Crops, Conflict, and Climate Change

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Agriculture is important for development

- In low income countries
  - $>$ 30% of GDP
  - $>$ 40% of employment
  - $\approx$ 35% of expenditure
- Low-income households
  - More likely to be farmers (or farm laborers)
  - Spend a higher share of their income on food
  - Are highly heterogeneous
    - ★ different land and labor endowments
    - ★ varying production and consumption patterns

Assessing distributional impacts of agricultural shocks requires

- A general equilibrium approach
  - agricultural products are traded internationally
- Accounting for household heterogeneity
  - Factor endowment differences (land and labor)
  - Production variety (wheat or coffee)
  - Consumption variety (wheat, rice, or cassava)
- International trade linkages and household heterogeneity jointly determine the impact of shocks on inequality

What do we do?

- Develop discrete choice general equilibrium trade model with households as central actors
  - As producers, households allocate land and labor to different plots
    - ★ can also work off-farm
    - ★ can adjust choices
  - Consume different goods
  - Yields income-percentile specific predictions of impact
- Model quantified with
  - Households surveys from 51 developing countries
  - USITC ITPD-E database for 98 countries
- We study the impact of
  - Export bans triggered by the war in Ukraine
  - Shocks to agricultural yields triggered by future climate change

Preview of results

- War-induced food inflation: 2.06% $\downarrow$ in average income
- Climate change: 9.72% $\downarrow$ in average income
- Poor households suffer considerably bigger and more variable losses
- Household heterogeneity and disaggregate data are of first order importance

Model

Model: Summary

- N countries indexed with n and H households indexed with h
- Households have different Cobb-Douglas preferences for consumption of crops and products
- Households have land and labor endowments, modeled as continua, with crop-specific Frechet-distributed productivity
  - Choose crops to produce on your land
  - Choose labor supply to sectors or crops

Model: Additional components

- Manufacturing
  - Produced by a fixed factor and labor (no land)
  - Traded and consumed like crops
- Services
  - Produced by a fixed factor and labor (no land)
  - Not traded and but consumed locally
- Fertilizers
  - Produced by a fixed factor (no land or labor)
  - Traded but not consumed (only input)
- Fixed factors can be owned by households

Model: Three price indices

- Price of goods

$$P_j^n = \left[\sum_{m'} \vartheta_j^{n,m'} \left(p_j^{m'} \tau_j^{n,m'} \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$$

- Price of labor (wage income)

$$\Phi_L^{n,h} = \left(\sum_{j \in \mathcal{S}} \left(w_j^n A_{L,j}^{n,h} \right)^{\theta_L} \right)^{\frac{1}{\theta_L}}$$

- Rental rate of land (return on land)

$$\Phi_T^{n,h} = \left(\sum_{j \in \mathcal{S}} \left(r_j^n A_{T,j}^{n,h} \right)^{\theta_T} \right)^{\frac{1}{\theta_T}}$$

Model: Welfare

- Income from labor $R_L^{n,h} = \Phi_L^{n,h} \overline{L}^{n,h}$
- Income from land and fixed factors $R_T^{n,h} = \Phi_T^{n,h} \overline{T}^{n,h} + r_M^n \overline{M}^{n,h} + r_S^n \overline{S}^{n,h}$
- Household specific consumer price index

$$P^{n,h} = \prod_j \left(P_j^n\right)^{\alpha_j^{n,h}},$$

- Welfare

$$V^{n,h} = \frac{R_L^{n,h} + R_T^{n,h}}{P^{n,h}}$$

- Key channels: $P^{n,h}$, $\Phi_T^{n,h}$, $\Phi_L^{n,h}$

Discussion: What did we achieve with the model?

- Deaton welfare (with some abuse of notation)

$$\widehat{V^{n,h}} = -\sum_j \widehat{p_j^n}\alpha_j^{n,h} + \sum_j \widehat{p_j^n}\kappa_{T,j}^{n,h} + \sum_j \widehat{w_j^n}\kappa_{L,j}^{n,h} + \widehat{r_M^n}\kappa_M^{n,h} + \widehat{r_S^n}\kappa_S^{n,h}$$

- Welfare herein

$$\widehat{V^{n,h}} = \frac{\widehat{\Phi_L^{n,h}}\kappa_L^{n,h} + \widehat{\Phi_T^{n,h}}\kappa_T^{n,h} + \widehat{r_M^n}\kappa_M^{n,h} + \widehat{r_S^n}\kappa_S^{n,h}}{\prod_j \left(\widehat{P_j^n}\right)^{\alpha_j^{n,h}}}$$

- Key similarity: detailed household heterogeneity
- Key difference: Use structural price indices instead of prices
  - Price indices embed prices plus other information: productivity dispersion, responses, GE effects, geography, factor endowments, etc.

Data & Quantification

Data

- Land and labor income shares of household
  - Household Impacts of Tariffs database (HIT) by World Bank
  - 54 low- and middle-income countries & many crops
  - Representative households put into 100 bins
- Import shares, including domestic absorption
  - Int. Trade and Prod. Database for Estimation (ITPD-E) by USITC
  - Detailed agriculture data (about 20 crops)
  - Additional 47 "central" economies
- Productivity of crops by country
  - Global Agro-Ecological Zones data (GAEZ) by FAO
  - Aggregated to county level
  - Productivity shocks under climate change

Calibration

- Fréchet parameters estimated using GAEZ and HIT databases
  - $\theta_T = 1.70$ with $(1.22, 1.95)$
  - $\theta_L = 1.83$ with $(1.49, 3.38)$
- Trade elasticity
  - $1 - \sigma = -4.0$ (from Simonovska and Waugh, 2014)
- Production function
  - $\beta_L = 0.55$, $\beta_T = 0.22$, and $\beta_M = 0.23$ (from Sotelo, 2020)
- Utility function
  - $\alpha_j^{n,h}$ (shares taken directly from HIT database)

War-induced Food Price Hikes

Simulation I: War-induced food price hikes

- Export supply shock
  - Ukraine: No imports/exports any agri. products and fertilizers
  - Russia: Ban on exporting wheat, rice, corn, other cereals, sugar, other oilseeds, and fertilizers
- Sources: News (Reuters, WSJ, CNBC, Agri-Pulse, NPR, etc.), WB Trade Watch Newsletter, and others.
- Plug prohibitively high trade costs to simulate export bans

