Impacts of Technological Assumptions on Agricultural Yield Forecasts under Climate Change

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Introduction

A number of studies have investigated the effects of climate change on agricultural production, specifically grains and oilseeds in the U.S. Yet, these studies vary widely in terms of the assumptions they make about the form of functional form of technology and yield trends.

The purpose of this research is to measure the effect of weather shocks on corn production in the Midwest, and how yield responses to these shocks vary by region. Once spatial technological heterogeneity is incorporated into yields models, we estimate corn productivity changes (measured in yields per acre) under various weather and technological scenarios.

Methods

We use county-level data from 1975 to 2012. Weather data was obtained from the PRISM Climate Group of the University of Oregon, and consists of monthly observations of precipitation, minimum and maximum temperatures for each county. Average annual dry land county production yield data was obtained from the National Agriculture and Statistics Service (NASS). The period in question is a relatively good representation of longer time frame for modeling the distribution of weather in the Midwest. The states included in our area of study are: Iowa, Illinois, Indiana, Michigan, Ohio, Nebraska, Kansas, Minnesota, South Dakota and Wisconsin. These states have similar crop calendars, beginning in late April-May, and harvesting in Oct-Nov.

Our econometric model consists of a county fixed effects spatial lag model, regressing average annual county yields per acre on weather variables for the critical period of crop development (June, July and August), incorporating spatially autocorrelated effects, and spatial interactions with weather variables as measured from a center point of our sample.

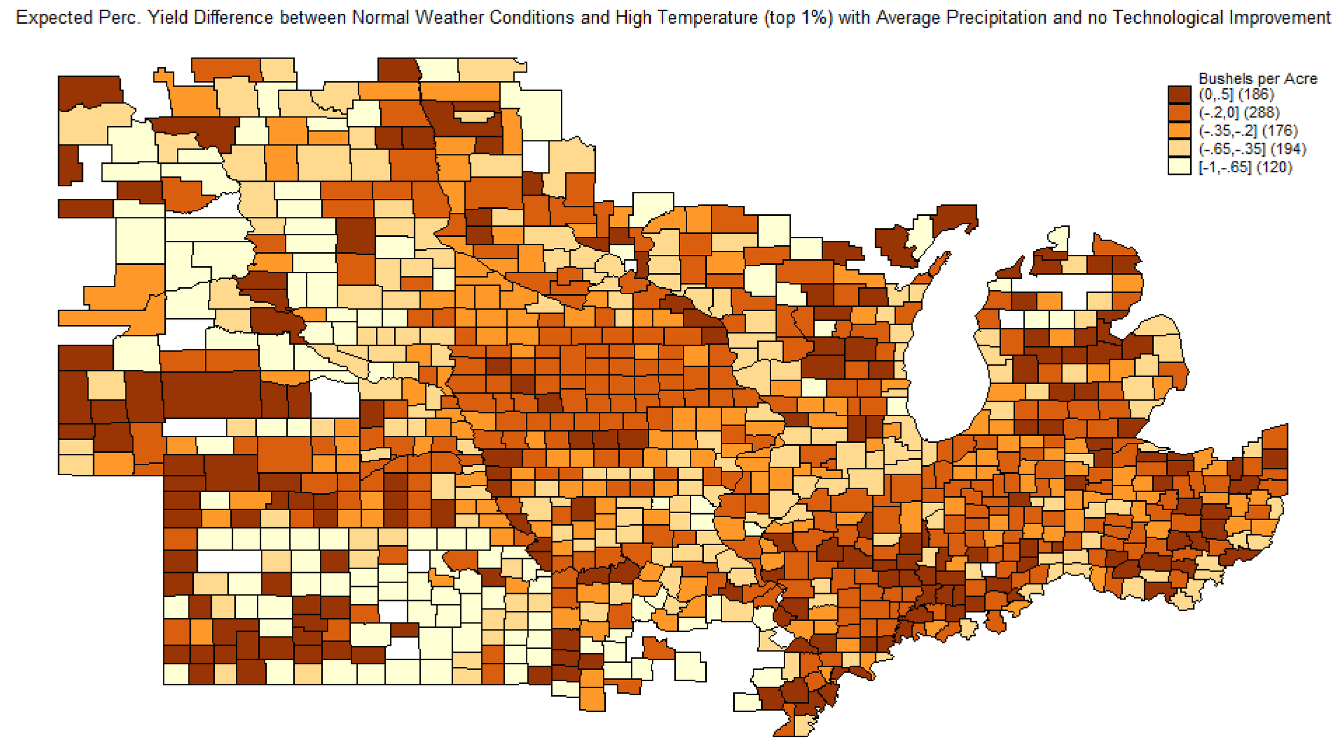
$$\mathbf{y} = \rho(\mathbf{I_T} \otimes \mathbf{W_N})\mathbf{y} + \mathbf{X}_{Int}\boldsymbol{\alpha} + \mathbf{X}_{Tr}\boldsymbol{\beta} + \mathbf{X_W}\boldsymbol{\gamma} + \boldsymbol{\varepsilon}$$

