Climate Change, Agriculture and Poverty Vulnerability

Presentation by
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Based on joint work with Amer Ahmed, Noah Diffenbaugh, David Lobell, Navin Ramankutty, Pedram Rowhani and Wolfram Schlenker

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Interdisciplinary Research is Challenging!
So you need great collaborators!
Overview

• Brief review of climate change debate:
  – Science: Detection vs. attribution
  – What is the role of agriculture in GHG emissions?
  – What is the role for agriculture in GHG abatement?
  – Abatement unlikely to be sufficient to prevent climate change; adaptation will be required

• What are the agricultural impacts of climate change?
  – Two different approaches to estimation of crop impacts:
    • Crop models
    • Statistical analyses of yields and crop land rents
  – Consensus projections: Low-Medium-High productivity
  – Implications for agricultural production, trade and poverty

• The issue of climate volatility:
  – Changes in frequency and intensity of extreme events
  – Impact of extreme climate events on poverty
Climate Science Debate

Detection:
- Little doubt about global warming – despite short run temperature downturn and climate-gate, notwithstanding!
- Rise in atmospheric CO2 also unambiguous, as are anthropogenic contributions

Attribution:
- Much more complex
- Making the connection from rising GHG concentrations to global warming/climate change requires a “counterfactual” experiment: observe temp in absence add’l GHGs
- Hence need for climate models

Not dissimilar from problem faced by economists who also cannot conduct controlled experiments. E.g., what was the impact of NAFTA on the US?
General Circulation Model ("GCM")

Laws of Physics!!!

Australia Government BOM
Climate models are not unlike global economic models

- General Circulation Models (GCMs) are large scale models of physical interactions between sea/atmosphere; climate/topography etc. – build up from grid cell level
- Built on basic physical principles, much like theoretical economic principles underpinning Computable General Equilibrium models such as GTAP
- When run the model, these grid cells interact – climate evolves over time; akin to dynamic economic models in need for careful treatment of stocks and flows
- If want to understand the impact of increased anthropogenic GHG releases on climate, calibrate model to track current climate with observed GHG forcings, then run the counterfactual in which human GHG emissions are not present: Do the confidence intervals overlap?
Overview

• **Brief review of climate change debate:**
  – Science: Detection vs. attribution (and Climate-gate!)
  – **What is the role of agriculture in GHG emissions?**
  – What is the optimal extent of GHG abatement? And what is the role for agriculture in such abatement?
  – Abatement will not be sufficient to prevent climate change; adaptation will be required

• **What are the agricultural impacts of climate change?**
  – Two different approaches to estimation of crop impacts:
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• **The issue of climate volatility:**
  – Changes in frequency and intensity of extreme events
  – Importance for agriculture and the poor
Agriculture is the largest source of non-CO2 GHGs.

Agriculture and forestry account for 1/3 of GHG emissions.
Agriculture accounts for 60% of global non-CO2 GHG emissions

Source: Rose and Lee, chp. 5 in Hertel, Rose and Tol (2009)
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    • Bottom-up crop models
    • Top-down statistical analyses
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Land-based mitigation offers low cost options for abatement

- Modified GTAP model in which we have incorporated detailed MACs from US EPA for emissions sources
- Also include estimates of intensive and extensive margins of forest carbon sequestration
- Raise carbon tax/subsidy worldwide to $100/tonne of carbon = $30/tonne CO2
- At this level of taxation, land based abatement is comparable to that from fossil fuel combustion

Source: Golub, Hertel, Lee, Rose and Sohngen (2009)
A global carbon tax changes the pattern of trade: Change in trade balance ($mill) with global tax/sequestration subsidy of $30/TCO2e for agr and forestry

- US increases net agric exports, decreases forest product net exports

Source: Golub, Hertel, Lee, Rose and Sohngen (2009)
But leakage is an issue if not all countries participate

Impact of US only tax on agricultural abatement

GHG emissions from RoW Agr rise
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% yield change of Maize (T = + 2°C)

No change in planting & harvest dates

Allow changes in planting & harvest dates
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The statistical challenge: what is the relationship between temperature and yields?

Graph A (Scatter Plot)

Source: Wolfram Schlenker’s presentation at WB Workshop: 10/22/2009
Simple regression analysis
Suggests a positive relationship,
But yields in South Africa
May be higher for other reasons

Source: Wolfram Schlenker’s presentation at WB Workshop: 10/22/2009
Once we factor in the unique Characteristics of the two Economies, yields fall with higher temperatures.

