Weather, Climate, Agricultural Output and Prices

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The Near-term Impacts of Climate Change on Investors
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Outline

1. US is Biggest Producer of Basic Calories
2. Extreme Heat Crucial Driver of Agricultural Production
3. Small Production Changes Translate into Large Price Swings
4. Observed Climate Change Already Has Observable Effect
5. Limited Innovation in Sensitivity to Weather

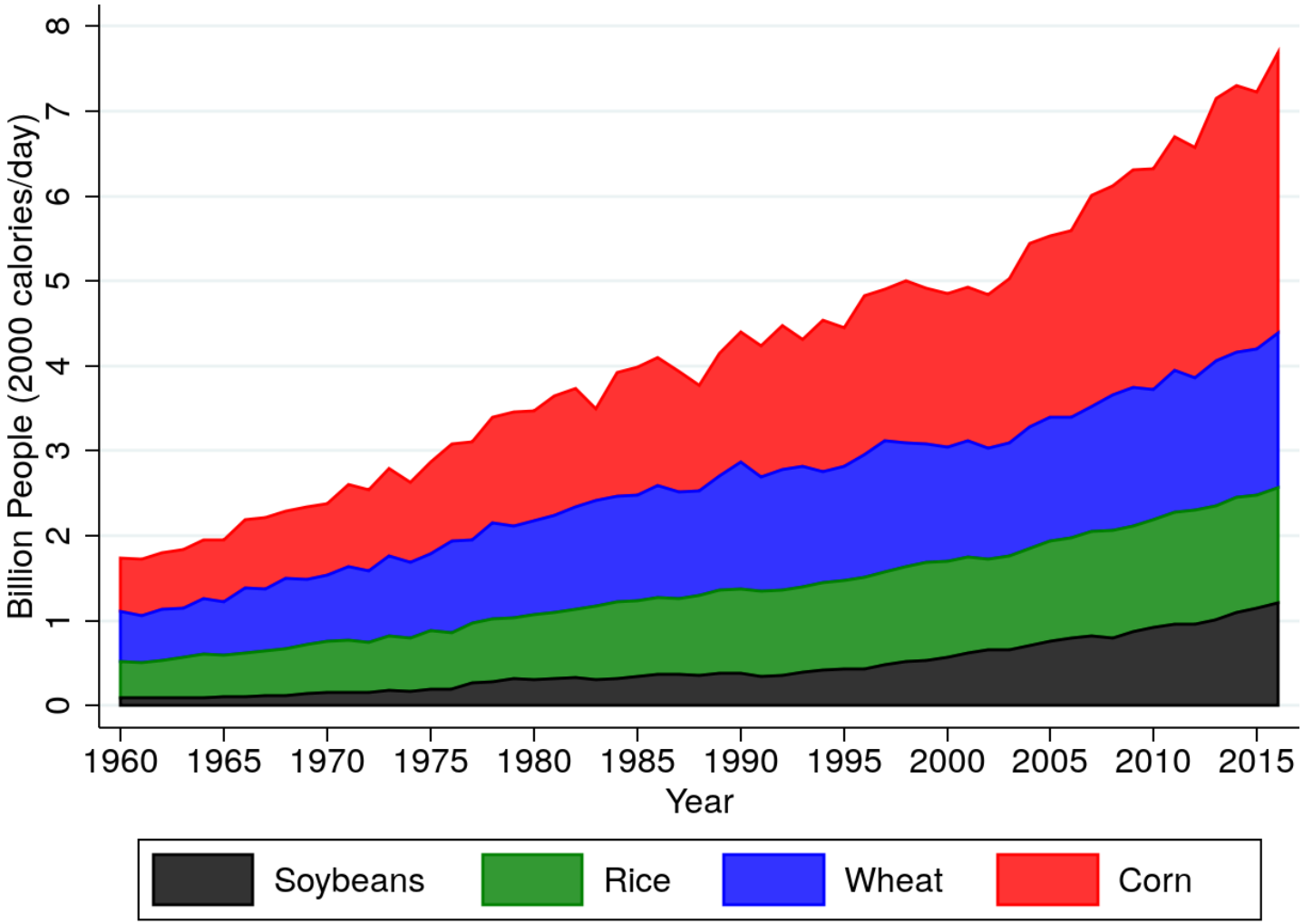
Outline

Introduction: Agricultural Production

- Agricultural (green) revolution
  - Before 1950
    - Increase in production through increase in growing area
    - Yields (output per area) rather constant
  - After 1950
    - Increase in production mostly through higher yields
    - Growing area increased moderately