Where $(\mathbf{I_T} \otimes \mathbf{W_N})\mathbf{y}$ is the spatial lag matrix of dimensions NT x N, $\mathbf{W_N}$ is an N x N standardized queen matrix, $\mathbf{I_T}$ is a T x T identity matrix, and $\otimes$ is the Kronecker product. $\mathbf{X}_{Int}$ is an NT x N county fixed effects matrix; $\mathbf{X}_{Tr}$ is a NT x S state level time trend matrix; $\mathbf{X_W}$ is an NT x K weather variable matrix; and $\boldsymbol{\varepsilon}$ is a vector of error terms under the usual assumptions. The variables to estimate are: ρ, the spatial autocorrelation coefficient; $\boldsymbol{\alpha}$, counties fixed effects; $\boldsymbol{\beta}$, state time trend coefficient; $\boldsymbol{\gamma}$, vector of weather variables coefficients. N= 974 counties, S= 12 States, T= 38 years.

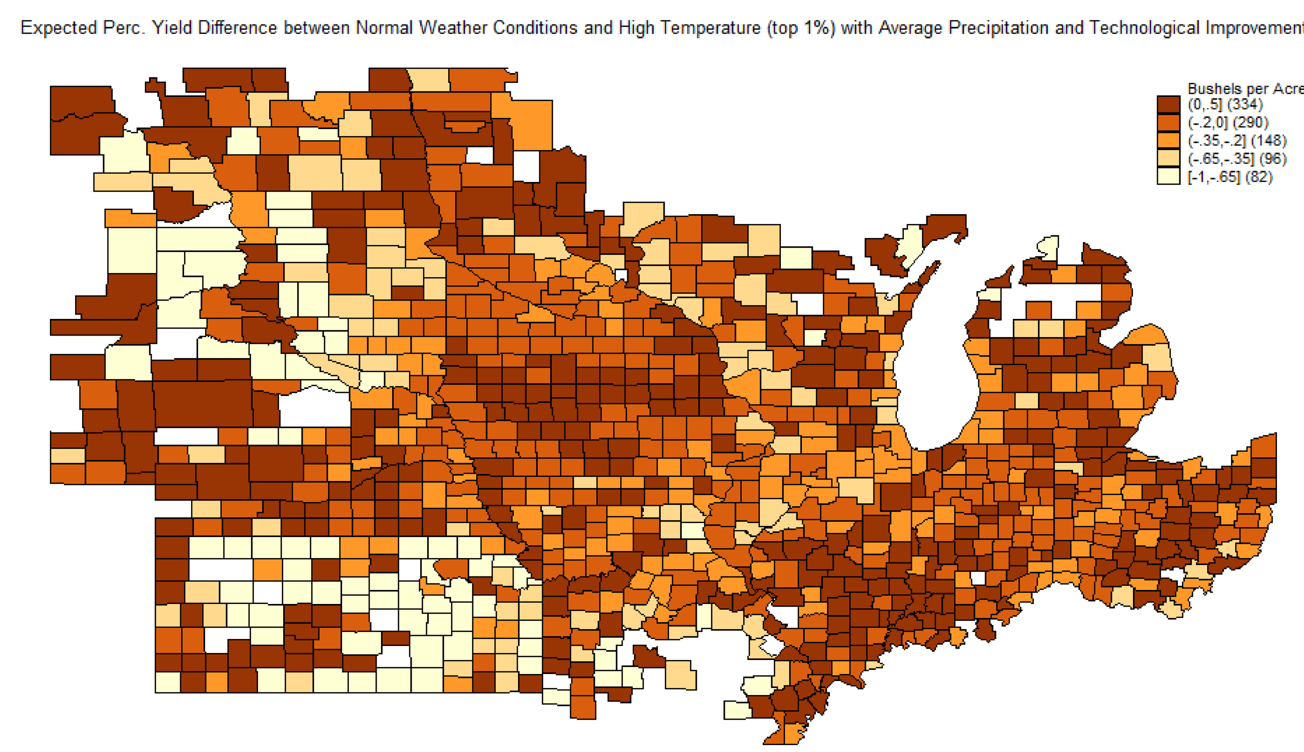
The weather variables used in the model are: Average temperature for June, July and August, and its squared value; average precipitation for June, July and August, and its squared value; interaction of temperature and precipitation; distance in longitude degrees from Peoria, IL; and distance in latitude degrees from Peoria, IL.