Source: Wolfram Schlenker’s presentation at WB Workshop: 10/22/2009
Panel estimation has also permitted identification of critical thresholds: *US maize yield response to temperature*

Source: Schlenker and Roberts, NBER working paper
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Synthesis of statistical studies

• Undertaken by David Lobell (Stanford) based on work published in Science as well as a survey of other published work

• Relatively near term time horizon: 2030

• Estimates for 6 crop categories:
  – Tropical maize adversely affected due to low responsiveness to CO2 fertilization, greater sensitivity to heat stress
  – Consider most-likely case, as well as 5th percentile (pessimistic scenario) and 95th percentile (optimistic scenario) values in distribution of potential yield impacts

• Incorporate into GTAP model of global trade and production to assess impacts on prices, trade and poverty
Overall average yield changes due to climate change in 2030: All crops ($$ weighted)

**Pessimistic scenario**

Overall Yield Changes (%) for 2030, with CO2 effects - Low Productivity

**Optimistic scenario**

Overall Yield Changes (%) for 2030, with CO2 effects - High Productivity
Most likely case: Impact of Climate Change on Yields in 2030; all crops (value-weighted)
Maize is more sensitive to temperature extremes.

Most likely yield impact due to climate change in 2030: Maize vs. Wheat

Impact on wheat yields is mixed.
Impact of medium run climate change: High productivity (clear), central case (grey) and low productivity (black) scenarios in 2030

Low productivity scenario leads to productivity reductions in nearly all regions

Low productivity scenario associated with global price rises

Source: Hertel, Burke and Lobell, 2009
Linkages from climate change through agriculture to poverty

• To date, most of focus has been on food availability and prices; higher food prices hurt all households, but hurt the poor relatively more due to large food budget share.

• However, impact on poverty will depend on both spending and earnings effects; the latter are more complex; also depend on prices and returns to agricultural producers.

• Worldwide climate change is a bit like global “supply control” – it raises farm prices, can benefit producers who are not themselves severely affected by climate change.
Decomposing poverty impacts by spending & earnings effects: median % change by stratum vs. avg price change

Stratum key: Bubbles scaled by the percentage of poor residing in that grouping (country avg)
- red = ag self employed
- orange = non-ag self employed
- green = urban labor
- blue = rural labor
- purple = transfer dependent
- black = urban diversified
- grey = rural diversified

Low prod scenario benefits agr specialized hhlds
But raises poverty for urban wage labor hhlds

Source: Hertel, Burke and Lobell, 2009
Summary of Findings: Impacts of Potential Climate Change on Agriculture in 2030

• Central case scenario has very modest impacts on global crop prices: adverse shocks in tropics offset by beneficial productivity shocks in temperate zones.

• High/Low scenarios capture tails of climate-productivity distribution (5% prob in each tail).

• In adverse (Low Productivity) case:
  – Global staple grains prices rise by 10 – 60%.
  – Agricultural factor returns rise in most regions.
  – Average poverty falls in agr specialized hhlds.
  – Average poverty rises in rural and urban wage labor hhlds, nonfarm specialized and transfer dependent hhlds.
  – National poverty rates fall in regions where climate impacts are more modest and poverty is concentrated in rural sector.
What about the impact of increasing climate volatility?

• In many cases, agricultural producers will be able to adapt to gradual changes in climate over the next century via:
  – Changes in management practices
  – Changes in varieties of crops and livestock farmed
• However, nations’ abilities to adapt to extreme events is less certain – particularly if those events (drought, flooding, etc.) become either more frequent or more intense
• Poor are likely to be most vulnerable to climate volatility:
  – Live in more exposed locations
  – Large budget share devoted to staple foods
  – Heavy reliance on agriculture for incomes
• Key knowledge gap: What is the impact of increasing climate volatility on poverty vulnerability?
Historical volatility in grains production in Tanzania

Source: Authors’ estimation; Grains Productivity Volatility in Tanzania Characterized as Mean-Zero Normal Distributions of Interannual Percentage Changes, 1971-2001
It may be a good idea to remove the sigmas for consistency with Table 1.

s2

saahmed, 4/16/2009
Impacts of 1-in-30 extremes on % changes in grain output could be large for some countries (1971-2001)

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>-13</td>
</tr>
<tr>
<td>Brazil</td>
<td>-62</td>
</tr>
<tr>
<td>Chile</td>
<td>-29</td>
</tr>
<tr>
<td>Colombia</td>
<td>-18</td>
</tr>
<tr>
<td>Indonesia</td>
<td>-14</td>
</tr>
<tr>
<td>Mexico</td>
<td>-75</td>
</tr>
<tr>
<td>Mozambique</td>
<td>-29</td>
</tr>
<tr>
<td>Malawi</td>
<td>-66</td>
</tr>
<tr>
<td>Peru</td>
<td>-27</td>
</tr>
<tr>
<td>Philippines</td>
<td>-15</td>
</tr>
<tr>
<td>Thailand</td>
<td>-33</td>
</tr>
<tr>
<td>Tanzania</td>
<td>-20</td>
</tr>
<tr>
<td>Uganda</td>
<td>-24</td>
</tr>
<tr>
<td>Venezuela</td>
<td>-39</td>
</tr>
<tr>
<td>Vietnam</td>
<td>-12</td>
</tr>
<tr>
<td>Zambia</td>
<td>-75</td>
</tr>
</tbody>
</table>
Historical volatility in grains production and prices in Tanzania

