Climate Change, Global Markets and Food Security

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Need to distinguish between two aspects of climate change

- Extreme events and *inter-annual variability*:
 - Changing frequency of extreme events
 - Implications for commodity markets
 - Domestic and international trade policies as vehicles for (mal)adaptation
- *Decadal changes*: Long run impacts of climate change:
 - Projected agricultural impacts
 - Adaptation to climate change
 - Role of international trade in food security
 - Climate change in the broader context of global change

Increased frequency of extreme events

- The frequency with which historical (1986-2005) June-July-August maximum temperature and precipitation occurs in future under RCP 8.5 is quite high – particularly for extreme hot events
- The combination of hot and dry weather is particularly problematic for crops



Source: Diffenbaugh and Field (2013)



US Corn Yield Response to Temp GDD = Growing Degree Days

Schlenker and Roberts (2009)

S _00

-0.07

Step Function Polynomial (8th-order

Piecewise Linear

10

15

20

Temperature (Celsius)

25

Increasing temperature extremes drive increased yield volatility



% change in standard deviation of weighted individual drivers of Yield Ratio (YR)

Source: Diffenbaugh, Hertel et al (2012)

Validation:

The combination of high resolution climate results with the Schlenker-Roberts yield function performs well vs. history at U.S. national scale



Distribution of Yield Ratio

Variability (std dev) of the nat'l yield ratio doubles under future climate with historic yield function (will evaluate changes in yield function later on)



Outline

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Policies and institutional constraints matter for corn markets

- **Prior to 2006 :** *Corn-crude price correlation = 0.32*
- High oil prices from Sept. 2007 Oct. 2008 encouraged significant ethanol-petrol substitution: *Corn-crude price correlation* = 0.92
- **RFS dictates lower bound on production; became binding, end** 2008: *Corn-crude price correlation: 2008/09 = 0.56*

Institutional constraints limit price responsiveness of corn demand



The inter-annual price response to commodity supply volatility depends on interplay between oil prices and RFS



High Oil Prices (assuming blend wall is relaxed by 2020) \rightarrow more elastic corn demand due to price-responsive sales to liquid fuel market: *Less volatility*



Low Oil Prices \rightarrow RFS binding/Inelastic corn demand as ethanol production is dictated by policies instead of markets; *Greater volatility*

Economic Scenarios

- We combine historic and future climates with 5 alternative economic scenarios
- 1) Economy in 2001
- 2) Economy in 2020 with High Oil Prices and
 - a. RFS mandate (corn ethanol only) in place (15bgy not initially binding)
 - **b. RFS mandate waived**
- 3) Economy in 2020 with Low Oil Prices
 - a. RFS mandate in place ((corn ethanol only: 15bgy binding in 2020)
 - b. RFS mandate waived, but only in 2020

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Impact of corn supply shocks on US corn price volatility across climate regime, under two energy futures: *No Adaptation* (standard deviation in inter-annual % price change)



• Future climate doubles yield volatility, quadruples price volatility in the absence of adaptation (e.g., increased stockholding)

Impact of corn supply shocks on US corn price volatility across climate regime, under two energy futures: : *No Adaptation* (standard deviation in inter-annual % price change)



 In future economy, price volatility is diminished due to growth and integration unless the biofuel mandate remains in place in which case it is exacerbated

Source: Diffenbaugh, Hertel et al (2012)

Economic integration and (mal)adaptation

- Intersectoral integration:
 - Market driven (e.g. higher energy prices) is beneficial adaptation
 - Policy driven (RFS mandate) exacerbates volatility: maladaptation
- International integration:
 - Partial: fix tariffs at currently applied rates
 - Eliminate tariffs: full trade liberalization

Source: Verma, Hertel, Diffenbaugh (2014)



Adaptation wedges under future climate: metric = SD of year on year corn price changes in 2020

Plant breeding to adapt yield function for high temperatures could also limit volatility

- X-axis varies critical b
 threshold at which damages arise; if increase from 29 to 32.5°C, no change in yield volatility
 If moderate rate of
- If moderate rate of yield loss due to excess heat by 0.7, then increase in critical threshold to 31°C is sufficient



Source: Diffenbaugh, Hertel et al (2012)

Adapting location of production may also limit future climate impacts

<u>Mean GDD above 29°C</u> doubles over much of current corn belt, with current values found northward in the future climate.