Results

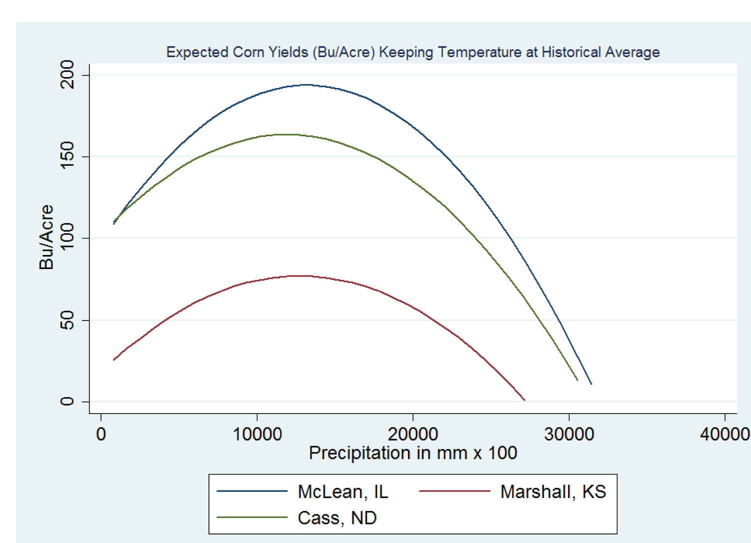
Scenario under no technological improvement

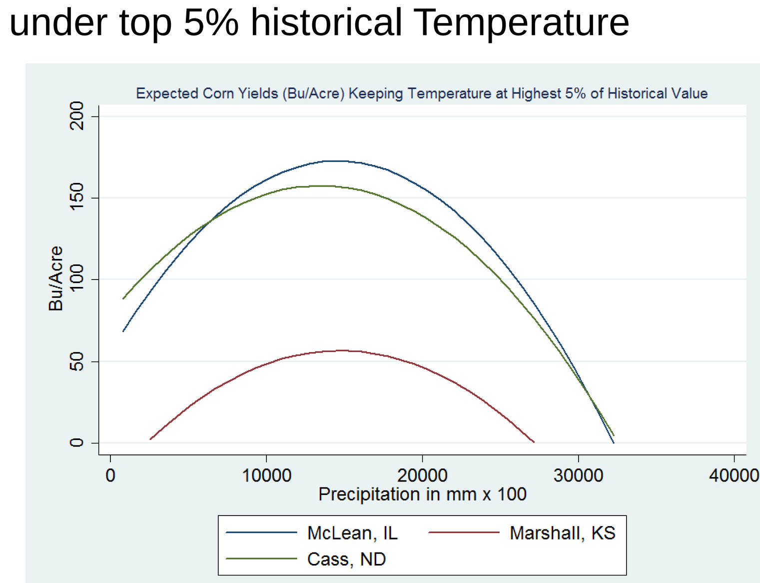


Scenario under 10 year technological improvement



Expected Corn Yields under Average Temperature and under top 5% historical Temperature





Results

State	Average Tech. Effect in bu/ acre per year
IL	1.8317
IN	1.4592
IA	2.1963
MI	1.5354
MN	2.4152
NE	1.8361
OH	1.1736
WI	1.1093

Conclusions

Strong evidence of spatial technological effects

Local effects of weather on yields must be considered when modeling. One model does not fit all.

Weather shocks can be mitigated by technological effects

Effects of high temperature shocks on yields decrease with precipitation

Literature cited

Woodard, Joshua D. "Impacts of Weather and Time Horizon Selection on Crop Insurance Ratemaking: A Conditional Distribution Approach." *The North American Actuarial Journal, forthcoming*.

For further information

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