ExtremeHeat}_{\ell kt+s}) + \gamma_{\ell t} + \delta_{kt} + \mu_{\ell k} + \varepsilon_{\ell kt}$$

The effects are concentrated in border policies



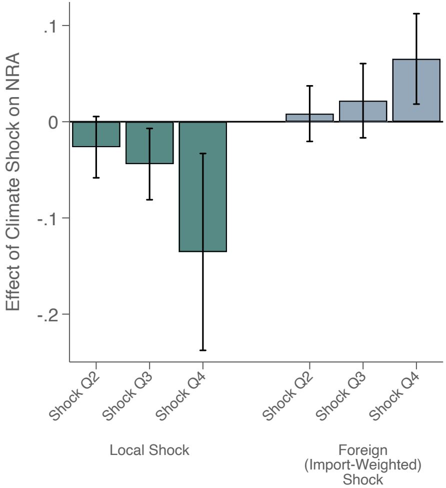
$$\text{NRA}^{\text{component}}_{\ell kt} = g(\text{ExtremeHeat}_{\ell kt}) + \gamma_{\ell t} + \delta_{kt} + \mu_{\ell k} + \varepsilon_{\ell kt}$$

The effects appear in 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



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

Result 3: stronger effects at decadal frequency $(N_{\text{full}} = 1,951)$

Sample:	Full Sample		Major Crops	Staple Crops	Cash Crops
Years of Extreme Heat (Local)	-0.0242**	-0.0252**	-0.0620**	-0.0758**	-0.0311
	(0.0111)	(0.0110)	(0.0259)	(0.0266)	(0.0400)
Years of Extreme Heat (Foreign Import-Weighted)		0.0179*	0.0254*	0.0237	0.0272
		(0.00969)	(0.0123)	(0.0127)	(0.0185)

Result 4: stronger effects before elections $(N_{\text{full}} = 15,860)$

	Full Sample	Major Crops	Staple Crops	Cash Crops
Q2 Extreme Heat Exposure x No Election	-0.0429*	-0.0724	-0.0509	-0.0259
	(0.0222)	(0.0445)	(0.0390)	(0.0486)
Q3 Extreme Heat Exposure x No Election	-0.0138	-0.0788	-0.0561	-0.0182
	(0.0236)	(0.0654)	(0.0719)	(0.0163)
Q4 Extreme Heat Exposure x No Election	-0.0172	-0.0948	-0.104	-0.0126
	(0.0374)	(0.101)	(0.0946)	(0.0216)
Q2 Extreme Heat Exposure x Election	-0.0120	-0.0689**	-0.0820**	0.0680
	(0.0172)	(0.0315)	(0.0316)	(0.0600)
Q3 Extreme Heat Exposure x Election	-0.0363	-0.110**	-0.145**	0.0217
	(0.0230)	(0.0543)	(0.0627)	(0.0223)
Q4 Extreme Heat Exposure x Election	-0.108**	-0.382**	-0.436***	0.0203
	(0.0490)	(0.149)	(0.142)	(0.0246)
p-value, Q4 x Election - Q4 x No Election	*0.08*	*0.03*	*0.04*	*0.34*

Conversely, weaker effects under debt stress ($N_{\text{full}} = 13,544$)

	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)

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

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

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

Scenario 1: heat waves

- Elevated $\text{ExtremeHeat}_{\ell k}$ for a group of countries
  - At the in-sample 95th percentile
  - Simulate production losses, equilibrium prices, policy responses
- Goal: quantify losses under endogenous vs. exogenous policy

$$\frac{\Delta W^{\text{endog}} - \Delta W^{\text{exog}}}{|\Delta W^{\text{endog}}|} \quad \text{for} \quad \Delta W = W^1 - W^0$$

Important distributional consequences, but ambiguous total effects

		Shocked continent			
	$\Delta\%$	Africa	Americas	Asia	Europe
Shocked continent	W	-12	13	199	-35
	CS	105	20	242	698
	PS	-38	-3	-43	-14
Rest of world	W	-64	-25	94	-22
	CS	-52	-14	-8	-38
	PS	50	8	32	37

Important distributional consequences, but ambiguous total effects

		Shocked continent			
	Δ%	Africa	Americas	Asia	Europe
Shocked continent	W	-12	13	199	-35
	CS	105	20	242	698
	PS	-38	-3	-43	-14
Rest of world	W	-64	-25	94	-22
	CS	-52	-14	-8	-38
	PS	50	8	32	37

Important distributional consequences, but ambiguous total effects

		Shocked continent			
	Δ%	Africa	Americas	Asia	Europe
	W	-12	13	199	-35
Shocked continent	CS	105	20	242	698
	PS	-38	-3	-43	-14
	W	-64	-25	94	-22
Rest of world	CS	-52	-14	-8	-38
	PS	50	8	32	37

