Estimating the Economic Impact of Climate Change in the Agricultural Sector

Wolfram Schlenker[1]

[1]Columbia University and NBER

Washington DC, January 27 2011

Outline

1. Why Impacts on US Agriculture Might be Economically Meaningful
2. Potential Impacts of Climate Change on US Agriculture
3. Technological Progress: Evolution of Heat Tolerance
4. Agriculture's Role in Fighting Global Warming
5. Conclusions

Outline

1. Why Impacts on US Agriculture Might be Economically Meaningful
2. Potential Impacts of Climate Change on US Agriculture
3. Technological Progress: Evolution of Heat Tolerance
4. Agriculture's Role in Fighting Global Warming
5. Conclusions

Consumer Surplus

- Agriculture accounts for small share of US GDP
  - 2-3% of GDP
  - Does that mean impacts are negligible?

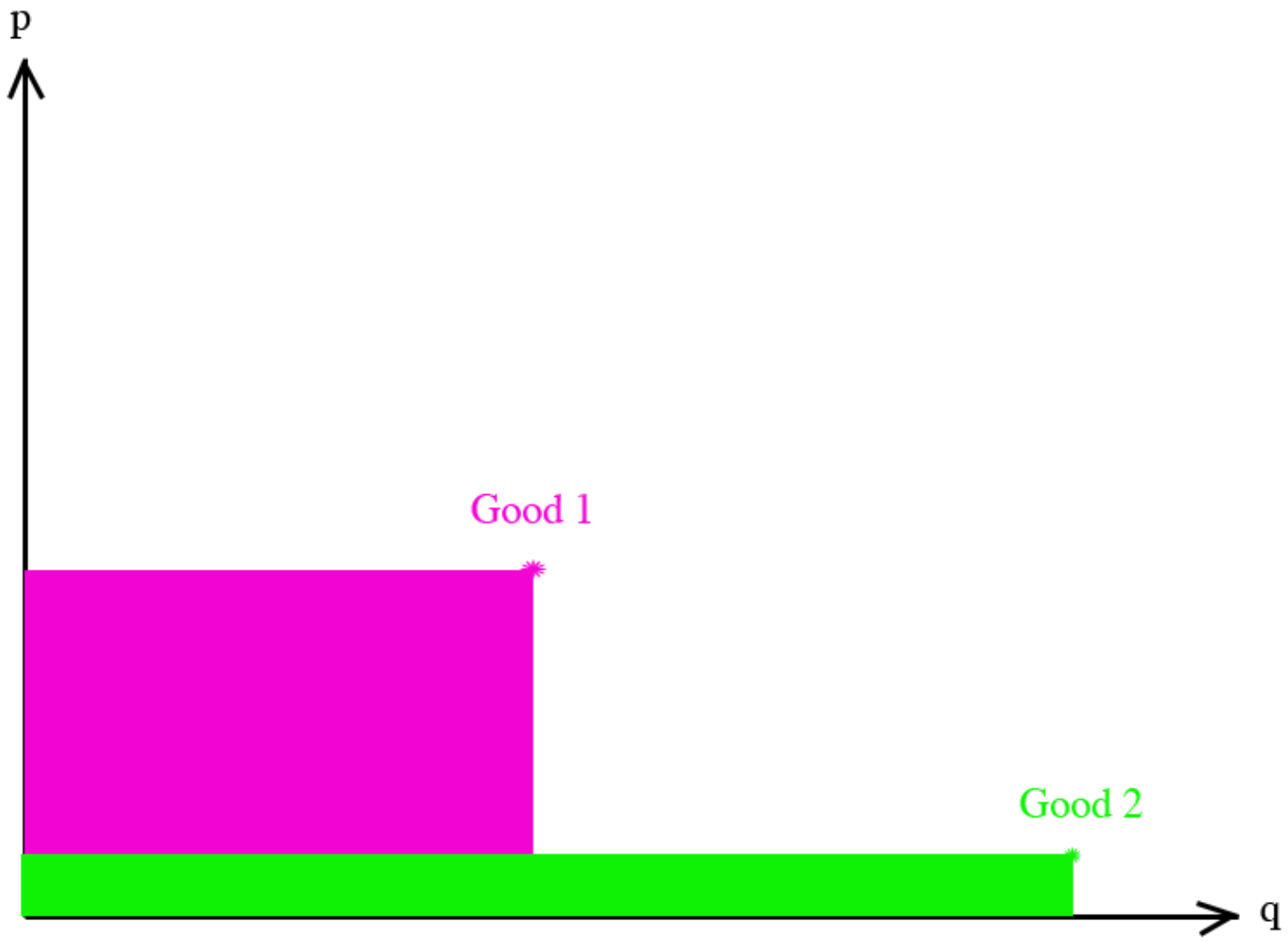
Consumer Surplus

- Agriculture accounts for small share of US GDP
  - 2-3% of GDP
  - Does that mean impacts are negligible?
- Adam Smith: Paradox of value / price
  - Why is the price of diamonds (nonessential good) so high, while the price of water (essential good) is low
    - Price of a good depends on scarcity!