1 in 30 productivity draw from here

Prices have been more volatile than production

Interannual Percentage Change

Productivity
Price

Source: Authors’ estimation; Grains Productivity and Price Volatilities in Tanzania Characterized as Mean-Zero Normal Distributions of Interannual Percentage Changes, 1971-2001
It may be a good idea to remove the sigmas for consistency with Table 1

saahmed, 4/16/2009
Poverty impact of a 1 in 30 Climate Extreme

Source: Ahmed, Diffenbaugh and Hertel, 2009
Thresholds are important in light of projected increases frequency in both intensity of extreme climate events

- Consider three distinct agricultural productivity stressors:
  - **Wet**: the percent of annual total precipitation due to events exceeding the 1961-1990 95th percentile
  - **Dry**: the maximum number of consecutive dry days
  - **Heat**: the heat wave duration index (the maximum period greater than 5 days with the daily maximum temperature greater than the 1961-1990 normal)
- **Draw on “CMIP3” project heavily used in the IPCC Fourth Assessment Report for estimates**
- **Compare 1971 to 2000 with and 2071 to 2100 period under the IPCC’s A2 scenario.**
<table>
<thead>
<tr>
<th>Country</th>
<th>Current Climate</th>
<th>2071-2100 A2 Climate</th>
<th>Change in Poverty Impact of Changing Extreme Dry Event Intensity (Current Climate minus 2071-2100 A2 Climate)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of Average Consecutive Dry Days in Extreme Climate Year</td>
<td>Additional Share of Population Impoverished (in percentage points)</td>
<td>Additional Number of People Impoverished (in millions)</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>94.71</td>
<td>110.1</td>
<td>1.35</td>
</tr>
<tr>
<td>Brazil</td>
<td>120.67</td>
<td>132.19</td>
<td>0.07</td>
</tr>
<tr>
<td>Chile</td>
<td>66.14</td>
<td>75.72</td>
<td>0.06</td>
</tr>
<tr>
<td>Colombia</td>
<td>77.16</td>
<td>71.07</td>
<td>0.00</td>
</tr>
<tr>
<td>Indonesia</td>
<td>62.61</td>
<td>59.41</td>
<td>-0.11</td>
</tr>
<tr>
<td>Mexico</td>
<td>91.87</td>
<td>116.17</td>
<td>1.76</td>
</tr>
<tr>
<td>Mozambique</td>
<td>105.99</td>
<td>117.12</td>
<td>0.42</td>
</tr>
<tr>
<td>Malawi</td>
<td>143.53</td>
<td>147.25</td>
<td>0.27</td>
</tr>
<tr>
<td>Peru</td>
<td>102.11</td>
<td>105.8</td>
<td>0.01</td>
</tr>
<tr>
<td>Philippines</td>
<td>60.49</td>
<td>58.75</td>
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<tr>
<td>Thailand</td>
<td>97.47</td>
<td>107.49</td>
<td>0.01</td>
</tr>
<tr>
<td>Tanzania</td>
<td>132.73</td>
<td>132.27</td>
<td>-0.01</td>
</tr>
<tr>
<td>Uganda</td>
<td>72.26</td>
<td>66.79</td>
<td>-0.06</td>
</tr>
<tr>
<td>Venezuela</td>
<td>138.86</td>
<td>151.1</td>
<td>0.07</td>
</tr>
<tr>
<td>Vietnam</td>
<td>79.59</td>
<td>82.93</td>
<td>0.01</td>
</tr>
<tr>
<td>Zambia</td>
<td>175.42</td>
<td>181.94</td>
<td>4.64</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>101.35</strong></td>
<td><strong>107.26</strong></td>
<td><strong>0.53</strong></td>
</tr>
</tbody>
</table>

Source: Authors’ simulations

Source: Ahmed, Diffenbaugh and Hertel, 2009
Conclusions

• Considerable uncertainty about future climate change, impacts in agriculture and consequences for global welfare/poverty

• Agriculture provides a key linkage between climate volatility and poverty vulnerability:
  – Depends on both spending and earnings effects
  – Impact on poverty is ambiguous in many cases

• Impacts are likely to be complex:
  – Changes in variance as well as mean of climate
  – Extreme outcomes likely to be more important than changes in mean temperature, precipitation
  – More work needed to capture key thresholds in climate, agriculture and economic responses