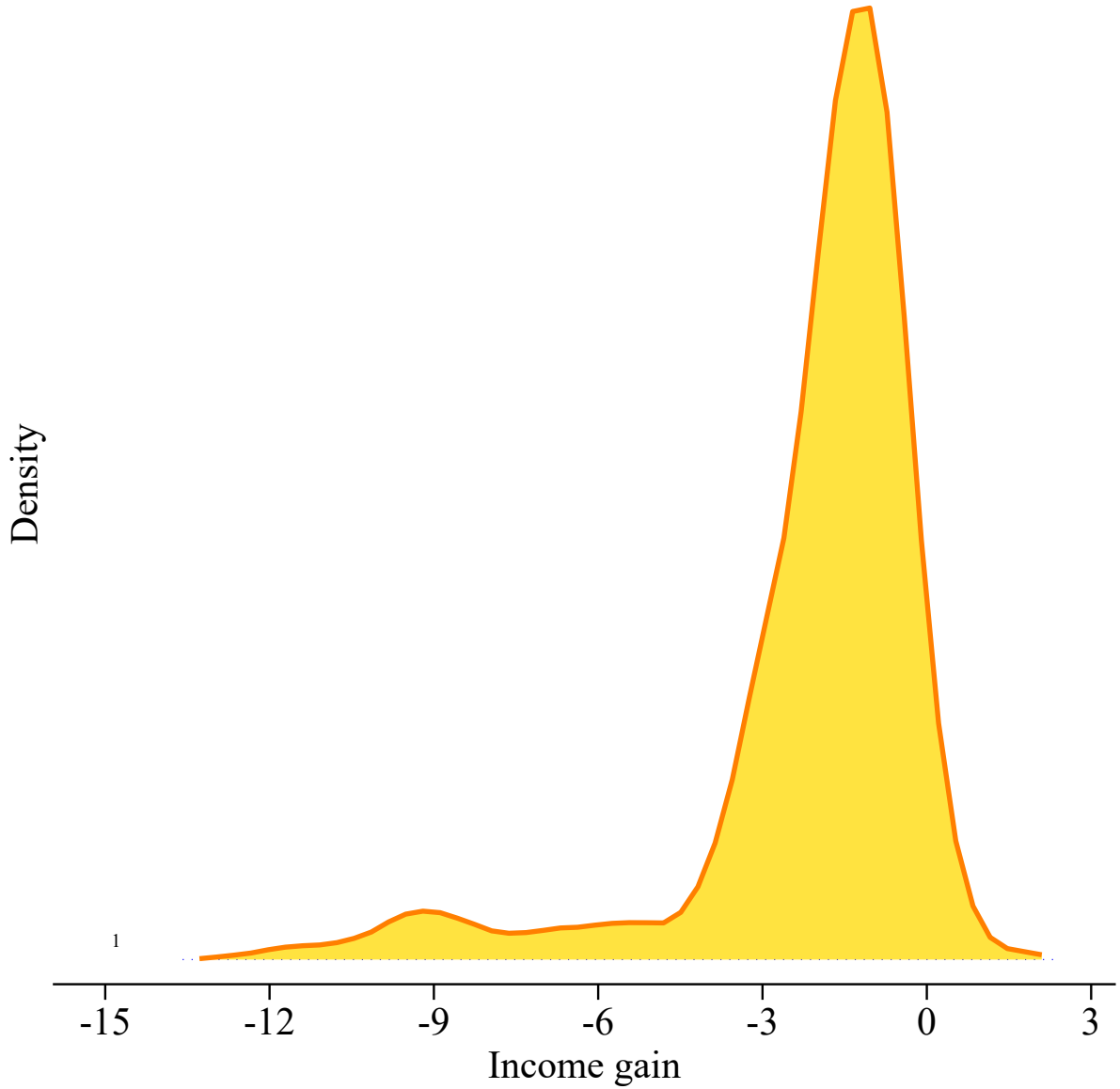
Simulation I: Goodness of fit

Dependent variable	**Observed price change**					
Sample	All products			Selected products corn, wheat, rice, soya, sugar, and other cereals		
		No outliers	Winsorized		No outliers	Winsorized
	(1)	(2)	(3)	(4)	(5)	(6)
Predicted price change	0.640***	0.752**	0.885***	0.687**	0.989**	0.952**
	(0.185)	(0.156)	(0.203)	(0.231)	(0.234)	(0.241)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.319	0.415	0.367	0.674	0.732	0.696
Adj. R-squared	0.227	0.331	0.281	0.486	0.565	0.520
Obs.	311	295	311	102	92	102

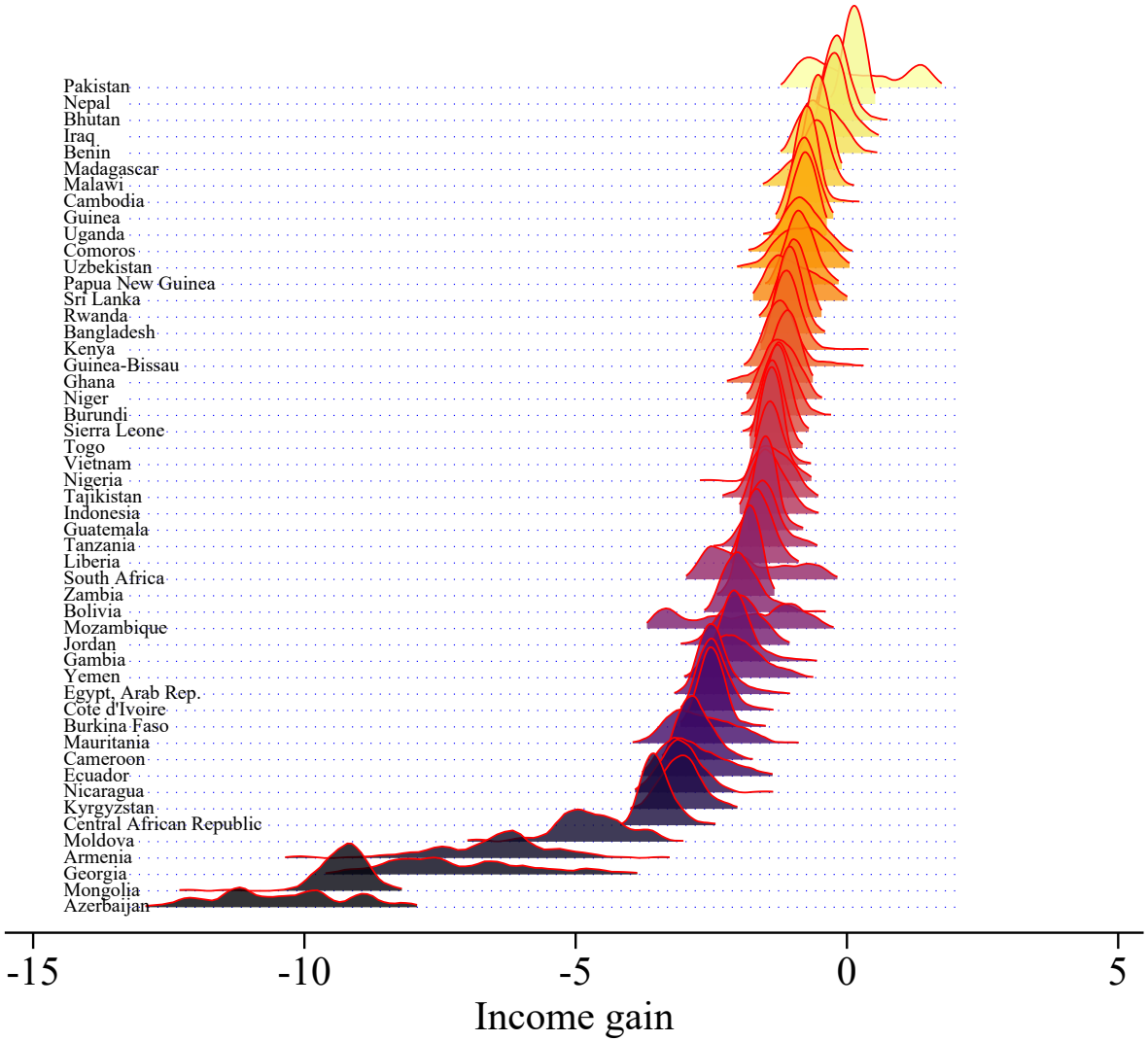
Simulation I: Preview of results

	ΔWelfare				ΔIncome			ΔCPI	Exposure
	Average	Bottom 25%	Top 25%	Single HH.	Total	Labor	Land	HH.	Imports
Panel A: All countries (pooled)									
Average	-2.06	-2.23	-1.81	-1.90	-0.10	-0.07	-0.18	2.02	5.42
Pop w. average	-1.33	-1.54	-1.02	-1.12	0.36	0.29	0.45	1.72	4.30
SD	2.12	2.41	1.91	2.05	1.63	1.23	2.26	1.25	5.35
Minimum	-10.41	-11.79	-9.27	-9.92	-7.11	-5.11	-8.74	0.03	0.30
Median	-1.38	-1.42	-1.33	-1.31	0.28	0.24	0.32	1.76	3.66
Maximum	0.14	0.06	1.35	0.89	1.84	1.81	2.60	8.24	19.97