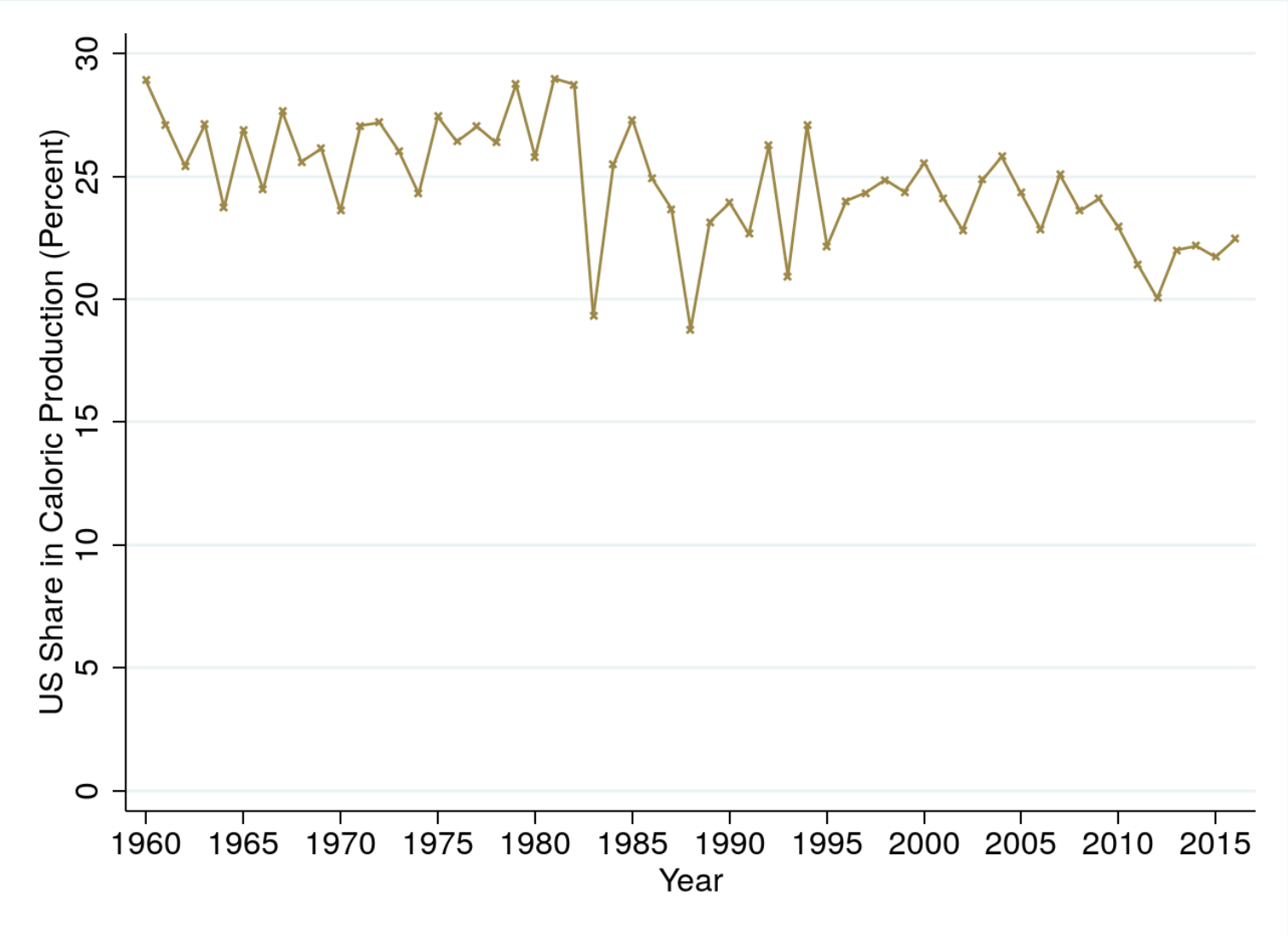
- Four commodity crops are the basis for caloric consumption
  - Maize (corn), wheat, rice and soybeans
  - 75% of the calories humans consume
    - Either directly or indirectly (used as feedstock)
  - Converting production quantity into common unit: calories
    - Calories / bushel for each crop
    - Instead of trillions of calories: billon of people on 2000 calorie / day diet