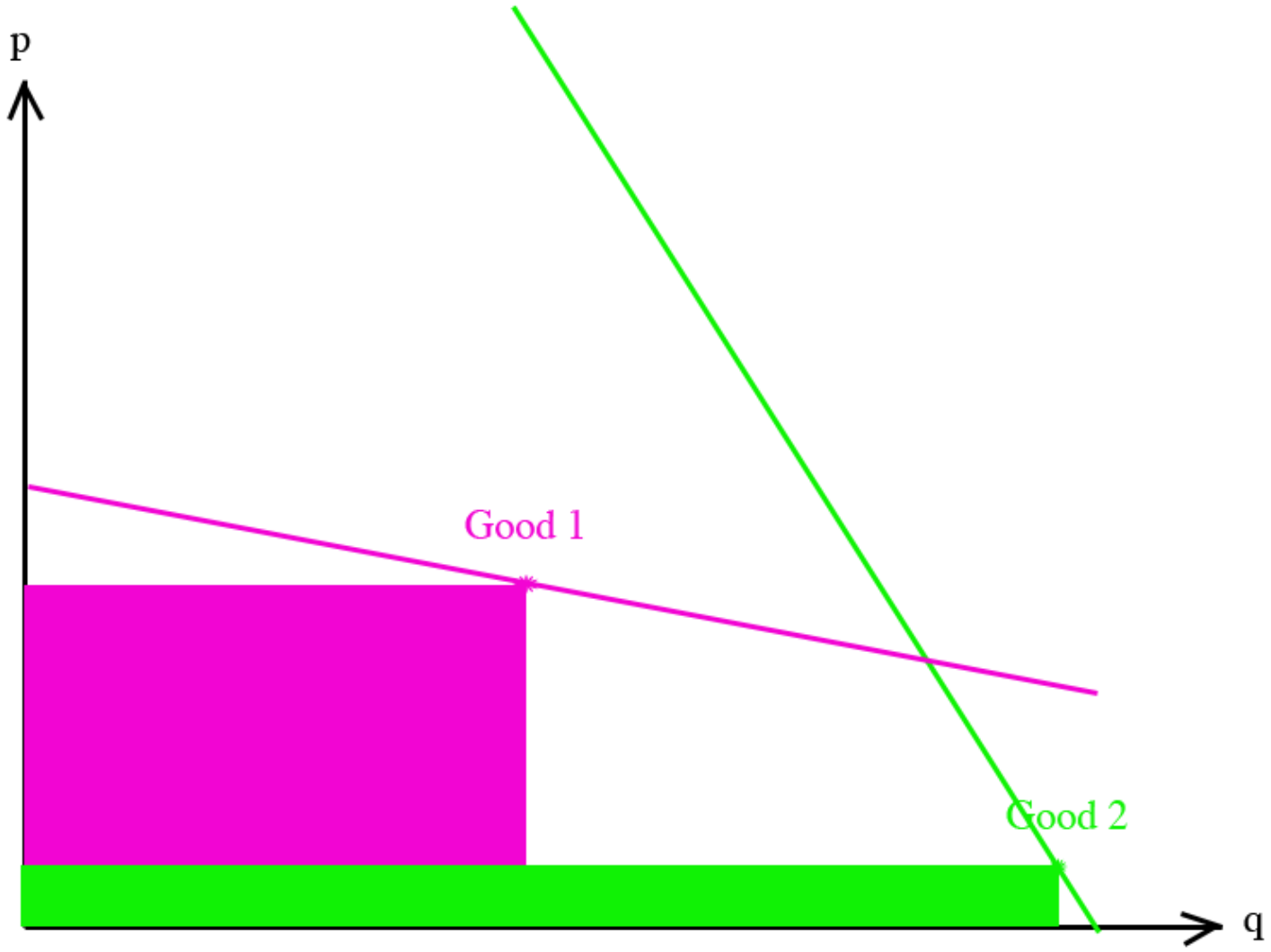
Consumer Surplus

Consumer Surplus

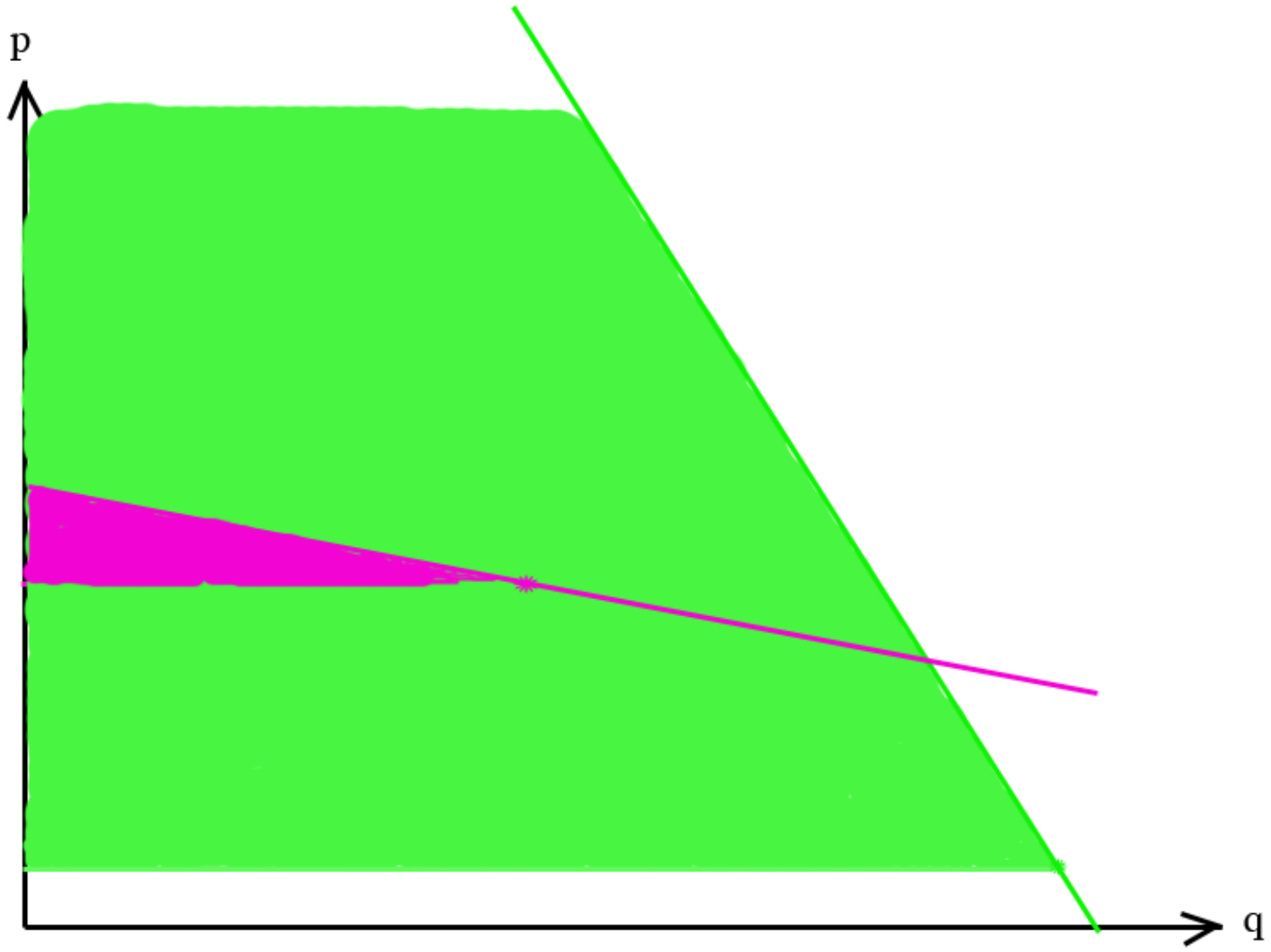
Consumer Surplus



Consumer Surplus



Consumer Surplus



Consumer Surplus

- Agriculture accounts for small share of US GDP
  - 2-3% of GDP
  - Does that mean impacts are negligible?
- Adam Smith: Paradox of value / price
  - Why is the price of diamonds (nonessential good) so high, while the price of water (essential good) is low
    - Price of a good depends on scarcity!
- GDP is not a welfare measure
  - Agricultural demand is highly inelastic ($\sim$0.05)
  - Low price, but large consumer surplus