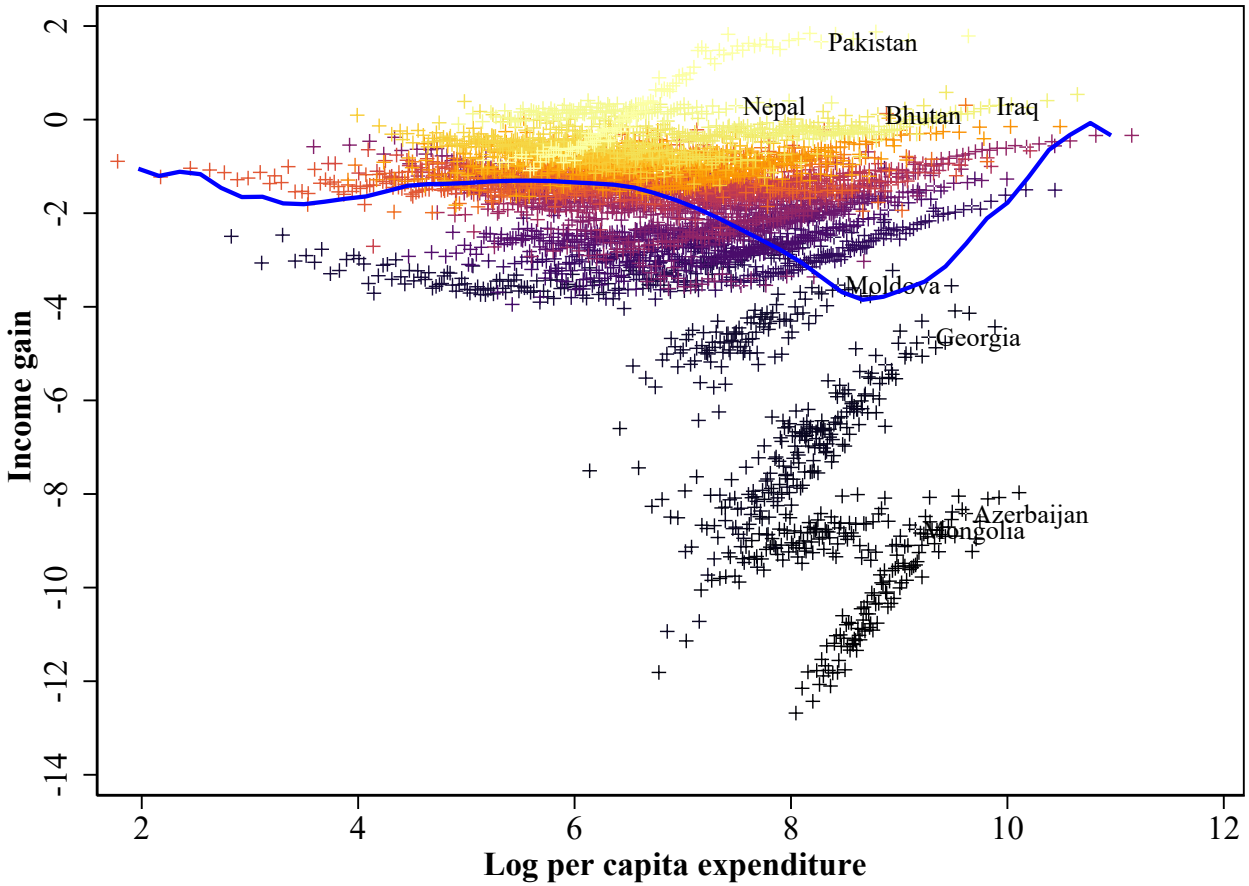
Simulation I: Density of income change (pooled)



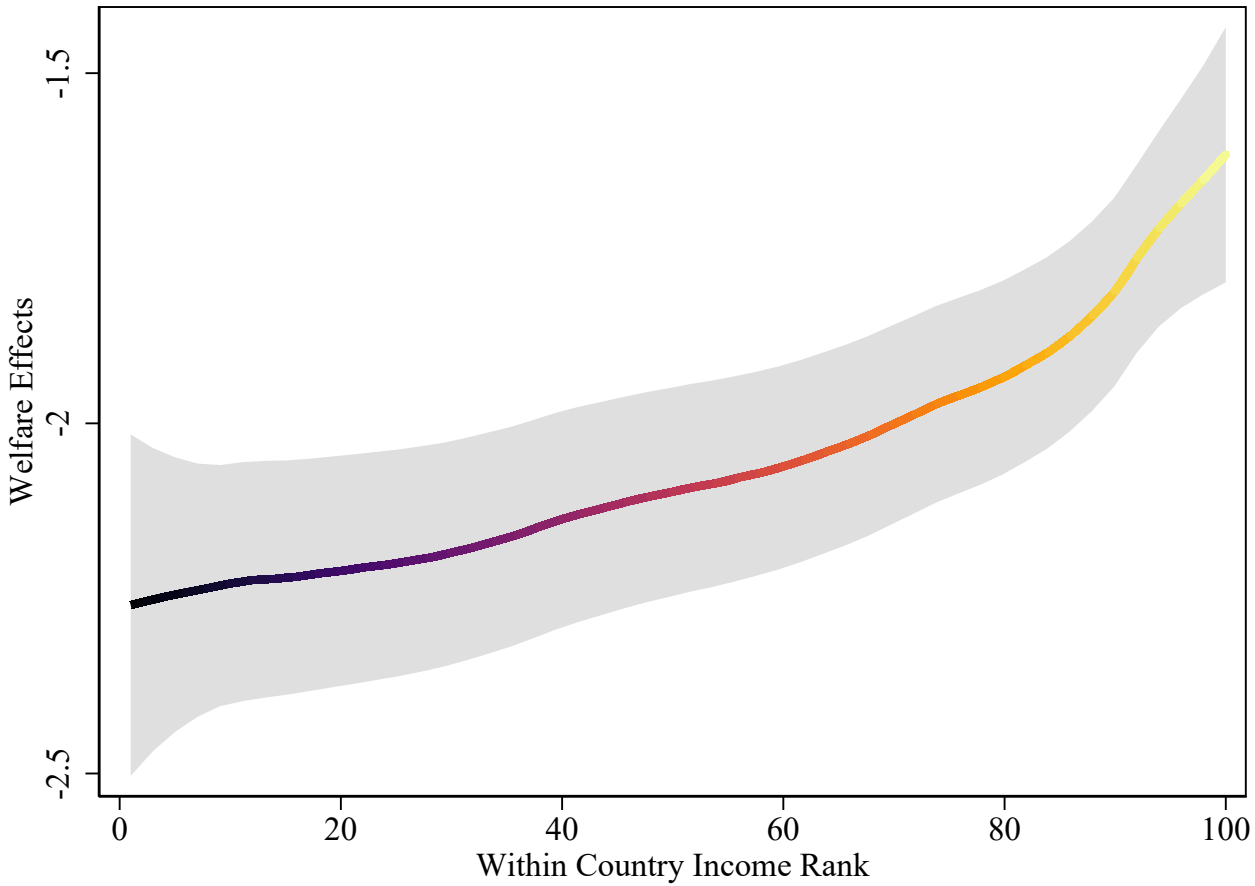
Simulation I: Density of income change (full)



