Crops, Conflict, and Climate Change

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World Bank - Development Research Group

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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% ↓ in average income
- Climate change: 9.72% ↓ 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 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

\[ P^n_j = \left[ \sum_{m'} \vartheta_{j,m'} \left( p_{j,m'}^n \tau_{j,m'}^n \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \]

- Price of labor (wage income)

\[ \Phi^{n,h}_L = \left( \sum_{j \in S} \left( w_{j}^{n} A_{L,j}^{n,h} \right)^{\theta_L} \right)^{\frac{1}{\theta_L}} \]

- Rental rate of land (return on land)

\[ \Phi^{n,h}_T = \left( \sum_{j \in S} \left( r_{j}^{n} A_{T,j}^{n,h} \right)^{\theta_T} \right)^{\frac{1}{\theta_T}} \]
Model: Welfare

- Income from labor: \( R_{L}^{n,h} = \Phi_{L}^{n,h}L^{n,h} \)
- Income from land and fixed factors:
  \[ R_{T}^{n,h} = \Phi_{T}^{n,h}T^{n,h} + r_{M}^{n}M^{n,h} + r_{S}^{n}S^{n,h} \]
- Household specific consumer price index:
  \[ P_{n,h} = \prod_{j} (P_{j}^{n})^{\alpha_{j}^{n,h}} \]
- 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)

\[
\hat{V}^{n,h} = -\sum_j \hat{p}_j^n \alpha_j^{n,h} + \sum_j \hat{p}_j^n \kappa_{T,j}^{n,h} + \sum_j \hat{w}_j^n \kappa_{L,j}^{n,h} + \hat{r}_M^n \kappa_M^{n,h} + \hat{r}_S^n \kappa_S^{n,h}
\]

- Welfare herein

\[
\hat{V}^{n,h} = \frac{\Phi_L^n \kappa_L^{n,h} + \Phi_T^n \kappa_T^{n,h} + \hat{r}_M^n \kappa_M^{n,h} + \hat{r}_S^n \kappa_S^{n,h}}{\prod_j \left(\hat{P}_j^n\right)^{\alpha_j^{n,h}}}
\]

- 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
  - $\alpha_{j,n}^{n,h}$ (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

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Observed price change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All products</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample</td>
<td>No outliers</td>
</tr>
<tr>
<td>Predicted price change</td>
<td>(1)</td>
</tr>
<tr>
<td></td>
<td>0.640***</td>
</tr>
<tr>
<td></td>
<td>(0.185)</td>
</tr>
<tr>
<td>Country FE</td>
<td>Yes</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.319</td>
</tr>
<tr>
<td>Adj. R-squared</td>
<td>0.227</td>
</tr>
<tr>
<td>Obs.</td>
<td>311</td>
</tr>
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</table>
Simulation I: Preview of results

<table>
<thead>
<tr>
<th></th>
<th>ΔWelfare</th>
<th>ΔIncome</th>
<th>ΔCPI</th>
<th>Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Bottom 25%</td>
<td>Top 25%</td>
<td>Single HH.</td>
</tr>
<tr>
<td>Average</td>
<td>-2.06</td>
<td>-2.23</td>
<td>-1.81</td>
<td>-1.90</td>
</tr>
<tr>
<td>Pop w. average</td>
<td>-1.33</td>
<td>-1.54</td>
<td>-1.02</td>
<td>-1.12</td>
</tr>
<tr>
<td>SD</td>
<td>2.12</td>
<td>2.41</td>
<td>1.91</td>
<td>2.05</td>
</tr>
<tr>
<td>Minimum</td>
<td>-10.41</td>
<td>-11.79</td>
<td>-9.27</td>
<td>-9.92</td>
</tr>
<tr>
<td>Median</td>
<td>-1.38</td>
<td>-1.42</td>
<td>-1.33</td>
<td>-1.31</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.14</td>
<td>0.06</td>
<td>1.35</td>
<td>0.89</td>
</tr>
</tbody>
</table>

*Panel A: All countries (pooled)*
Simulation I: Density of income change (pooled)
Simulation I: Density of income change (full)
Simulation I: Initial income and losses

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Simulation 1: Income rank and losses (average)
Simulation I: Correlates of losses
Simulation I: Correlates of losses (channels)

