Environmental Drivers of Agricultural Productivity Growth: CO_2 Fertilization of US Field Crops

Charles Taylor[1,2] and Wolfram Schlenker[1,2]

[1] Harvard University
[2] National Bureau of Economic Research (NBER)

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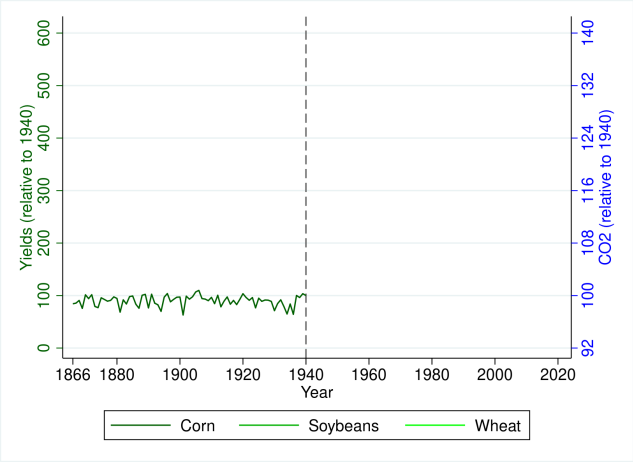
Outline

Motivation: CO_2 and US Yields



- What happened around 1940?
  - Remarkably steady upward trend
  - $+2$ bushels/acre/year
- Fluctuations around trend
  - Weather still important
- But why then?

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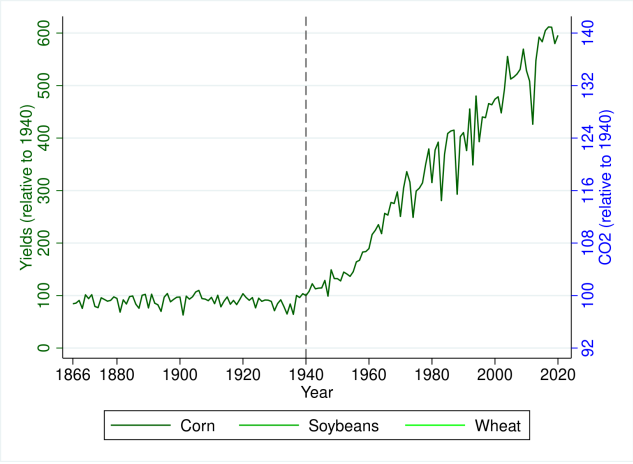

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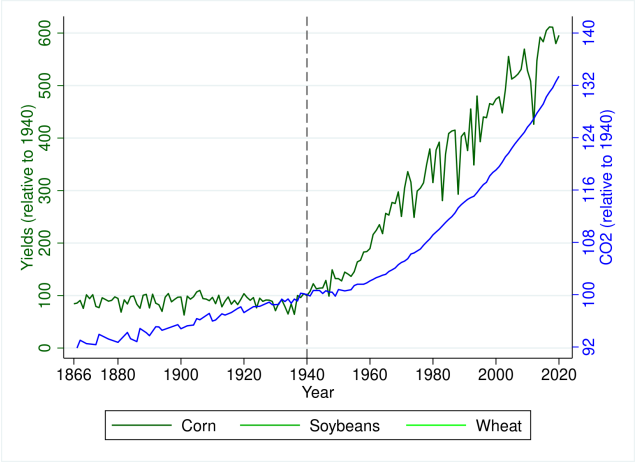

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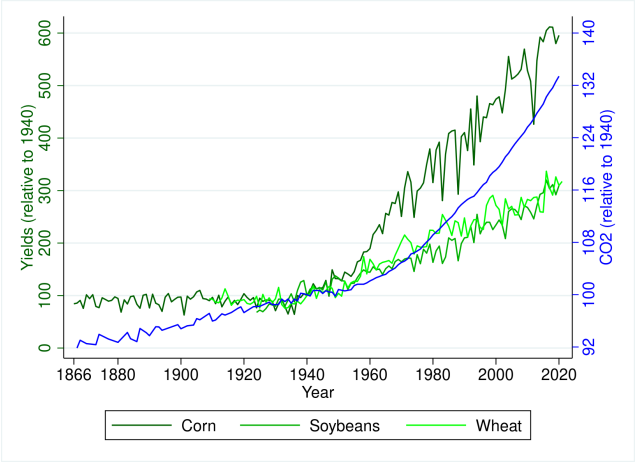

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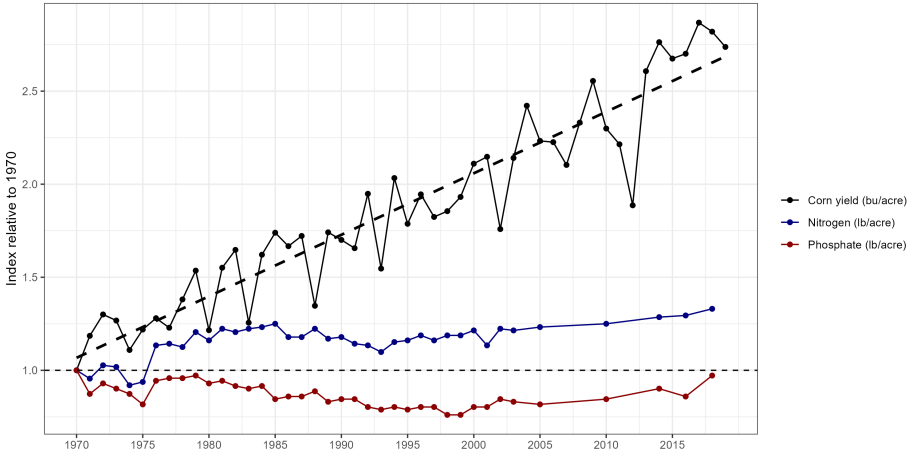
Intensification and improvements in technology