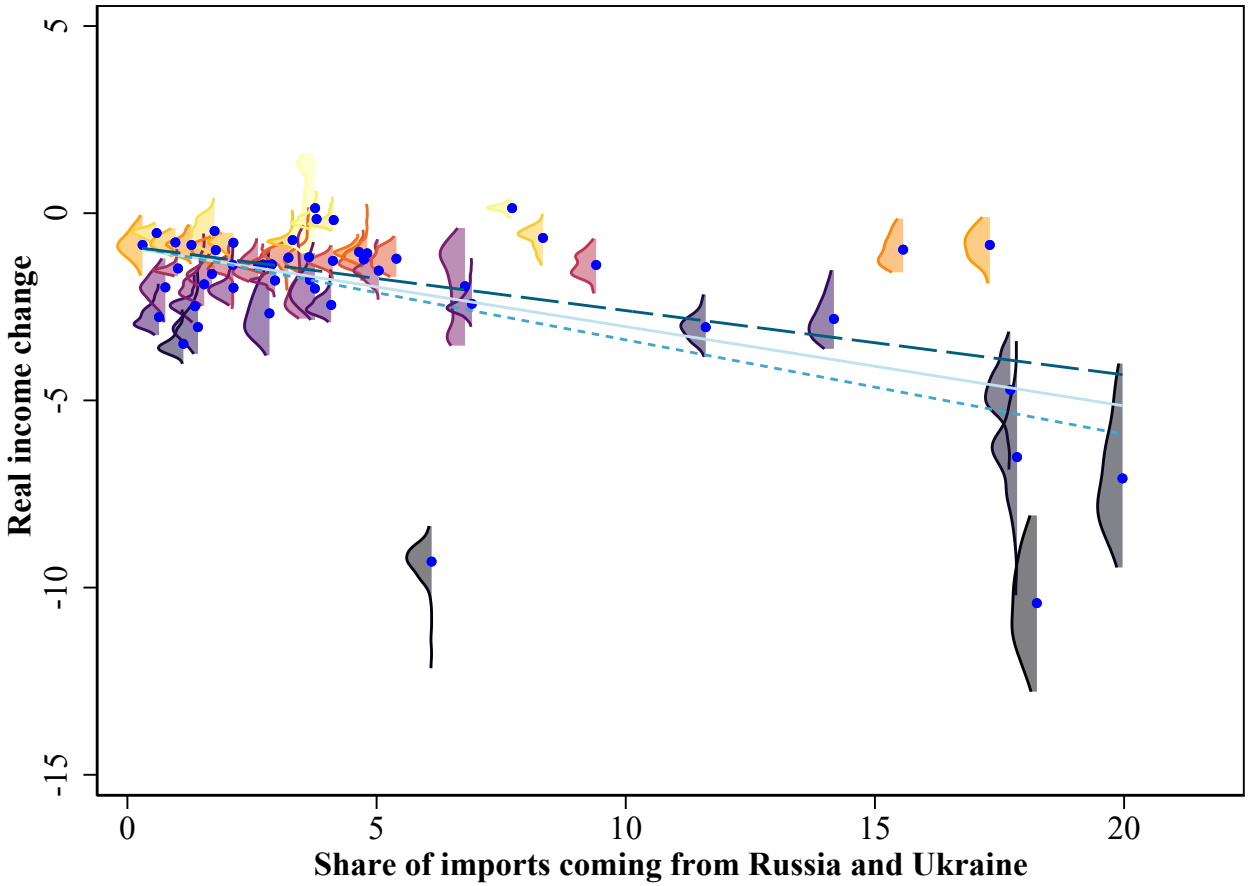
Simulation I: Initial income and losses



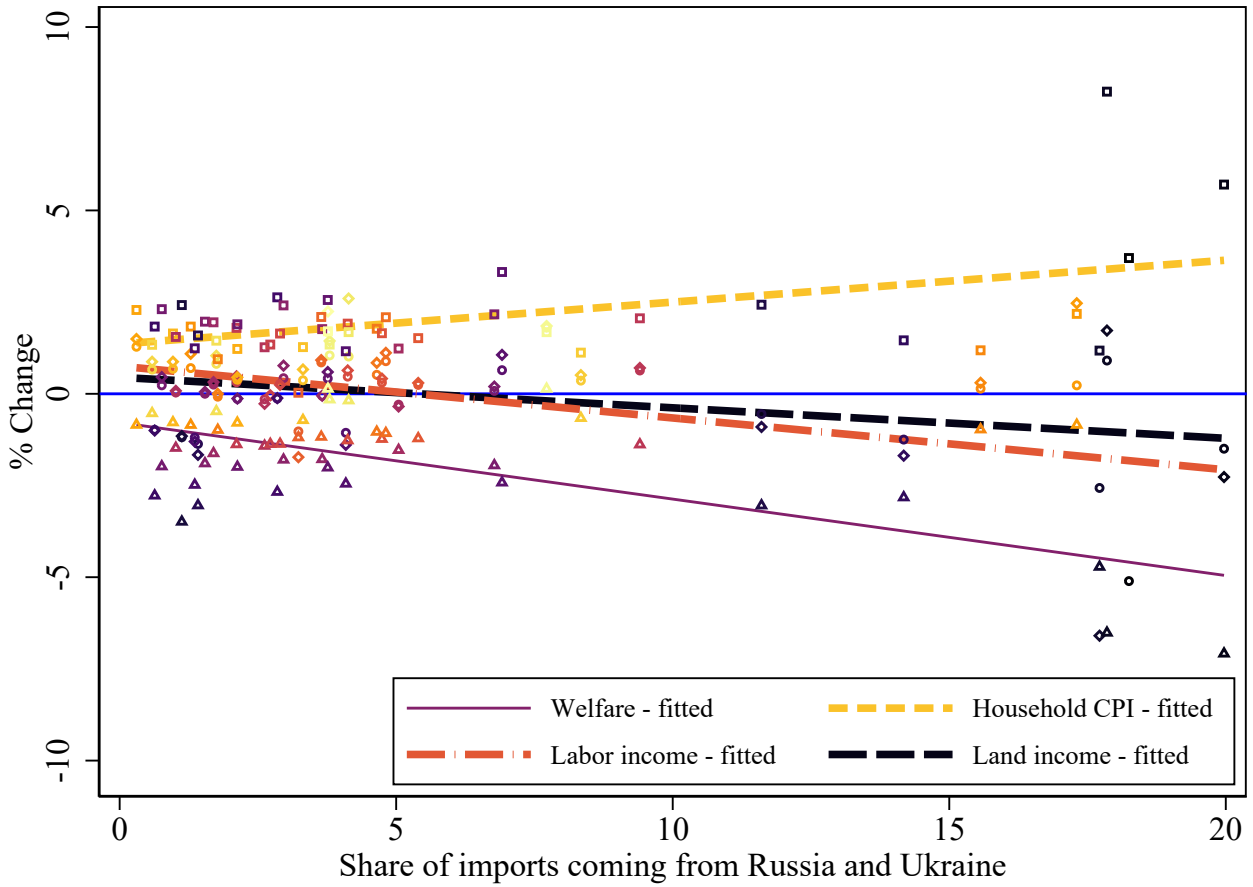
Simulation I: Income rank and losses (average)



Simulation I: Correlates of losses



Simulation I: Correlates of losses (channels)