World Caloric Production: Four Staple Commodities



Source: Foreign Agricultural Service

US Market Share



Source: Foreign Agricultural Service

Outline

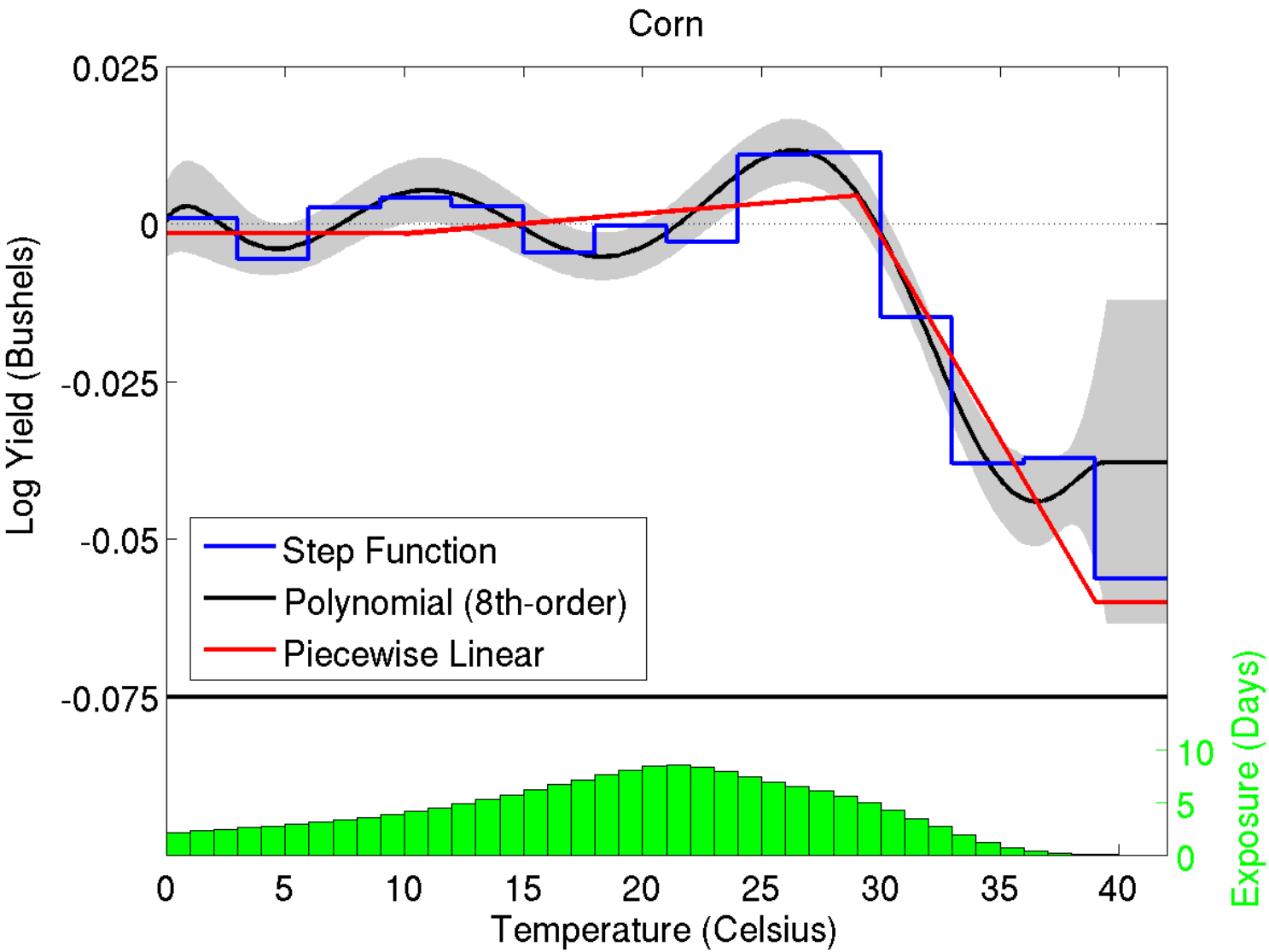
Link between Weather and US Corn Yields

- Schlenker & Roberts (PNAS, 2009): Statistical analysis
  - Eastern United States
    - Corn (biggest staple commodities in US)
    - 40% of the world's production in each crop
  - Panel of county-level yields
    - State-specific time trends to capture technological progress
    - Fixed effect to capture differences in space
  - Fine-scale weather (daily temperature / precip on 2.5mile grid)
  - Roughly 2000 counties x 56 years (1950-2005)

- Model accounts for
  - Flexible functional form in temperature
  - Quadratic in total precipitation