- Better seeds, machines, inputs, irrigation, etc.
- But intensification alone cannot not explain the increase in yield



Existing approaches to estimating yield responses to CO_2

1. Laboratory controlled-environments where CO_2 levels can easily be controlled
   - Insights from greenhouses (CO_2 is a purchased input)

2. Free-air concentration enrichment (FACE) experiments
   - Process involving a series of pipes in fields emitting CO_2-enriched air
   - Larger-scale trials in more realistic crop-growing conditions
   - Huge variation by crop / location; interactions with nutrients and water

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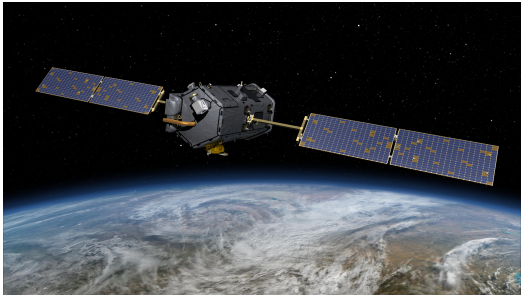
SOYFACE in Illinois (soybeans)

How representative is FACE of real world farms?

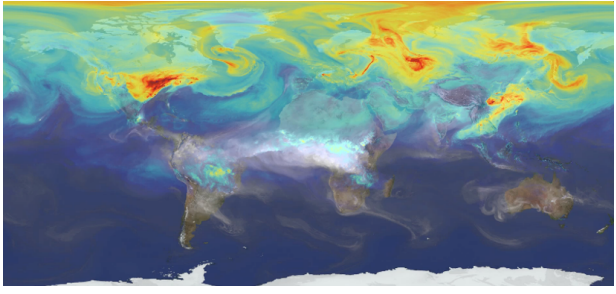
Approach: use econometric methods to estimate CO_2 impacts



OCO-2 satellite

Examine link between CO_2 anomalies and yields at the US county-year level

+ Realistic growing conditions on commercially-farmed fields (large N)
− Cannot control for other factors as well as experiments; low resolution



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How to estimate causal impacts with two trending variables?

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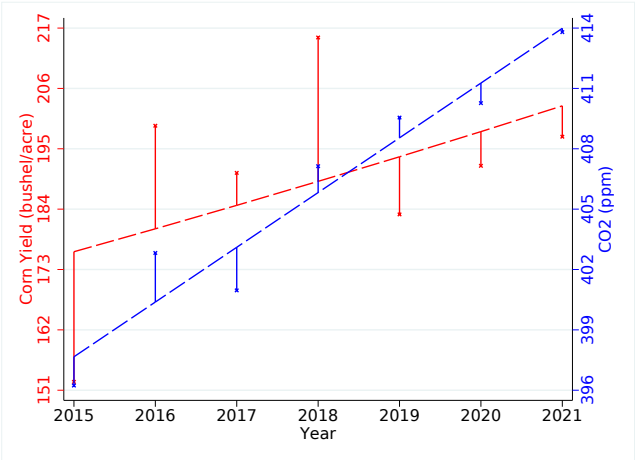
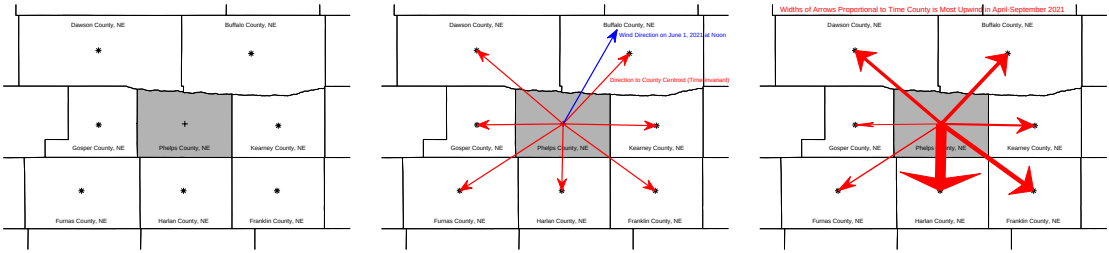


Example from Macoupin county, IL

Specification 2: wind instrument

Example for Phelps county, NE



- Define upwind county using hourly wind data
  - For each neighboring county we derive the angle between county centroids
  - For each hour: upwind where cosine of wind direction and county direction closest to -1
  - County that is is "upwind" for most hours April-September defined as upwind county

    $\rightarrow$ Harlan county to the south

Outline

Discussion

- 1 ppm of CO_2 $\Rightarrow$ yield increase of 0.2% to 0.5%, varying by crop
- CO_2 is increasing at 2 ppm/year $\Rightarrow$ large share of agricultural productivity growth driven by rising atmospheric CO_2
- Higher than most FACE experiments. Why?
  1. One FACE experiment in Midwest in Champaign, IL; 1 acre in total, mainly soybeans.
  2. CO_2 levels fluctuate widely due to air turbulence; crop response higher if CO_2 supplied steadily, 50% potential bias (Allen et al. 2020)
  3. FACE increases CO_2 by 200 ppm, possible decreasing marginal effects of large CO_2 increases
- What about innovation? Before 1940 crop yields were stagnant.

  "Wheat production witnessed wholesale changes in varieties and cultural practices...without these changes...yields everywhere would have plummeted due to the increasing severity of insects, diseases, and weeds." (Olmstead and Rhode 2002)
- Implications for climate change damage estimates