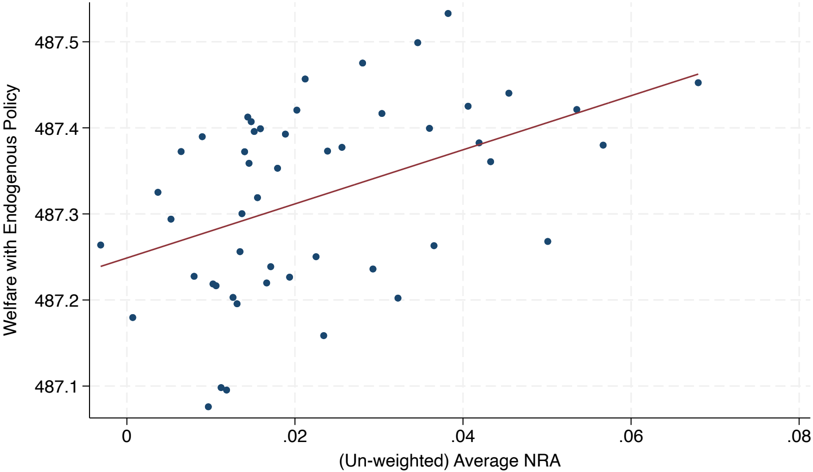
Important distributional consequences, but ambiguous total effects

		Shocked continent			
	Δ%	Africa	Americas	Asia	Europe
Shocked continent	W	-12	13	199	-35
	CS	105	20	242	698
	PS	-38	-3	-43	-14
Rest of world	W	-64	-25	94	-22
	CS	-52	-14	-8	-38
	PS	50	8	32	37

Random heatwaves shut down spatial correlation

	$\Delta\%$	Shocked countries	
		10 countries	30 countries
Shocked countries	W	-3	-4
	CS	225	970
	PS	-32	-28
Rest of world	W	-35	-41
	CS	-46	-46
	PS	50	49

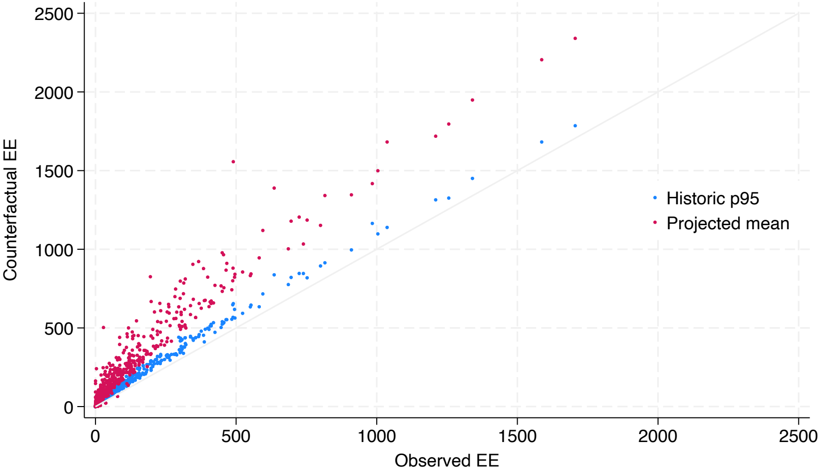
And highlight shock incidence vs. sign of existing distortions



Scenario 2: global climate change

- Elevated ExtremeHeat$_{\ell k}$ for the world
  - Based on 2091-2100 projections (GFDL-ESM4 model)
  - Extrapolation from "weather" to "climate" shocks
- Highlight role of policy interactions
  - Given scale of shocks, geographic incidence, and spatial correlation

More extreme than heat waves



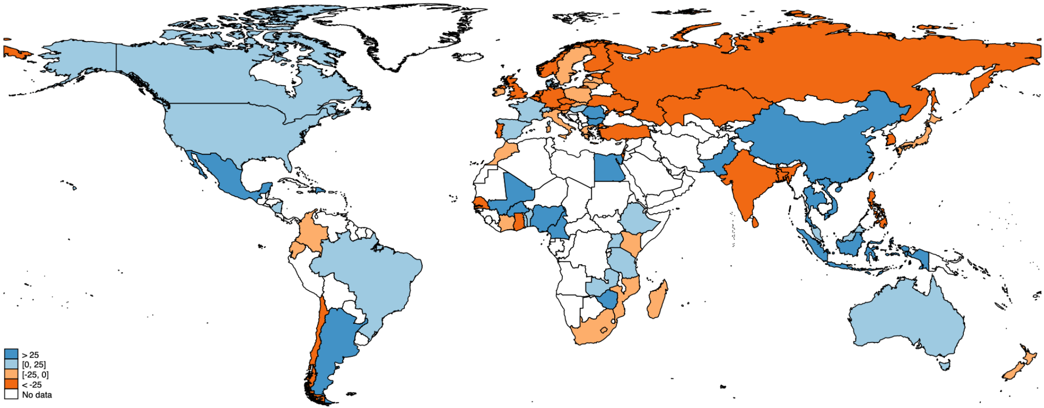
Global welfare losses 14% bigger under endogenous trade policy