Climate Change

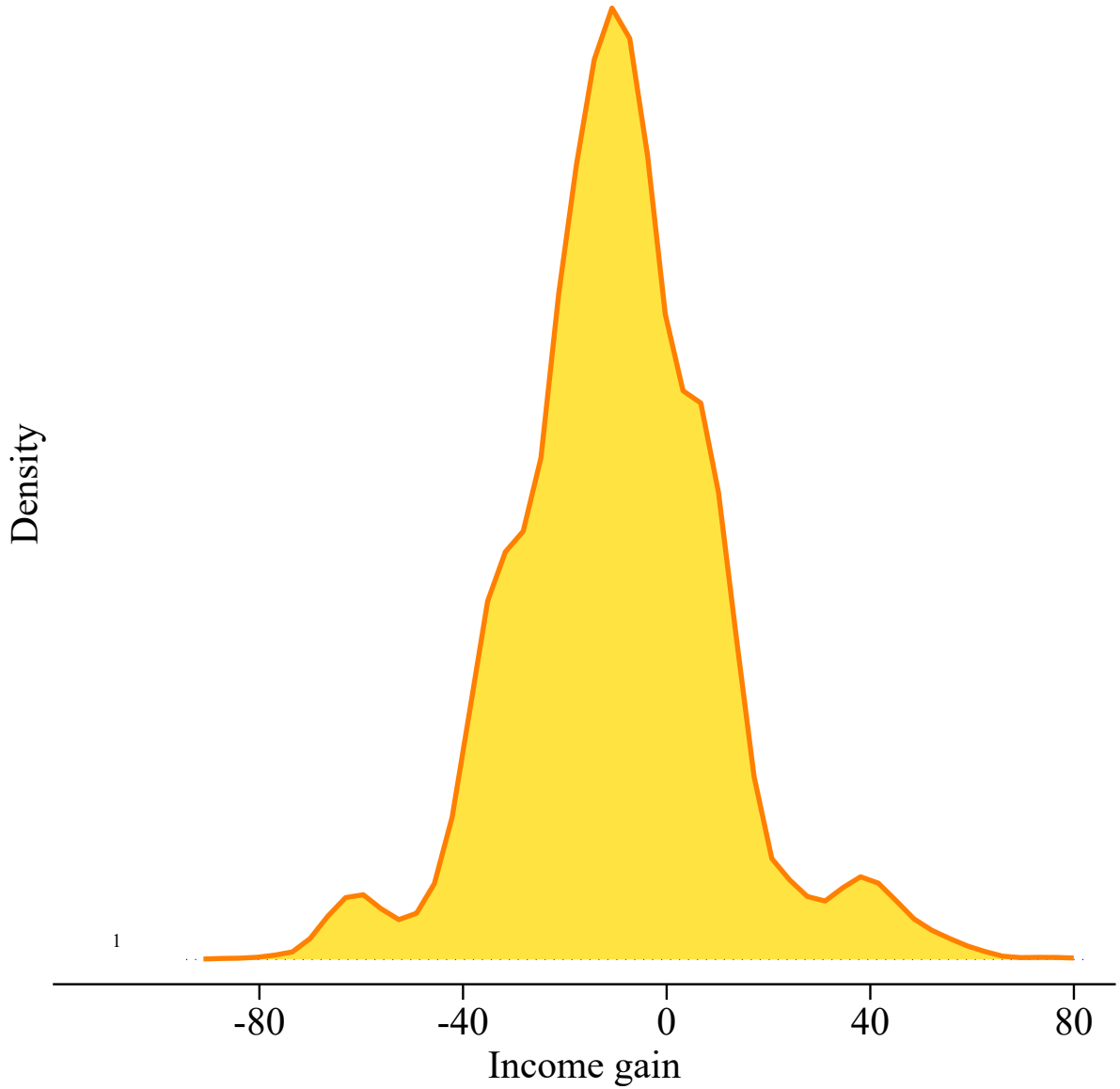
Simulation II: Climate change

- Climate change scenario used in Costinot et al. (2016) scenario
  - Reference in FOA GAEZ dataset: Hadley CM3 A1FI
  - Predictions for years from 2071 to 2100
  - Includes changes in temperature, precipitation, soil structure etc.
- Plug crop-specific productivity changes for each country

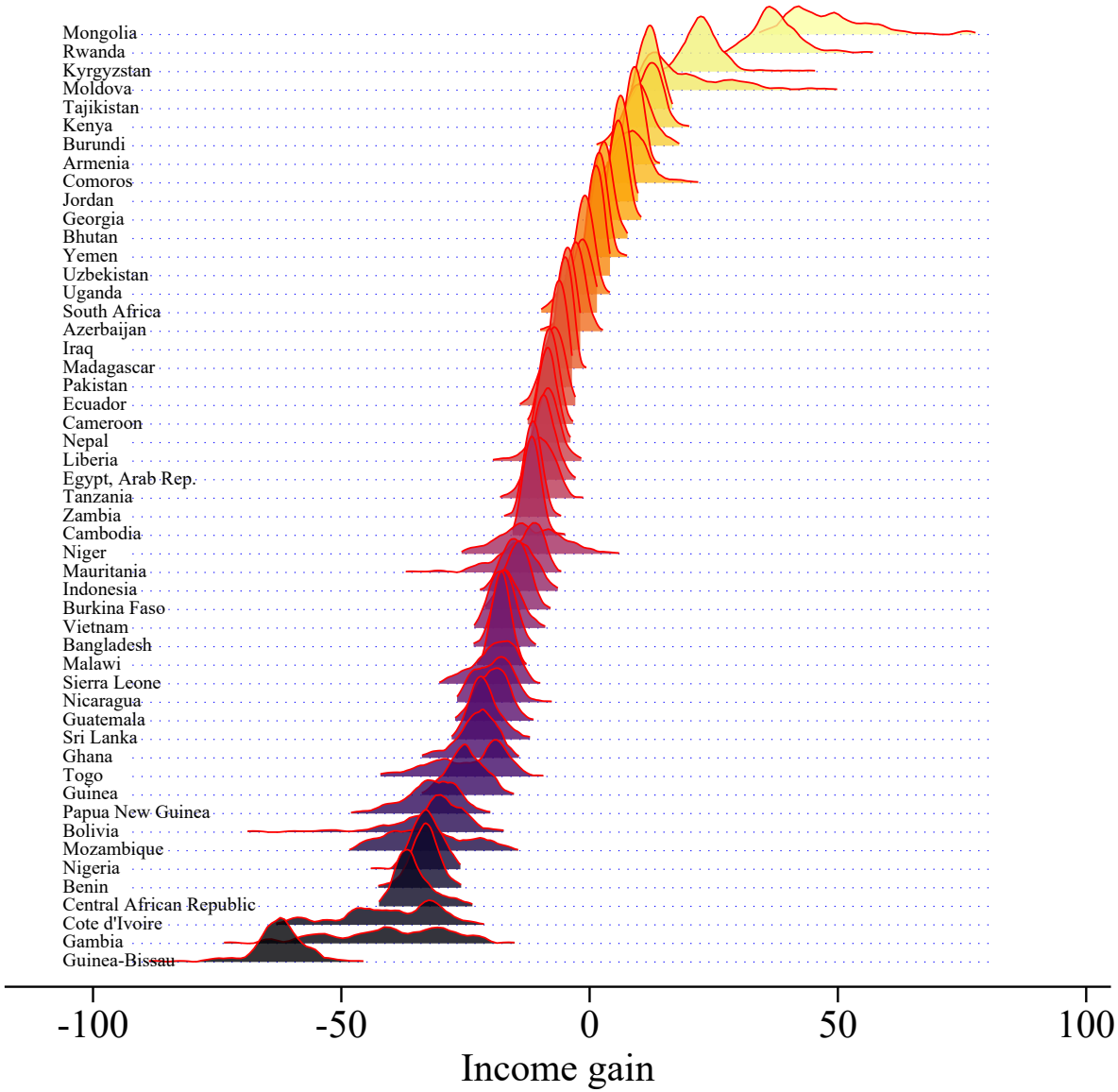
Simulation II: Preview of results

	ΔWelfare				ΔIncome			ΔCPI	Exposure
	Average	Bottom 25%	Top 25%	Single HH.	Total	Labor	Land	HH.	Yield
	Panel A: All countries (pooled)								
Average	-9.72	-11.60	-8.06	-8.64	-9.55	-8.24	-10.18	-0.05	-17.41
Pop w. average	-13.06	-15.10	-10.95	-11.86	-11.62	-9.32	-15.62	1.79	-29.48
SD	19.96	22.41	18.18	18.97	20.91	17.99	25.03	3.80	54.81
Minimum	-62.70	-67.17	-62.00	-61.90	-66.54	-64.27	-67.96	-10.32	-63.43
Median	-9.83	-10.69	-8.06	-8.82	-10.59	-9.24	-12.17	0.55	-37.81
Maximum	48.41	46.49	53.64	51.70	44.18	36.73	68.29	8.46	259.88