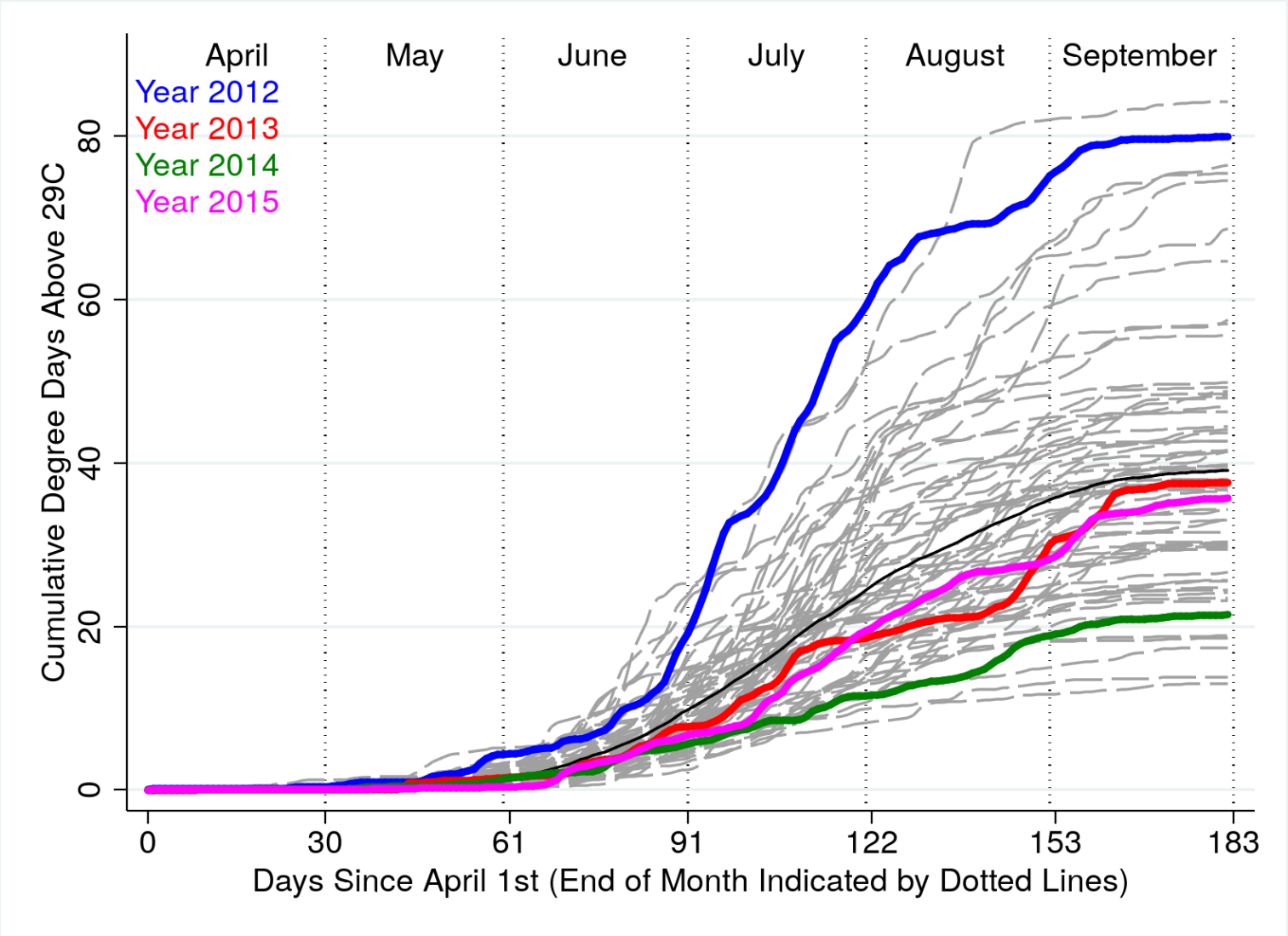
- Highly asymmetric relationship
  - Decline above optimal temperature order of magnitude of incline below it
    - Degree Days 29°C (84°F)
    - Count how much and how long temperatures exceed 29°C (84°F)
    - Beng 10 days 1C above is same as being 1 day 10C above!
  - Extreme heat predicted to increase nonlinearly
    - Attributable in large parts of anthropogenic influences
    - Fisher & Knutti (NCC 2015)