[Graph showing the relationship between the share of imports coming from Russia and Ukraine and various economic indicators, such as welfare, household CPI, labor income, and land income, with fitted lines representing the data trends.]
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

<table>
<thead>
<tr>
<th></th>
<th>ΔWelfare</th>
<th>ΔIncome</th>
<th>ΔCPI</th>
<th>Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Bottom 25%</td>
<td>Top 25%</td>
<td>Single HH.</td>
</tr>
<tr>
<td>Average</td>
<td>-9.72</td>
<td>-11.60</td>
<td>-8.06</td>
<td>-8.64</td>
</tr>
<tr>
<td>SD</td>
<td>19.96</td>
<td>22.41</td>
<td>18.18</td>
<td>18.97</td>
</tr>
<tr>
<td>Minimum</td>
<td>-62.70</td>
<td>-67.17</td>
<td>-62.00</td>
<td>-61.90</td>
</tr>
<tr>
<td>Maximum</td>
<td>48.41</td>
<td>46.49</td>
<td>53.64</td>
<td>51.70</td>
</tr>
</tbody>
</table>

*Panel A: All countries (pooled)*
Simulation II: Density of income change (pooled)
Simulation II: Initial income and losses

Azerbaijan    Bhutan    Georgia    Iraq    Moldova    Mongolia    Nepal    Pakistan

-100    -50    0    50    100

Income gain

2    4    6    8    10    12

Log per capita expenditure

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Simulation II: Income rank and losses (average)

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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

![Graph showing the relationship between productivity change and % change in welfare, household CPI, labor income, and land income. The graph demonstrates that income channels dominate in the simulation.](image)
Simulation II: Productivity changes are a key driver

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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,
  13. Oils and Fats, 14. Other staple food, 15. Beverages,
Data: Countries


- 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)

\[
Y^n_j(\theta_T, \theta_L) = \bar{p}^n_j \bar{A}^n_j \left( \frac{\theta_T - 1}{\theta_T} \right)^{\frac{\beta_T}{1-\beta_F}} \left( \frac{\theta_L - 1}{\theta_L} \right)^{\frac{\beta_L}{1-\beta_F}}
\]

- Objective function: match output shares

\[
\{\theta_T^*, \theta_L^*\} = \arg\min_{\theta_T, \theta_L} \sum_n \sum_j \left[ \bar{Y}^n_j - \frac{Y^n_j(\theta_T, \theta_L)}{\sum_k Y^n_k(\theta_T, \theta_L)} \right]^2
\]
Simulation A1: Conflict - only fertilizers

<table>
<thead>
<tr>
<th></th>
<th>ΔWelfare</th>
<th></th>
<th></th>
<th>ΔIncome</th>
<th></th>
<th>ΔCPI</th>
<th>Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Bottom 25%</td>
<td>Top 25%</td>
<td>Single HH.</td>
<td>Total</td>
<td>Labor</td>
<td>Land</td>
</tr>
<tr>
<td>Average</td>
<td>-1.67</td>
<td>-1.77</td>
<td>-1.52</td>
<td>-1.57</td>
<td>-0.40</td>
<td>-0.31</td>
<td>-0.57</td>
</tr>
<tr>
<td>Pop w. average</td>
<td>-1.24</td>
<td>-1.37</td>
<td>-1.02</td>
<td>-1.08</td>
<td>-0.01</td>
<td>-0.02</td>
<td>-0.02</td>
</tr>
<tr>
<td>SD</td>
<td>1.61</td>
<td>1.74</td>
<td>1.55</td>
<td>1.60</td>
<td>1.57</td>
<td>1.17</td>
<td>2.19</td>
</tr>
<tr>
<td>Minimum</td>
<td>-9.25</td>
<td>-10.18</td>
<td>-8.30</td>
<td>-8.94</td>
<td>-7.59</td>
<td>-5.43</td>
<td>-9.28</td>
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<tr>
<td>Median</td>
<td>-1.21</td>
<td>-1.26</td>
<td>-1.09</td>
<td>-1.16</td>
<td>0.11</td>
<td>0.10</td>
<td>0.13</td>
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<tr>
<td>Maximum</td>
<td>0.05</td>
<td>0.13</td>
<td>0.15</td>
<td>0.13</td>
<td>1.02</td>
<td>0.90</td>
<td>1.26</td>
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Panel A: All countries (pooled)
## Simulation A2: Conflict - only crops