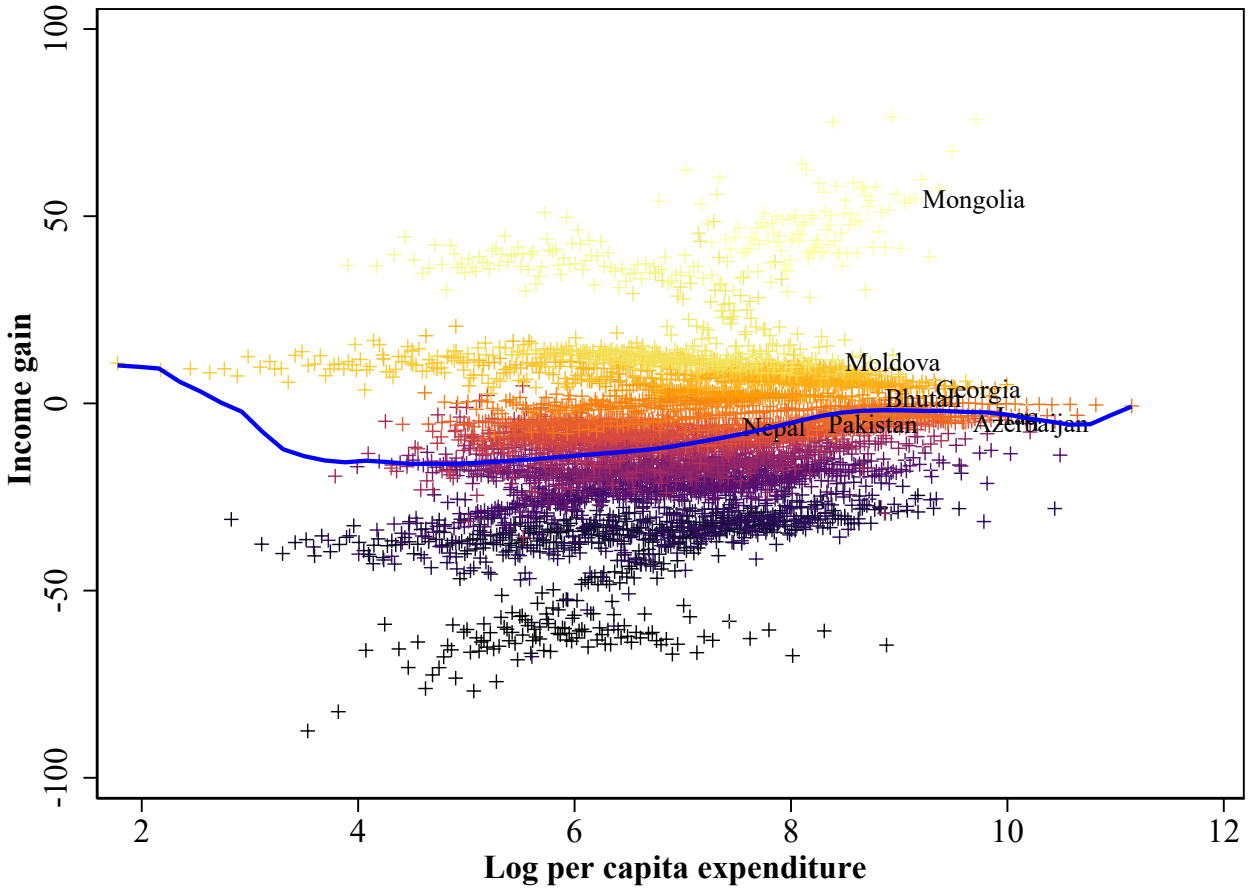
Simulation II: Density of income change (pooled)



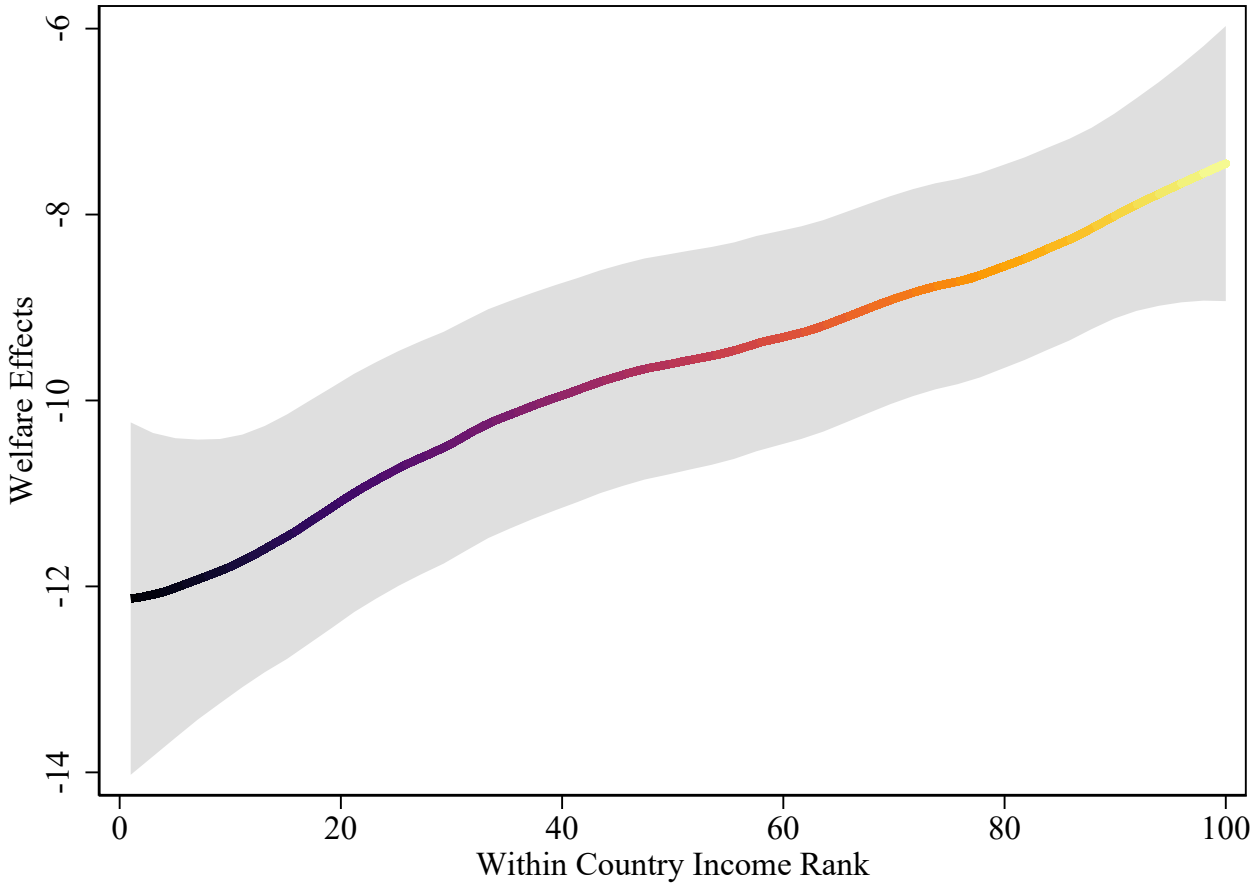
Simulation II: Density of income change (full)



Simulation II: Initial income and losses



Simulation II: Income rank and losses (average)