Corn Yields: Importance of Extreme Heat



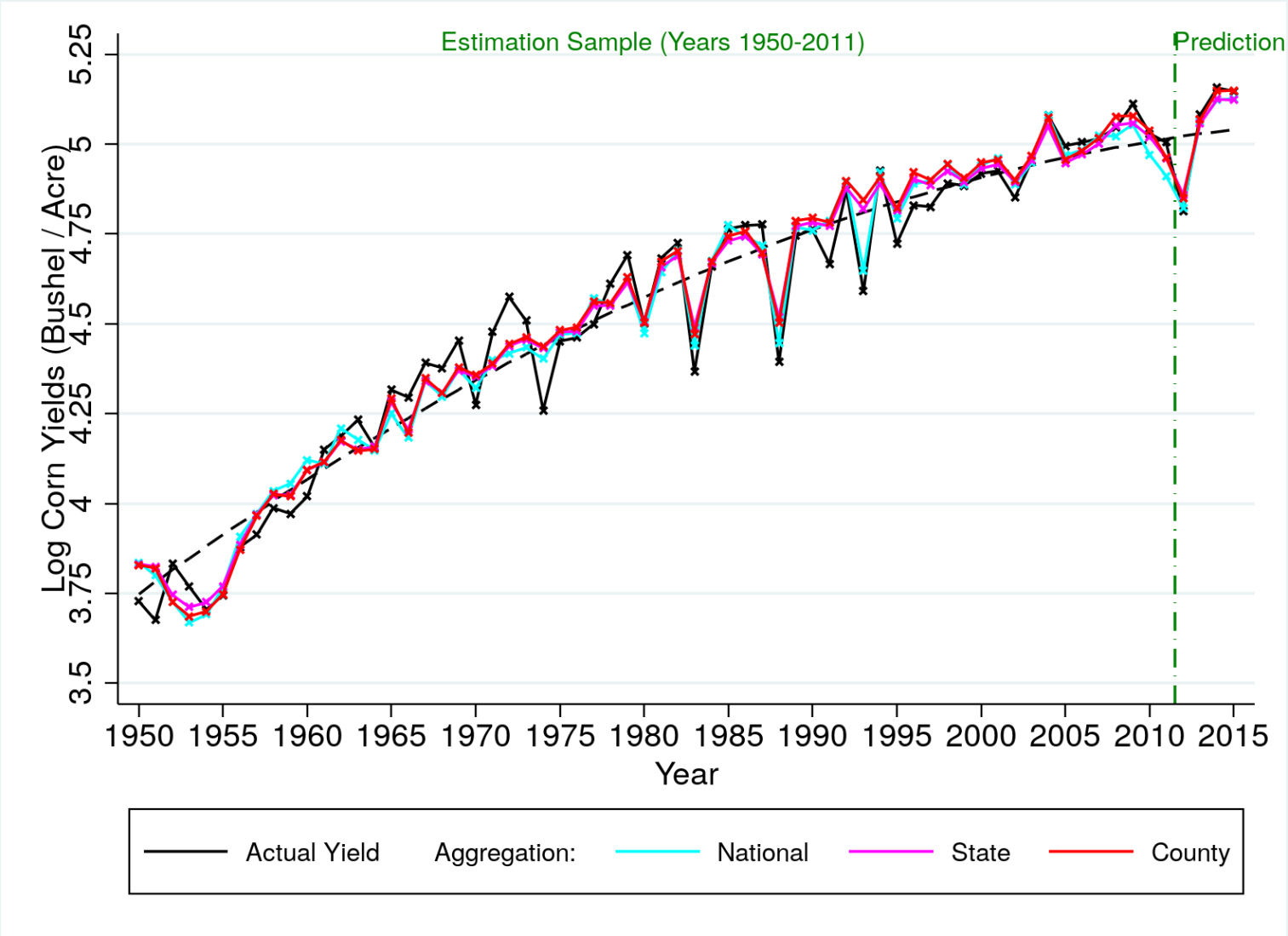
Source: Schlenker & Roberts (PNAS, 2009)

Extreme Heat 2012-2015 Versus 1950-2011



Source: D'Agostino & Schlenker (2016)

Can Model from 1950-2011 Explain Last 4 Years?



Source: D'Agostino & Schlenker (2016)