Consumer Surplus

- Agriculture accounts for small share of US GDP
  - 2-3% of GDP
  - Does that mean impacts are negligible?
- Adam Smith: Paradox of value / price
  - Why is the price of diamonds (nonessential good) so high, while the price of water (essential good) is low
    - Price of a good depends on scarcity!
- GDP is not a welfare measure
  - Agricultural demand is highly inelastic ($\sim$0.05)
  - Low price, but large consumer surplus
- Climate impacts
  - Small reduction in production result in
  - Large price changes (inelastic demand)
  - Potential for large welfare losses (consumer surplus)

Agriculture in US

- Four basic staple commodities
  - Corn, rice, soybeans, and wheat
  - 75% of calories humans consume worldwide
  - Recent tripling of prices: 1.25 trillion dollar surplus loss per year

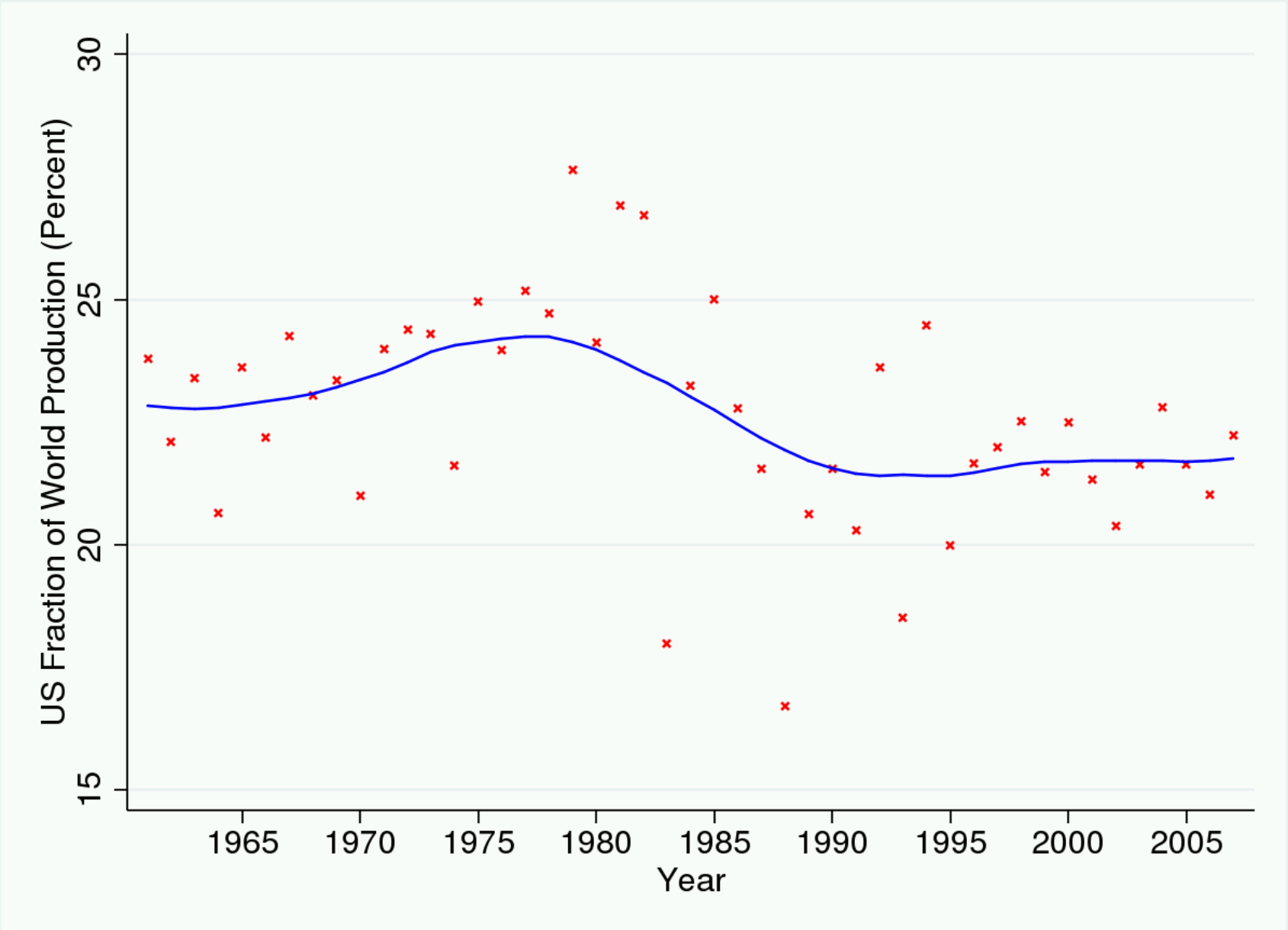
Agriculture in US

- Four basic staple commodities
  - Corn, rice, soybeans, and wheat
  - 75% of calories humans consume worldwide
  - Recent tripling of prices: 1.25 trillion dollar surplus loss per year
- World caloric production
  - Has been trending upward
    - before 1940: Mainly area expansion
    - after 1940: Mainly yield increases
  - Real price has fallen over 20th century

Agriculture in US

- Four basic staple commodities
  - Corn, rice, soybeans, and wheat
  - 75% of calories humans consume worldwide
  - Recent tripling of prices: 1.25 trillion dollar surplus loss per year
- World caloric production
  - Has been trending upward
    - before 1940: Mainly area expansion
    - after 1940: Mainly yield increases
  - Real price has fallen over 20th century
- US share of caloric production
  - Roughly constant around 23% (last 50 years)
  - Larger than Saudi Arabia's share of oil production
  - Impacts on US yields have potential to influence world markets

Agriculture in US



Outline

1. Why Impacts on US Agriculture Might be Economically Meaningful
2. Potential Impacts of Climate Change on US Agriculture
3. Technological Progress: Evolution of Heat Tolerance
4. Agriculture's Role in Fighting Global Warming
5. Conclusions