Conclusions

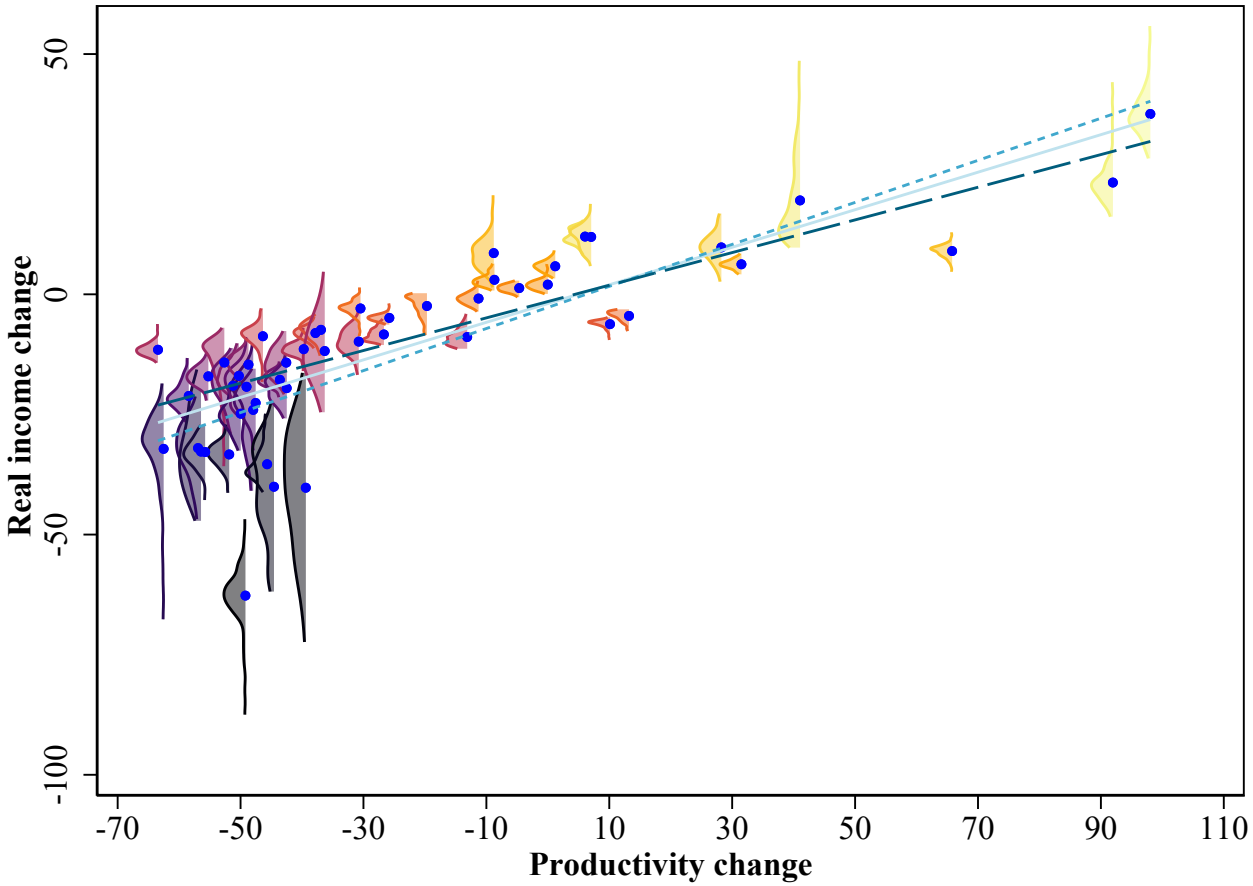
Conclusions

- Novel GE trade and agriculture model with
  - Land and labor allocation choice
  - Detailed household heterogeneity - consumption and income
- Recent war-induced export bans
  - Inflation, especially of wheat and fertilizers
  - Significant heterogeneity within and across countries
  - Losses are more severe for the poor
- Climate change
  - Large welfare losses for 3 out of 4 households
  - Losses are more severe for the poor
  - Some regions benefit

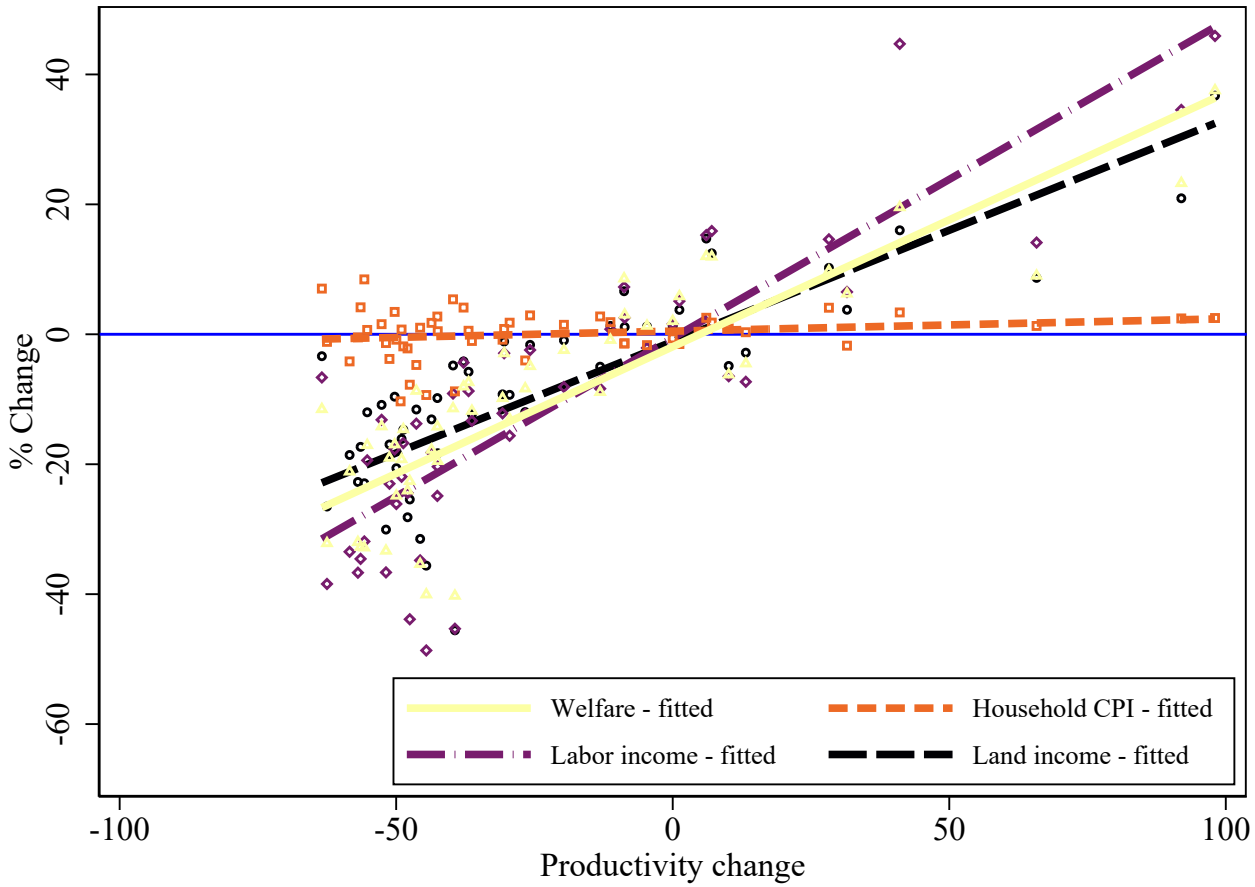
Thank you

Additional slides

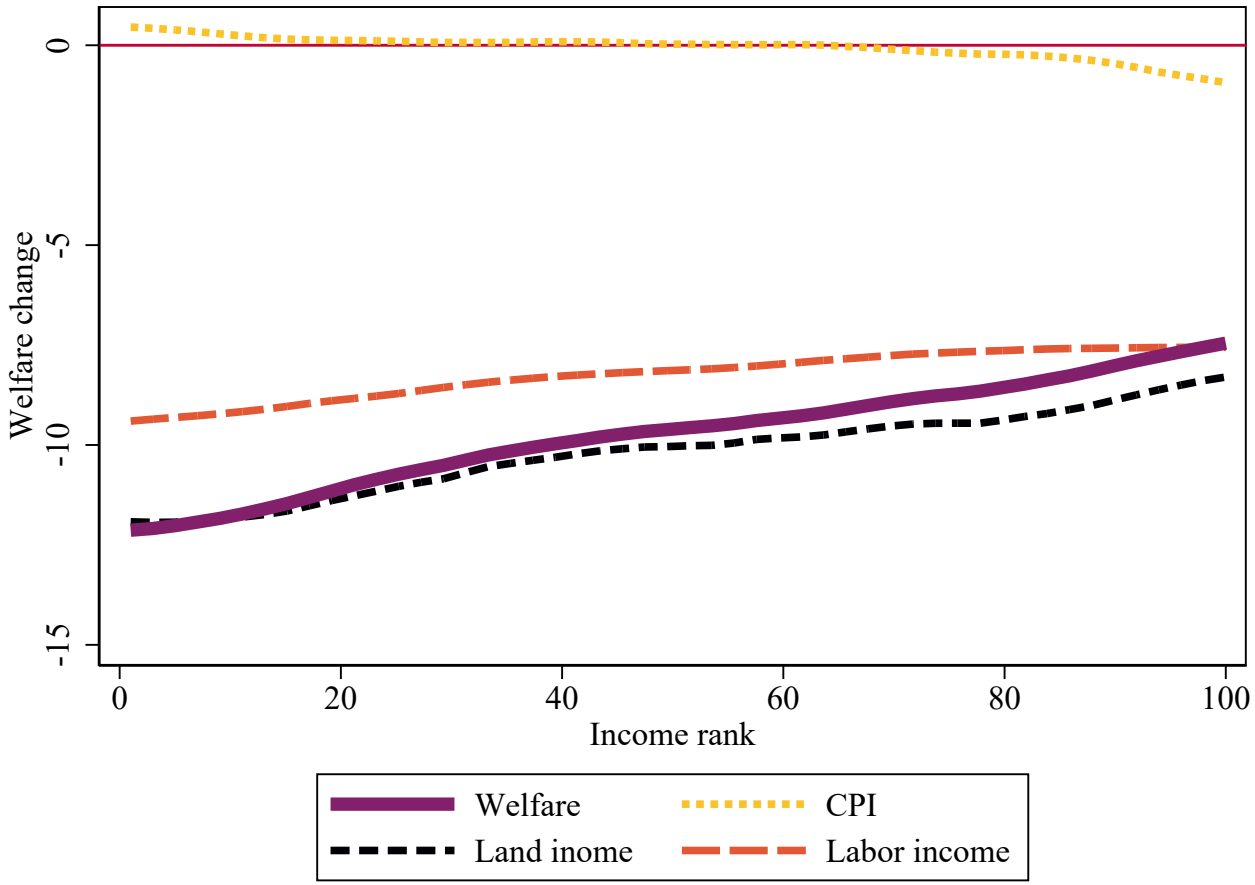
Simulation II: Income rank and losses (average)