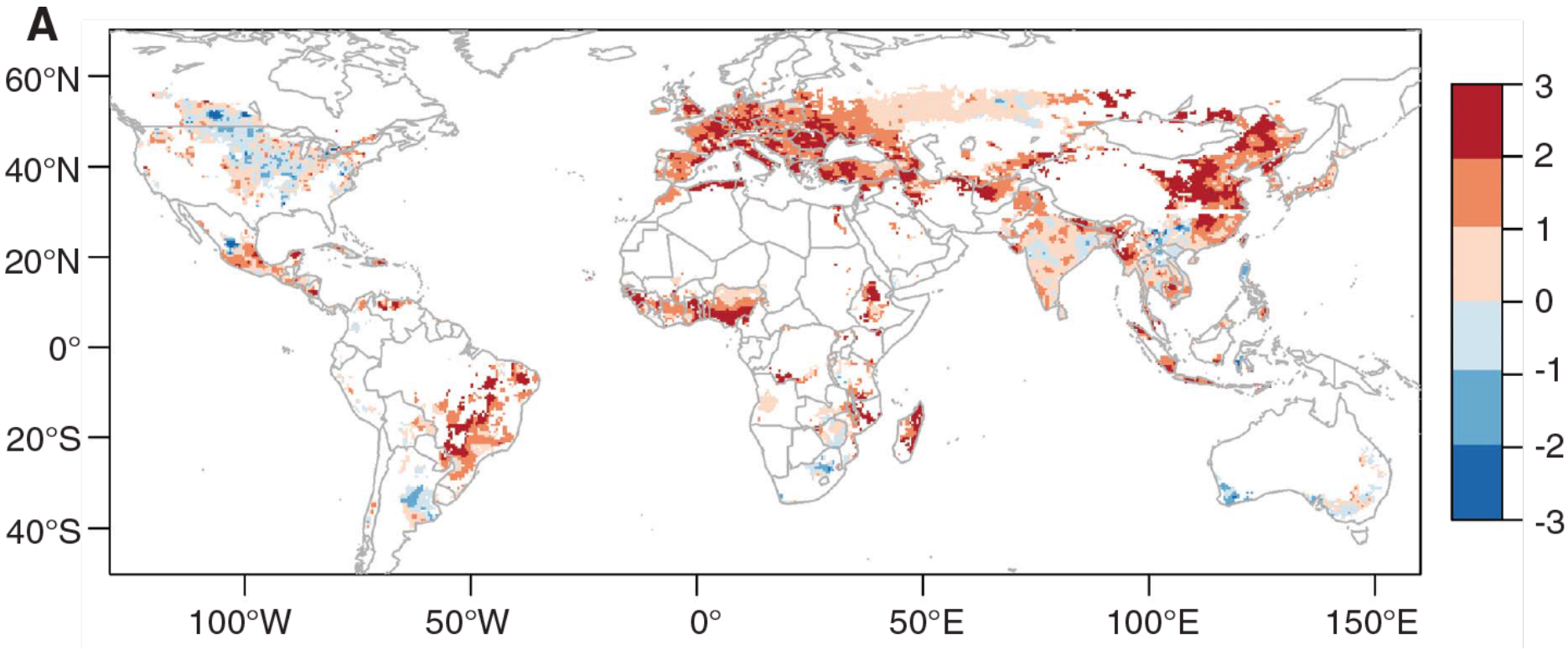
Outline

Supply / Demand Elasticities for Calories

- Roberts & Schlenker (AER, 2013)
  - Demand and supply elasticities of storable commodities
  - Common unit: calories from maize, wheat, rice, and soybeans
- Traditional Approach
  - Regress supply on expected price (futures price)
  - Concern: Futures price is endogenous
  - Example: Soybean Rust (Pest)
    - Farmers anticipate soybean rust (yield loss)
    - Endogenous response: decrease planting area (other crops more profitable)
    - Futures market: increase in futures price
    - Lower quantity and higher price? Movement along demand curve
  - Previous estimates find inelastic supply, yet simulations use positive elasticity
- Identification of Supply
  - Past yield shocks shift expected price
  - Instrument futures price in supply equation
- Significant supply (0.11) and demand elasticity (-0.05)
  - US biofuel mandate
    - Diverts 5% of calories from 4 staple into fuel
    - Responsible for 20-30% price increase