Analysis ignores the role of soils and infrastructure in determining the location of production



Blue area shows shows the county weights in US production that exceed 0.18%.

The red area shows the grid points with the minimum distance to a GDD value within 1 GDD of the original value under future climate.

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Climate change will render future productivity growth more challenging: IPCC WGII

- *"negative impacts* on avg yields become *likely in the* 2030's"
- "median yield impacts from 0 to -2%/decade over rest of century"



Source: Rosenzweig et al. 2013, PNAS; Results from 7 crop models (dashed lines omit CO2 effects)

Climate change will render future productivity growth more challenging: IPCC WGII

- "negative impacts on avg yields become likely in the 2030's"
- "median yield impacts from 0 to -2%/decade over rest of century"
- "negative impacts of more than 5% are more likely than not after 2050"



Source: Rosenzweig et al. 2013, PNAS; Results from 7 crop models (dashed lines omit CO2 effects)

Projecting food security impacts of climate change in 2050

- Crop yield impacts from AgMIP
- Economic impacts from SIMPLE
 - Validated over historical period (Baldos and Hertel, 2013a, b)
 - 15 regional markets are either:
 - Segmented (historical economy)
 - Integrated: (future world?)
 - Baseline driven by:
 - Population and income growth
 - Productivity growth in crops, livestock and food processing
 - Analyze full distribution of caloric intake to predict malnutrition headcount and gap



Sub Saharan Africa: Baseline 2006-50

AgMIP global yield impacts due to climate change in 2050 for staple grains & oilseeds vary widely by region, crop model & CO2 fertilization on/off



Source: Baldos and Hertel (forthcoming)

Impact of LR climate change on global malnutrition in 2050





- Uncertainty inherited from both climate and crop models
- CC generally boosts global malnutrition in 2050 – possibly by as much as 50%, relative to baseline;
- Some model combos result in slight improvements in 2050, relative to baseline

Impact of LR climate change on regional malnutrition in 2050: HADGEM/LPJmL combination

- Greatest potential for adverse impacts in South Asia (up to 120% rise in malnutrition, relative to the 2050 baseline)
- Sub Saharan Africa, maximum rise is 80%, while Rest of World small
- HADGEM/LPJmL only combination shown here



Segmented Markets

Source: Baldos and Hertel (forthcoming)

Market integration moderates most severe nutritional impacts

Crop Model: LPJmL Global Circulation Model: HADGEM



Source: Baldos and Hertel (forthcoming)

However, crop impact models do not reflect full extent of uncertainty

- Most biophysical crop models were developed for other purposes not focused on impacts of extreme temps
- White et al. review 221 studies using 70 crop models to assess climate impacts and find *only a handful consider*:
 - Effects of elevated CO2 on canopy temperature
 - Direct heat effects on key stages of crop development
- Only a subset of relevant processes are included in any one model; *often the omitted processes are*:
 - those that become *more damaging with climate change*
 - empirically *more important in context of tropical systems* (e.g. VPD, heat stress on crop development and pests and disease)

Economic impact models do not reflect full extent of adaptation uncertainty

- Most impact assessment models overstate scope for adaptation in poorest countries due to:
 - Credit constraints and other market failures
 - Weak institutions and corruption
 - Limited capacity for adaptive research and extension
- As a consequence, IAMs likely *understate impact* and *overstate scope for adaptation* to climate change *in the low income tropics*

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Climate change is just one of many drivers of global change and food security

Crop Model: LPJmL GCM: HADGEM



Source: Baldos and Hertel (forthcoming)

Main effect of market integration is to moderate malnutrition under worst case CC scenario

Crop Model: LPJmL GCM: HADGEM



Source: Baldos and Hertel (forthcoming)

Take-away Messages

- Extreme events and *inter-annual variability*:
 - Expect increasing frequency of extreme events
 - Free-flowing, international trade is an increasingly important vehicle for adaptation/moderation of economic impacts
 - Conversely, maladaptation through protectionist trade and domestic policies will likely become increasingly problematic
- Decadal changes: Long run impacts of climate change:
 - Modeled LR impacts on agriculture are highly uncertain
 - Non-modeled impacts and 'over-modeled' adaptation exacerbate uncertainty about future, particularly in developing 'South'
 - International trade can moderate food security impacts by allowing for LR shifts in the global pattern of production
 - Climate change is only one source of global change uncertainty influencing LR food security



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