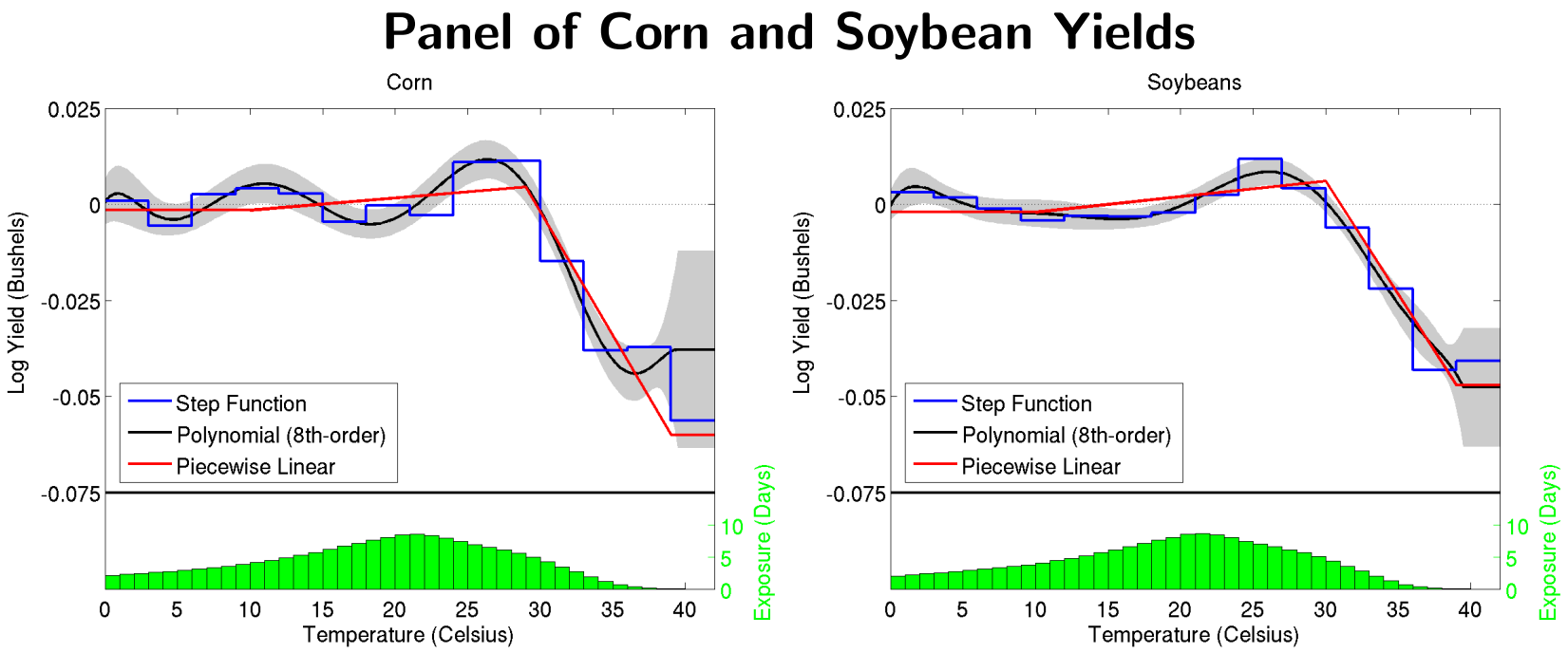
Link between Temperature and Yields

- Statistical Analysis
  - Panel of county-level yields in Eastern United States
  - Corn and Soybeans (two biggest staple commodities in US)
  - Fine-scale weather (daily temperature / precip on 2.5mile grid)
  - Years: 1950-2005

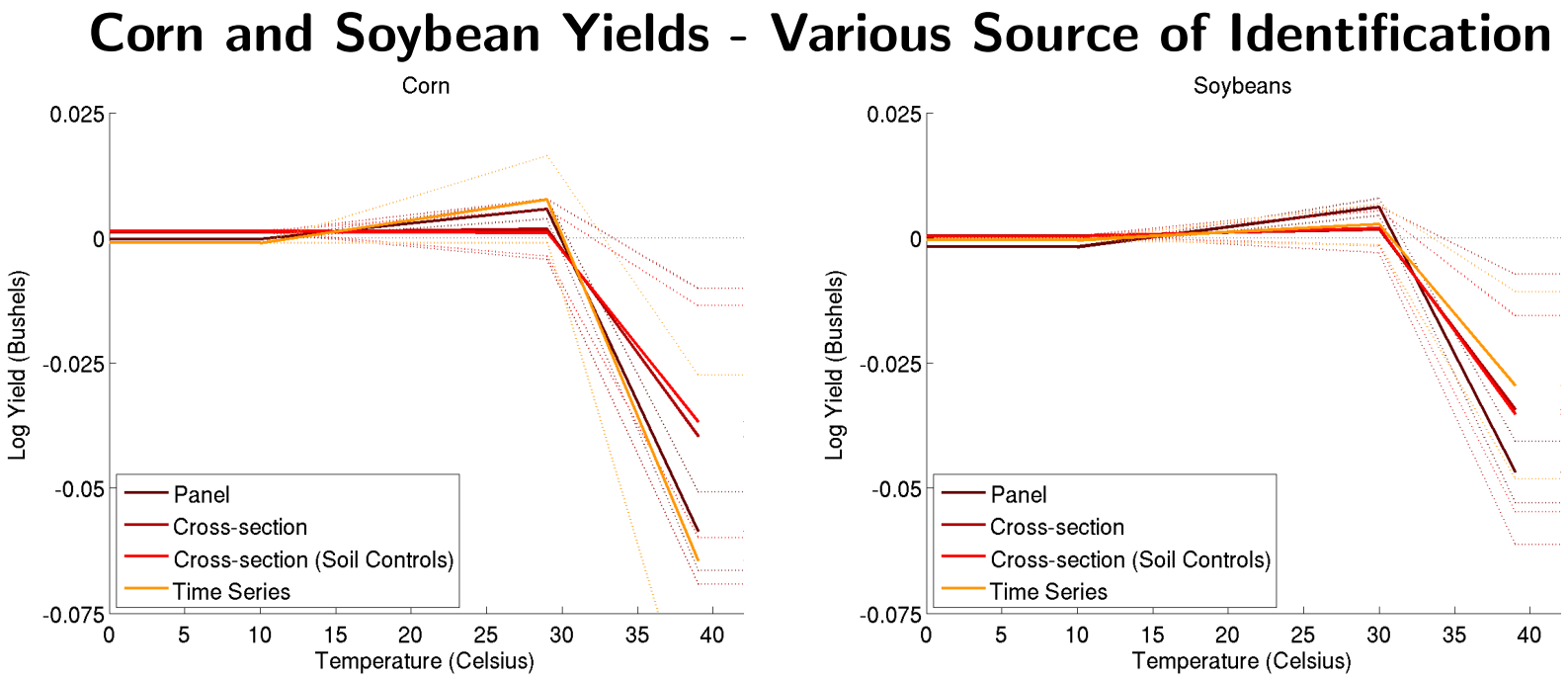
Link between Temperature and Yields

- Statistical Analysis
  - Panel of county-level yields in Eastern United States
  - Corn and Soybeans (two biggest staple commodities in US)
  - Fine-scale weather (daily temperature / precip on 2.5mile grid)
  - Years: 1950-2005
- Model accounts for
  - Amount of time spent in each 1°C interval
  - Quadratic in total precipitation
  - State-specific quadratic time trends
  - County fixed effects