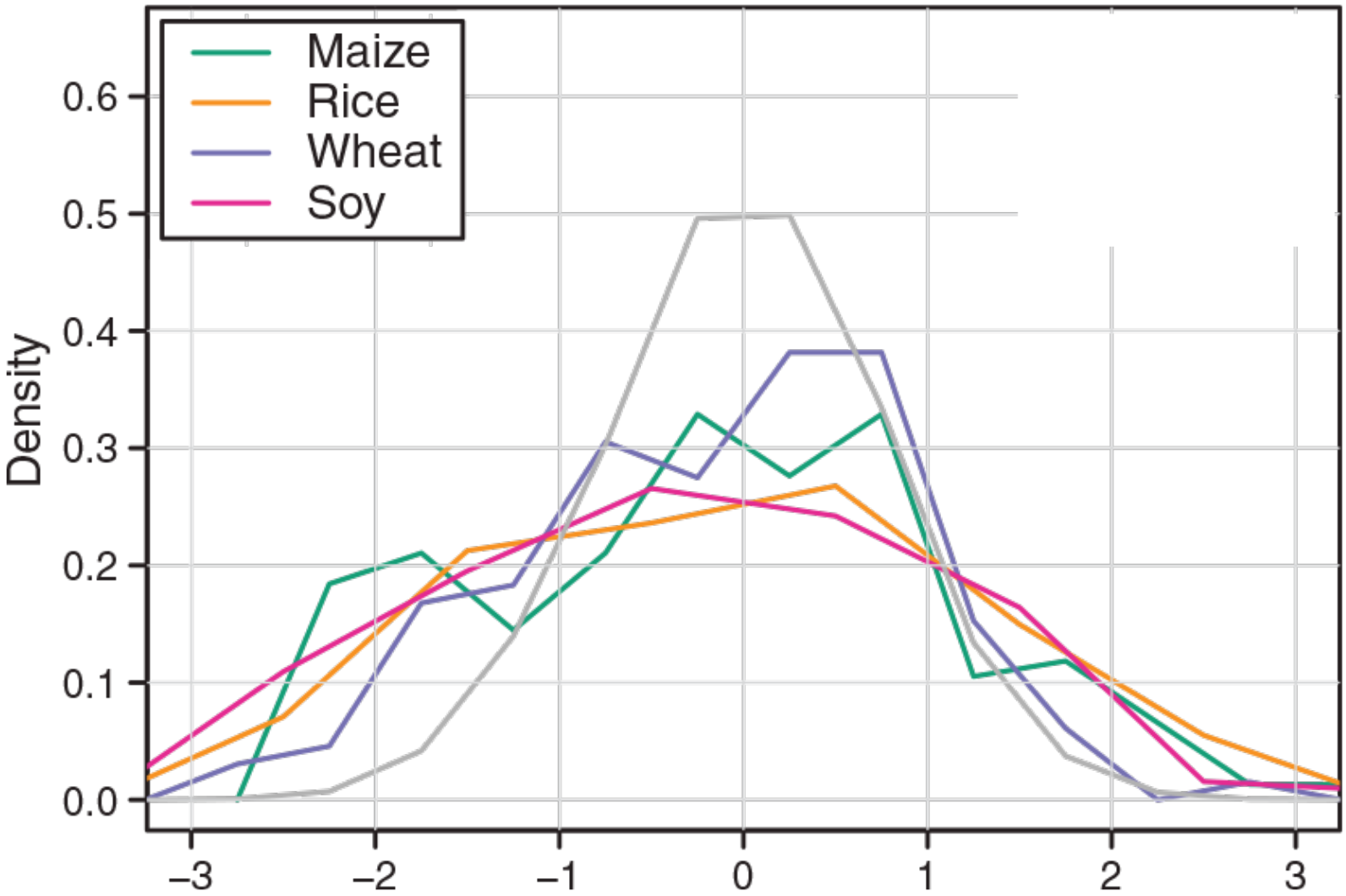
Outline

Temperature Trend (1980-2008) in Historic Std. Deviation



Lobell, Schlenker & Costa-Roberts (Science, 2011)

Country-Crop Specific Temperature Trends (1960-1980)