Simulation II: Income channels dominate



Simulation II: Productivity changes are a key driver



Data: Sectors

- Sectors:
  1. Wheat, 2. Rice, 3. Corn, 4. Other cereals, 5. Soya,
  6. Other oilseeds, 7. Sugar, 8. Legumes, 9. Fruits and vegetables,
  10. Nuts, 11. Eggs, Meat and Dairy, 12. Confectionery and Cocoa,
  13. Oils and Fats, 14. Other staple food, 15. Beverages,
  16. Cotton, 17. Tobacco, 18. Spices/herbs, 19. Alcohol, 20. Fish,
  21. Manufacturing, 22. Services, and 23. Fertilizers.

Data: Countries

- Main countries: Armenia, Azerbaijan, Bangladesh, Benin, Bhutan, Bolivia, Burkina Faso, Burundi, Cambodia, Cameroon, Central African Republic, Comoros, Cote d'Ivoire, Ecuador, Egypt, Ethiopia, Gambia, Georgia, Ghana, Guatemala, Guinea, Guinea-Bissau, Indonesia, Iraq, Jordan, Kenya, Kyrgyzstan, Liberia, Madagascar, Malawi, Mali, Mauritania, Moldova, Mongolia, Mozambique, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Papua New, Guinea, Rwanda, Sierra Leone, South Africa, Sri Lanka, Tajikistan, Tanzania, Togo, Uganda, Uzbekistan, Vietnam, Yemen and Zambia.

- Central economies: Argentina, Australia, Brazil, Canada, Switzerland, Chile, China, Colombia, Germany, Denmark, India, Spain, Finland, Mexico, United Kingdom, South Korea, Peru, Russia, Saudi Arabia, United States and 27 other countries.

Estimation of main elasticities (Fréchet shape)

- GMM similar to Costinot, et al. (2016)
- Output as a function of elasticities (given the shares from data)

$$Y_j^n(\theta_T, \theta_L) = \overline{p}_j^n \overline{A}_j^n \left(\left(\overline{\pi}_{T,j}^n \right)^{\frac{\theta_T - 1}{\theta_T}} \right)^{\frac{\beta_T}{1-\beta_F}} \left(\left(\overline{\pi}_{L,j}^n \right)^{\frac{\theta_L - 1}{\theta_L}} \right)^{\frac{\beta_L}{1-\beta_F}}$$

- Objective function: match output shares

$$\{\theta_T^*, \theta_L^*\} = \arg\min_{\theta_T, \theta_L} \sum_n \sum_j \left[\overline{Y}_j^n - \frac{Y_j^n(\theta_T, \theta_L)}{\sum_k Y_k^n(\theta_T, \theta_L)} \right]^2$$

Simulation A1: Conflict - only fertilizers

	ΔWelfare				ΔIncome			ΔCPI	Exposure
	Average	Bottom 25%	Top 25%	Single HH.	Total	Labor	Land	HH.	Imports
				Panel A: All countries (pooled)					
Average	-1.67	-1.77	-1.52	-1.57	-0.40	-0.31	-0.57	1.30	5.42
Pop w. average	-1.24	-1.37	-1.02	-1.08	-0.01	-0.02	-0.02	1.25	4.30
SD	1.61	1.74	1.55	1.60	1.57	1.17	2.19	0.37	5.35
Minimum	-9.25	-10.18	-8.30	-8.94	-7.59	-5.43	-9.28	-0.13	0.30
Median	-1.21	-1.26	-1.09	-1.16	0.11	0.10	0.13	1.28	3.66
Maximum	0.05	0.13	0.15	0.13	1.02	0.90	1.26	2.08	19.97

Simulation A2: Conflict - only crops

	ΔWelfare				ΔIncome			ΔCPI	Exposure
	Average	Bottom 25%	Top 25%	Single HH.	Total	Labor	Land	HH.	Imports
	Panel A: All countries (pooled)								
Average	-0.31	-0.37	-0.23	-0.26	0.45	0.36	0.58	0.77	5.42
Pop w. average	-0.05	-0.11	0.03	0.00	0.46	0.38	0.59	0.52	4.30
SD	0.88	1.12	0.67	0.78	0.48	0.41	0.68	1.11	5.35
Minimum	-4.17	-5.06	-2.74	-3.47	-0.11	-0.11	-0.13	0.02	0.30
Median	-0.10	-0.06	-0.09	-0.08	0.25	0.20	0.32	0.39	3.66
Maximum	0.76	0.88	1.35	1.09	2.28	1.80	3.29	6.27	19.97

Simulation A3: Conflict - retaliation

	ΔWelfare				ΔIncome			ΔCPI	Exposure
	Average	Bottom 25%	Top 25%	Single HH.	Total	Labor	Land	HH.	Imports
				Panel A: All countries (pooled)					
Average	-2.24	-2.43	-1.95	-2.05	0.23	0.18	0.22	2.55	5.42
Pop w. average	-1.43	-1.68	-1.06	-1.18	0.67	0.53	0.85	2.13	4.30
SD	2.30	2.66	2.03	2.20	1.90	1.48	2.67	1.68	5.35
Minimum	-10.87	-12.56	-9.55	-10.25	-6.32	-4.56	-8.65	-0.60	0.30
Median	-1.79	-1.61	-1.61	-1.60	0.49	0.35	0.51	2.36	3.66
Maximum	0.99	0.98	1.77	1.08	4.21	3.88	7.26	10.04	19.97

Simulation A4: Climate change - limited adjustment

	ΔWelfare				ΔIncome			ΔCPI	Exposure
	Average	Bottom 25%	Top 25%	Single HH.	Total	Labor	Land	HH.	Yield
Panel A: All countries (pooled)									
Average	-12.43	-14.45	-10.70	-11.41	-12.91	-11.71	-13.70	-0.94	-17.41
Pop w. average	-14.43	-16.58	-12.25	-13.24	-13.59	-11.70	-16.93	1.05	-29.48
SD	20.40	23.01	18.34	19.27	21.47	19.65	23.73	4.22	54.81
Minimum	-72.98	-76.58	-72.52	-72.34	-76.52	-75.20	-77.46	-13.13	-63.43
Median	-11.54	-11.98	-10.32	-10.99	-12.09	-11.18	-13.17	-0.19	-37.81
Maximum	34.28	33.81	36.22	35.42	34.61	31.54	41.32	7.18	259.88