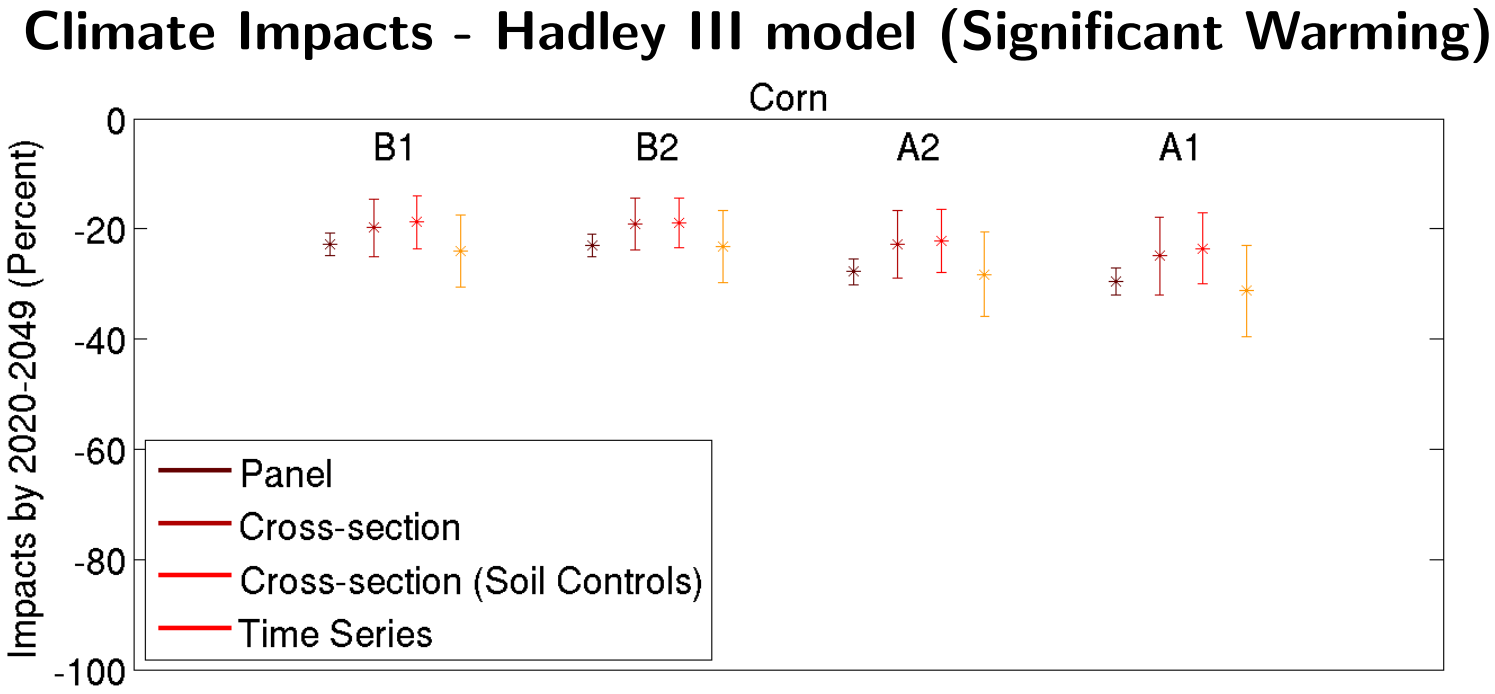
Link between Temperature and Yields



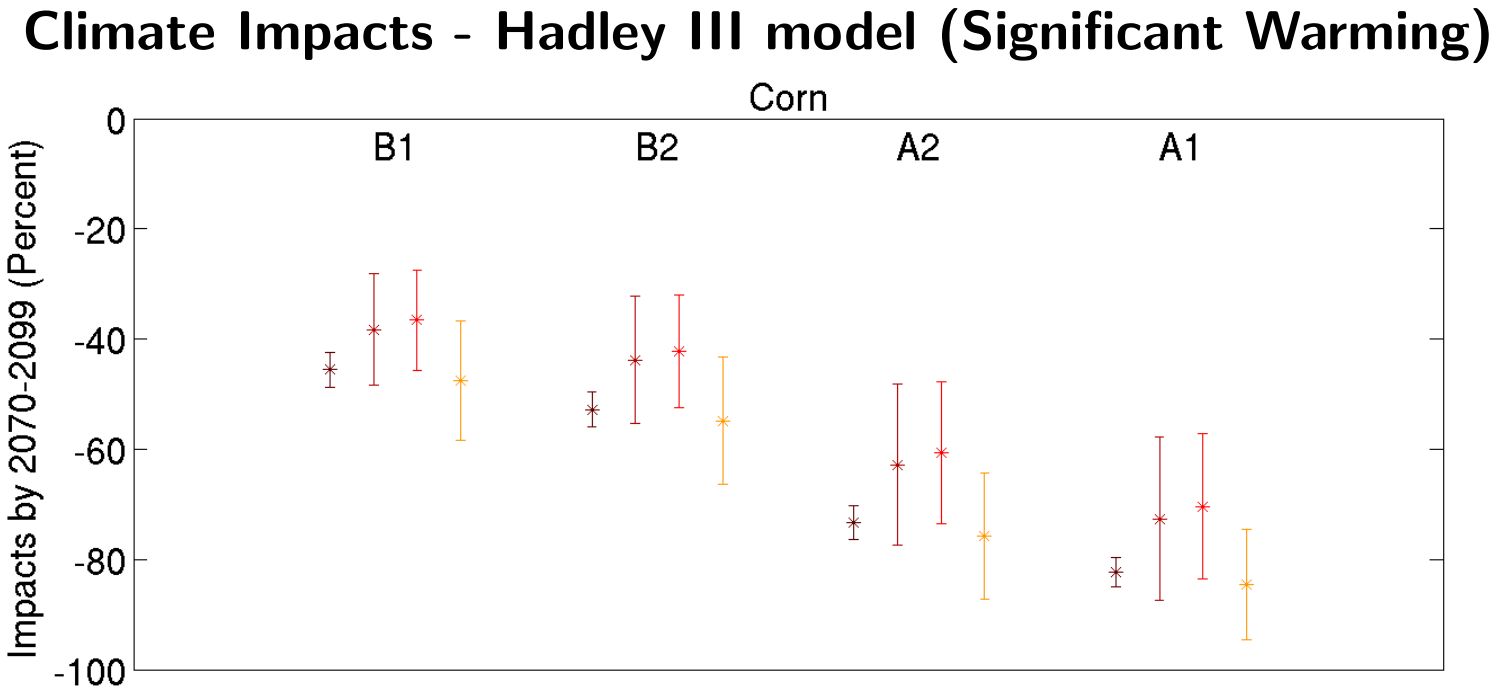
Link between Temperature and Yields



Link between Temperature and Yields



Link between Temperature and Yields



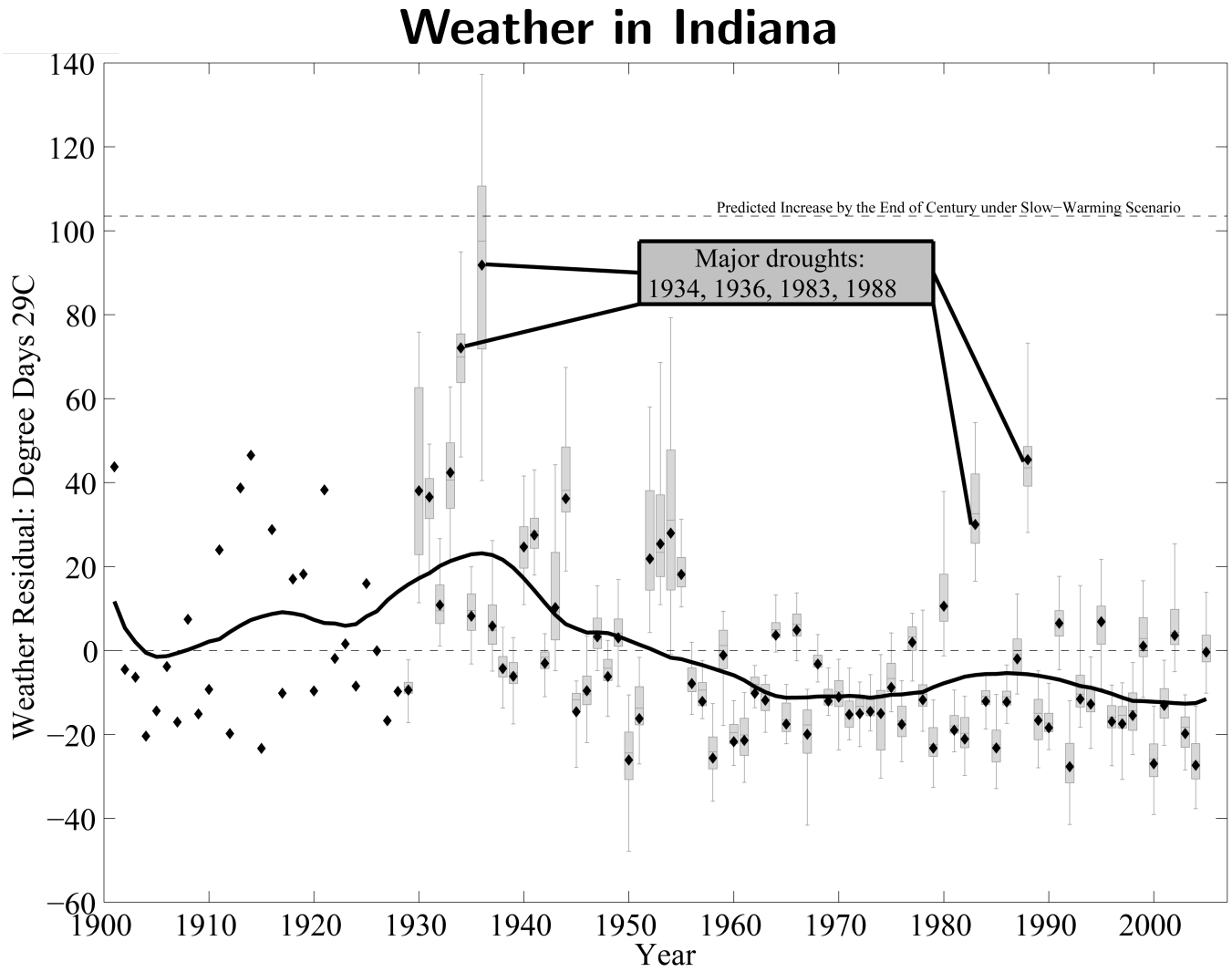
Link between Temperature and Yields

- Other parts of globe
  - Tropics: hotter baseline but lower temperature increases
- Can crop switching save the day?
- Cross-sectional analysis of farmland values
  - Accounting for extreme heat
  - Limit to Eastern United States
- Similar results
  - Large negative effect of extreme heat
  - Robust to myriad of specification checks
    - Different census years
    - Permutations of other control variables