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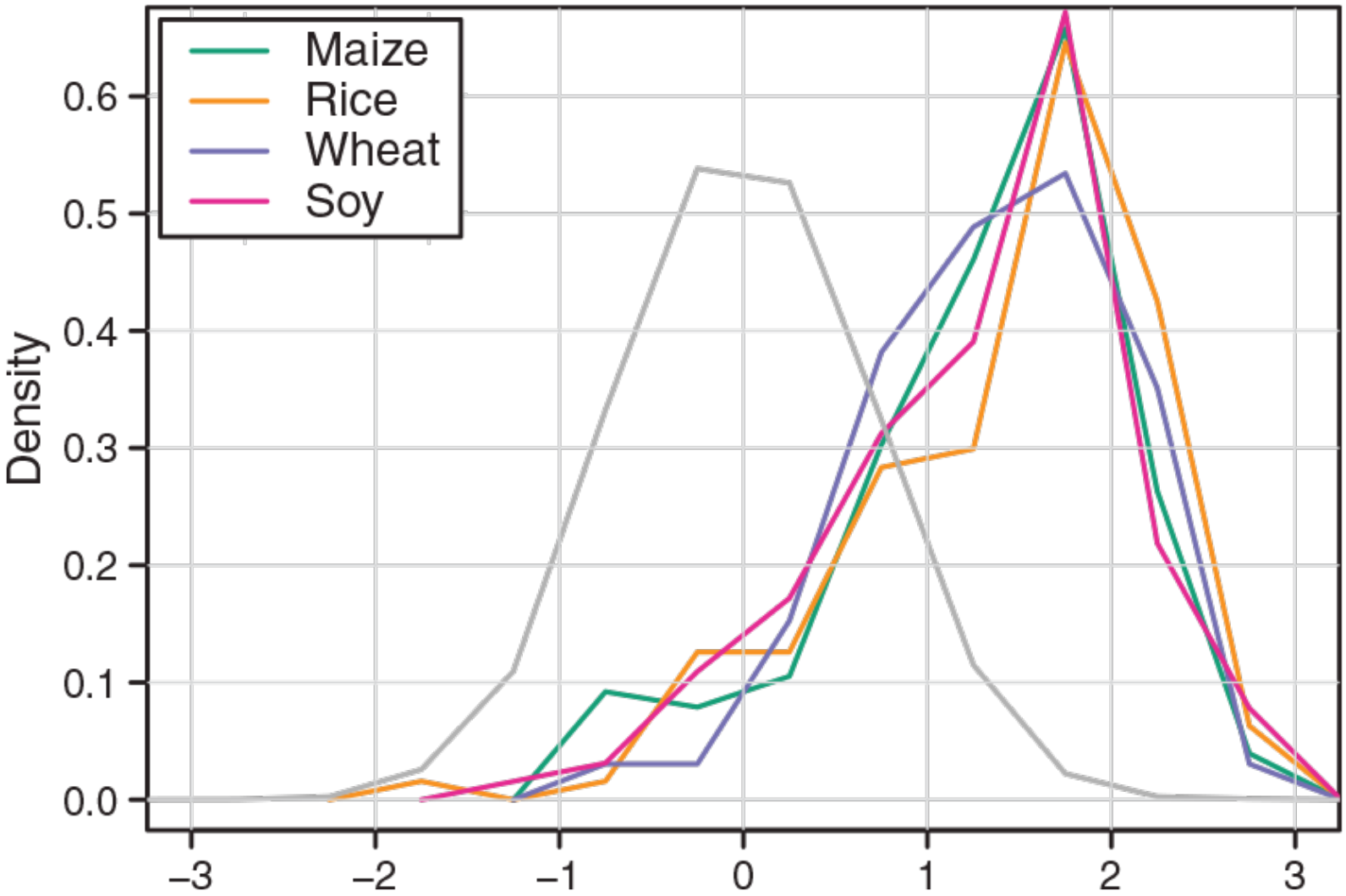

Lobell, Schlenker & Costa-Roberts (Science, 2011)

Predicted Impact of Observed Trend

Crop	Global production, 1998–2002 average (millions of metric tons)	Global yield impact of temperature trends (%)	Global yield impact of precipitation trends (%)	Subtotal	Global yield impact of CO_2 trends (%)	Total
Maize	607	−3.1 (−4.9, −1.4)	−0.7 (−1.2, 0.2)	−3.8 (−5.8, −1.9)	0.0	−3.8
Rice	591	0.1 (−0.9, 1.2)	−0.2 (−1.0, 0.5)	−0.1 (−1.6, 1.4)	3.0	2.9
Wheat	586	−4.9 (−7.2, −2.8)	−0.6 (−1.3, 0.1)	−5.5 (−8.0, −3.3)	3.0	−2.5
Soybean	168	−0.8 (−3.8,1.9)	−0.9 (−1.5, −0.2)	−1.7 (−4.9, 1.2)	3.0	1.3

Combined Price Effect: 18.9% (no CO_2 fertilization), 6.4% (including CO_2 fertilization)

Lobell, Schlenker & Costa-Roberts (Science, 2011)

Outline

Costly Adaptation to Extreme Heat

- Tremendous progress in average yields (3-fold increase since 1950)
- No improvement in sensitivity to extreme heat
  - Crops as sensitive in 2010 as in 1950
  - Sensitivity to vapor pressure deficit got worse (Lobell et al, Science 2014)
- Possible impediment to adaptation: subsidized crop insurance
  - Farmers don't have full incentive to deal with extreme
  - They will be bailed out to some extend
    - Catastrophic level (50% decline) free to farmers
- Who suffers from climate change?
  - Given US market size and correlation of shocks over Corn Belt
    - Production declines more than offset by price increase
    - Nature is doing what government tried for decades (supply restrictions)
  - Farmers likely see higher profits
  - Consumers suffer through higher prices (especially internationally)
    - Effects on conflict and migration (next talk)