Full sample	W	CS	PS	G
Endogenous	-2.96	-1.48	-0.37	-1.11
Exogenous	-2.55	-1.72	-0.81	-0.02
Difference (%)	-14	16	123	-98

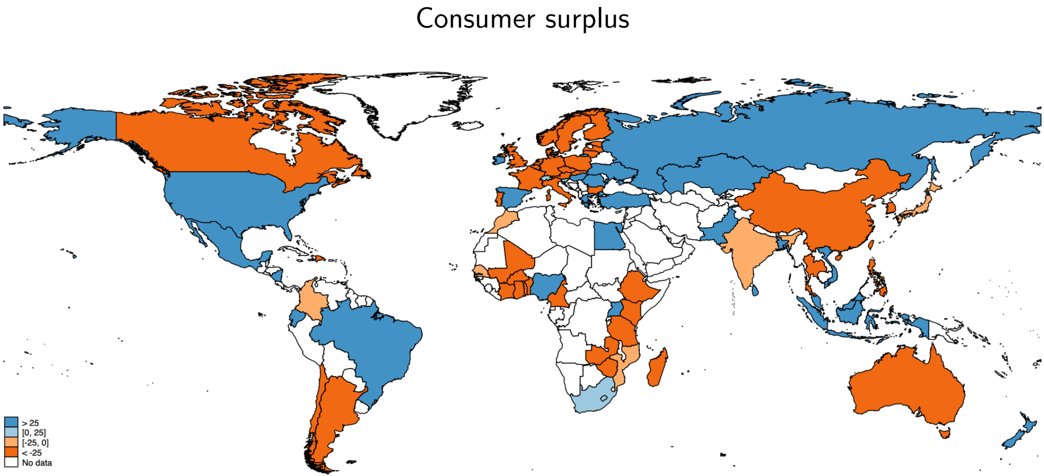
- Governments shield consumers and producers, but at great cost

Country-level effects

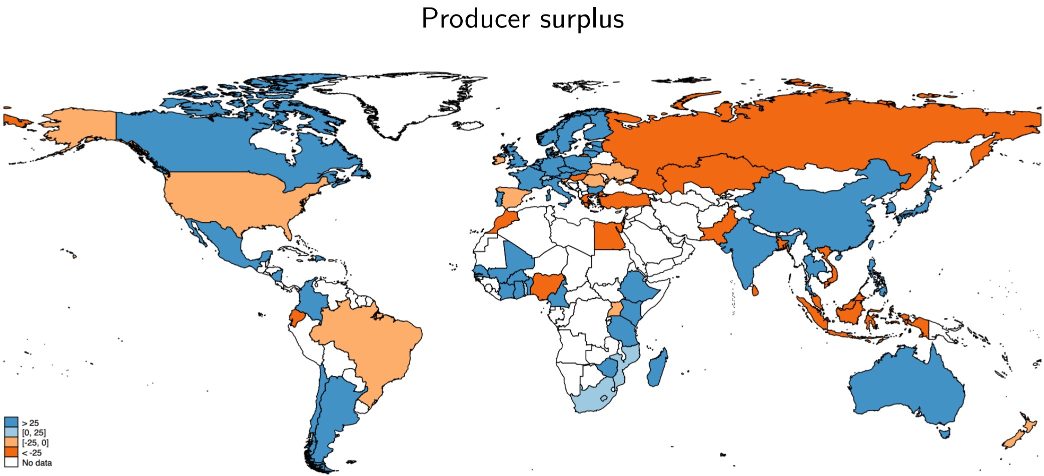
Welfare



Country-level effects



Country-level effects



Driven by country-crops with biggest production losses

Most impacted	W	CS	PS	G
Endogenous	-2.41	0.63	-2.13	-0.92
Exogenous	-1.73	-0.64	-1.15	0.06
Difference (%)	-28	201	-46	-107

- Governments aid domestic consumers, but hurt domestic producers

Opposite distributional effects elsewhere

Less impacted	W	CS	PS	G
Endogenous	-0.55	-2.11	1.76	-0.19
Exogenous	-0.82	-1.08	0.34	-0.08
Difference (%)	51	-49	81	-59

- Losses for foreign consumers, gains for foreign producers

Foreign policy responses are offsetting

Full sample	W	CS	PS	G
With FEE response (Δ%W)	-14	16	123	-98
Without FEE response (Δ%W)	-21	0	131	-99

Summary

- Extreme heat prompts pro-consumer trade policy
- Endogenous trade policy complicates global adaptation
  - Important distributional effects both 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		