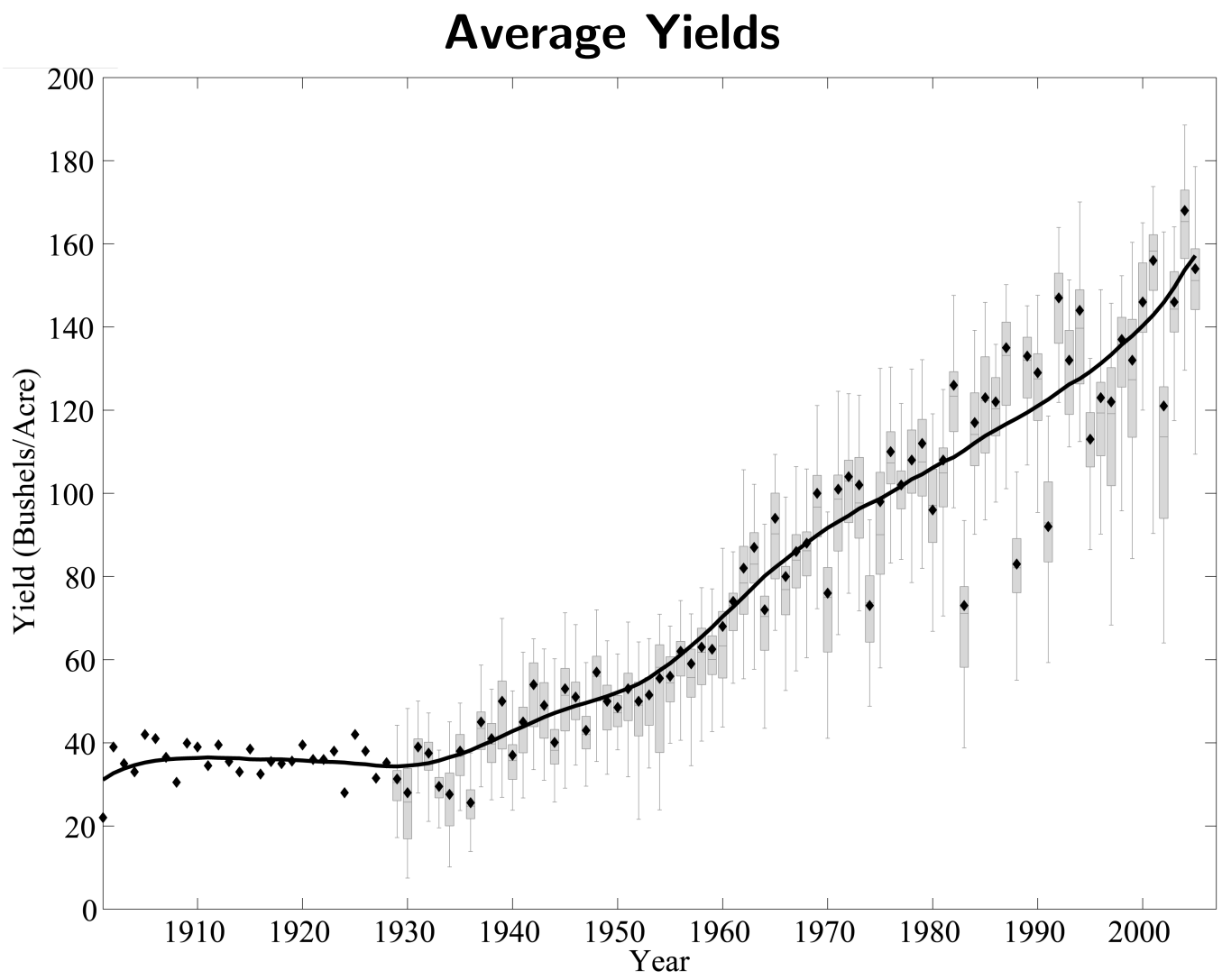
Outline

1. Why Impacts on US Agriculture Might be Economically Meaningful
2. Potential Impacts of Climate Change on US Agriculture
3. Technological Progress: Evolution of Heat Tolerance
4. Agriculture's Role in Fighting Global Warming
5. Conclusions