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<th></th>
<th>ΔCPI</th>
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<th>Exposure</th>
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<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Bottom 25%</td>
<td>Top 25%</td>
<td>Single HH.</td>
<td>Total</td>
<td>Labor</td>
<td>Land</td>
</tr>
<tr>
<td>Average</td>
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<td>-0.37</td>
<td>-0.23</td>
<td>-0.26</td>
<td>0.45</td>
<td>0.36</td>
<td>0.58</td>
</tr>
<tr>
<td>Pop w. average</td>
<td>-0.05</td>
<td>-0.11</td>
<td>0.03</td>
<td>0.00</td>
<td>0.46</td>
<td>0.38</td>
<td>0.59</td>
</tr>
<tr>
<td>SD</td>
<td>0.88</td>
<td>1.12</td>
<td>0.67</td>
<td>0.78</td>
<td>0.48</td>
<td>0.41</td>
<td>0.68</td>
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<tr>
<td>Minimum</td>
<td>-4.17</td>
<td>-5.06</td>
<td>-2.74</td>
<td>-3.47</td>
<td>-0.11</td>
<td>-0.11</td>
<td>-0.13</td>
</tr>
<tr>
<td>Median</td>
<td>-0.10</td>
<td>-0.06</td>
<td>-0.09</td>
<td>-0.08</td>
<td>0.25</td>
<td>0.20</td>
<td>0.32</td>
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<tr>
<td>Maximum</td>
<td>0.76</td>
<td>0.88</td>
<td>1.35</td>
<td>1.09</td>
<td>2.28</td>
<td>1.80</td>
<td>3.29</td>
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*Panel A: All countries (pooled)*
### Simulation A3: Conflict - retaliation

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<th>ΔCPI</th>
<th>Exposure</th>
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<tbody>
<tr>
<td></td>
<td>Average</td>
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<td>Top 25%</td>
<td>Single HH.</td>
<td>Total</td>
<td>Labor</td>
</tr>
<tr>
<td>Average</td>
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<td>-2.43</td>
<td>-1.95</td>
<td>-2.05</td>
<td>0.23</td>
<td>0.18</td>
</tr>
<tr>
<td>Pop w. average</td>
<td>-1.43</td>
<td>-1.68</td>
<td>-1.06</td>
<td>-1.18</td>
<td>0.67</td>
<td>0.53</td>
</tr>
<tr>
<td>SD</td>
<td>2.30</td>
<td>2.66</td>
<td>2.03</td>
<td>2.20</td>
<td>1.90</td>
<td>1.48</td>
</tr>
<tr>
<td>Minimum</td>
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<td>-12.56</td>
<td>-9.55</td>
<td>-10.25</td>
<td>-6.32</td>
<td>-4.56</td>
</tr>
<tr>
<td>Median</td>
<td>-1.79</td>
<td>-1.61</td>
<td>-1.61</td>
<td>-1.60</td>
<td>0.49</td>
<td>0.35</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.99</td>
<td>0.98</td>
<td>1.77</td>
<td>1.08</td>
<td>4.21</td>
<td>3.88</td>
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</table>

*Panel A: All countries (pooled)*
Simulation A4: Climate change - limited adjustment

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<th>ΔIncome</th>
<th></th>
<th>ΔCPI</th>
<th>Exposure</th>
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<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Bottom</td>
<td>Top</td>
<td>Single HH.</td>
<td>Total</td>
<td>Labor</td>
<td>Land</td>
</tr>
<tr>
<td>Average</td>
<td>-12.43</td>
<td>-14.45</td>
<td>-10.70</td>
<td>-11.41</td>
<td>-12.91</td>
<td>-11.71</td>
<td>-13.70</td>
</tr>
<tr>
<td>SD</td>
<td>20.40</td>
<td>23.01</td>
<td>18.34</td>
<td>19.27</td>
<td>21.47</td>
<td>19.65</td>
<td>23.73</td>
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<td>-76.58</td>
<td>-72.52</td>
<td>-72.34</td>
<td>-76.52</td>
<td>-75.20</td>
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<tr>
<td>Maximum</td>
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<td>33.81</td>
<td>36.22</td>
<td>35.42</td>
<td>34.61</td>
<td>31.54</td>
<td>41.32</td>
</tr>
</tbody>
</table>

*Panel A: All countries (pooled)*