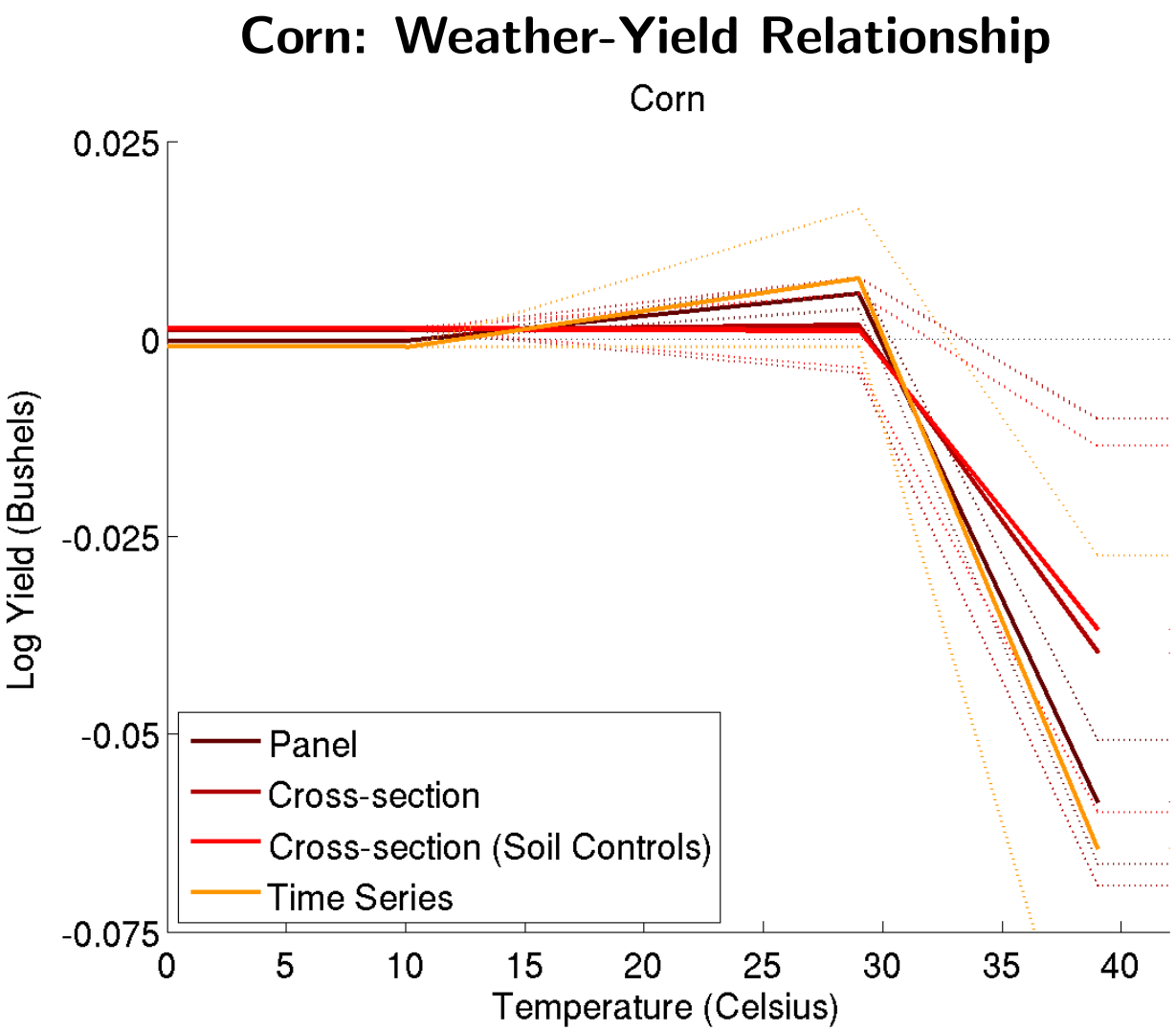
Evolution over Time



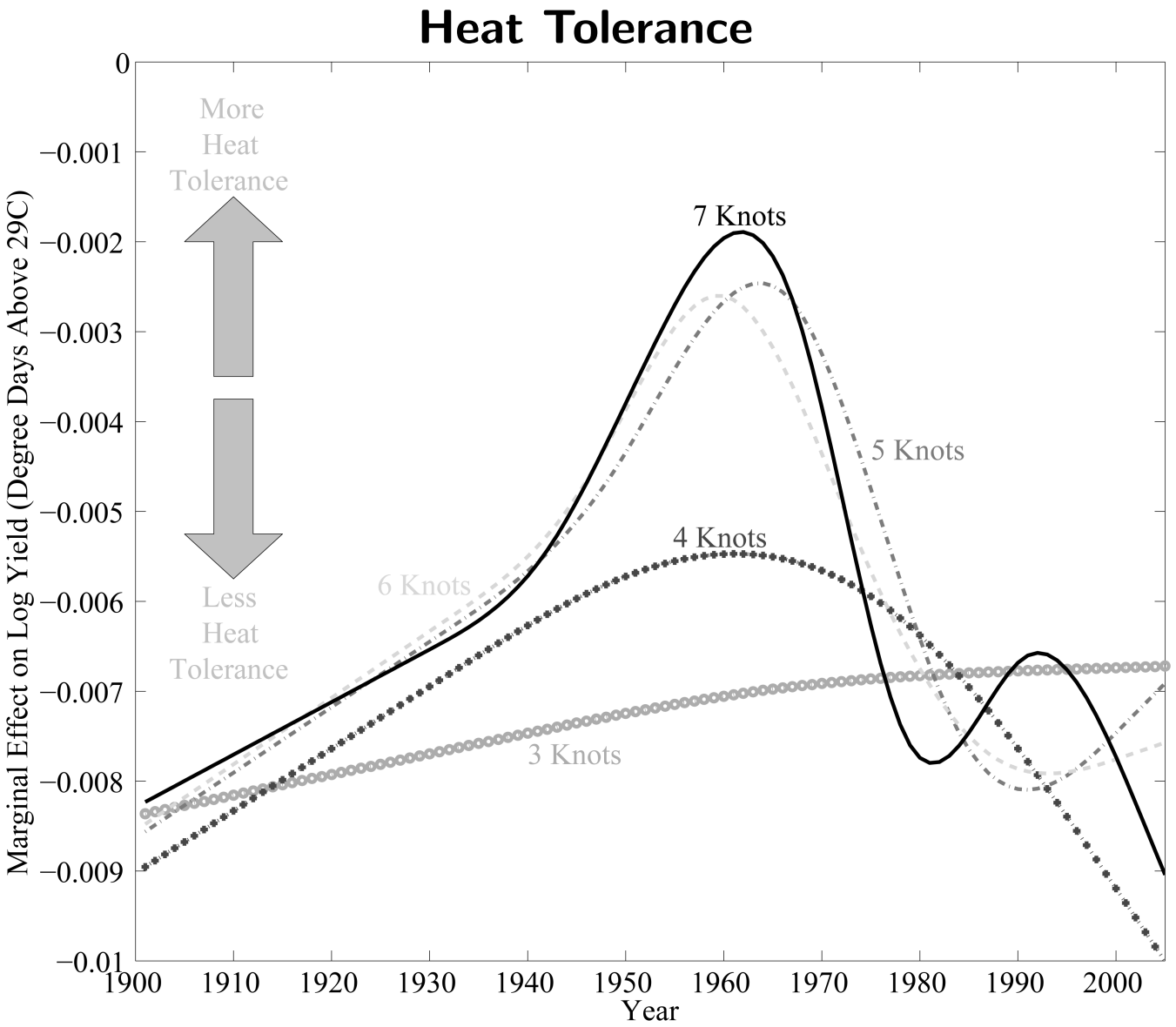
Evolution over Time



Evolution over Time



Evolution over Time



Outline

1. Why Impacts on US Agriculture Might be Economically Meaningful
2. Potential Impacts of Climate Change on US Agriculture
3. Technological Progress: Evolution of Heat Tolerance
4. Agriculture's Role in Fighting Global Warming
5. Conclusions

Agriculture and CO2 Emissions

- Land use change responsible for ∼20% of CO_2 emissions
  - Deforestation releases a lot of carbon

Agriculture and CO2 Emissions

- Land use change responsible for ∼20% of CO_2 emissions
  - Deforestation releases a lot of carbon
- Use of biofuels to reduce CO_2 emissions
  - Long history of biofuels: Model T ran on ethanol
  - Renewed interest due to climate change

Agriculture and CO2 Emissions

- Land use change responsible for ∼20% of CO_2 emissions
  - Deforestation releases a lot of carbon
- Use of biofuels to reduce CO_2 emissions
  - Long history of biofuels: Model T ran on ethanol
  - Renewed interest due to climate change
- Concern: Indirect land use change / food prices
  - 2009 Renewable Energy Standard
  - 5% of world caloric production of 4 basic staples go into biofuels
  - Predicted commodity price increase 20% (one third recycling ratio)
    - Reduces consumer surplus by 150billion annually
  - Supply mainly from extensive margin
    - Indirect land use change impacts CO_2 balance

Agriculture and CO2 Emissions

- Price increase / indirect land use change
  - Depends on demand and supply elasticity for calories
- Study identifying demand / supply elasticities
  - Demand: global yield shocks
  - Supply: lagged yield shocks
- Data
  - Yearly country level yield shocks
  - Combine 4 basic staples (corn, rice, soybeans, and wheat)
  - Futures price data (Chicago Board of Trade)

Agriculture and CO2 Emissions

	Model					
	2SLS	**3SLS**	**2SLS**	**3SLS**	**2SLS**	**3SLS**
	Demand and Supply Elasticities					
β_d	-0.0505***	-0.0554***	-0.0641**	-0.0797***	-0.0668***	-0.0634***
(s.e.)	(0.0190)	(0.0167)	(0.0243)	(0.0215)	(0.0241)	(0.0226)
β_s	0.1165***	0.1337***	0.0826***	0.0951***	0.0957***	0.0979***
(s.e.)	(0.0286)	(0.0241)	(0.0217)	(0.0189)	(0.0208)	(0.0189)
Δp	31.41	27.01	36.10	29.31	32.14	32.16
(95%)	(21.32,50.14)	(20.69,36.62)	(23.75,60.31)	(22.01,40.80)	(22.23,50.00)	(22.79,48.40)
N	42	42	42	42	41	41
I	2	2	3	3	3	3
K	1	1	1	1	2	2

β_d Demand elasticity
β_s Supply elasticity
Δp Predicted price increase (0% recycling as feed stock)

Outline

1. Why Impacts on US Agriculture Might be Economically Meaningful
2. Potential Impacts of Climate Change on US Agriculture
3. Technological Progress: Evolution of Heat Tolerance
4. Agriculture's Role in Fighting Global Warming
5. Conclusions

Conclusions

- Agriculture responsible for large consumer surplus
  - Food is essential good
  - US produces 23% of calories (four basic staples)

Conclusions

- Agriculture responsible for large consumer surplus
  - Food is essential good
  - US produces 23% of calories (four basic staples)
- Potential impact of climate change
  - Driving force: extreme heat
  - Large yield decline if maximum temperature rises a lot
  - Impact depends on baseline and predicted increase

Conclusions

- Agriculture responsible for large consumer surplus
  - Food is essential good
  - US produces 23% of calories (four basic staples)
- Potential impact of climate change
  - Driving force: extreme heat
  - Large yield decline if maximum temperature rises a lot
  - Impact depends on baseline and predicted increase
- Technological progress
  - Average yields have risen steadily since 1940
  - Not true for heat tolerance

Conclusions

- Agriculture responsible for large consumer surplus
  - Food is essential good
  - US produces 23% of calories (four basic staples)
- Potential impact of climate change
  - Driving force: extreme heat
  - Large yield decline if maximum temperature rises a lot
  - Impact depends on baseline and predicted increase
- Technological progress
  - Average yields have risen steadily since 1940
  - Not true for heat tolerance
- Ethanol mandate
  - Requires 5% of caloric production (4 basic staples)
  - Predicted to increase commodity prices by 20%
  - Indirect land use change

References

Papers with more detail available:
www.columbia.edu/∼ws2162