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Innovation, Climate, and Ontario Corn and Soybean Yield

Author: Yuetian Jiang

Department of Food, Agricultural, & Resource Economics – University of Guelph

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Yuetian Jiang, MSc student
Dept. of Food Agricultural & Resource Economics
University of Guelph
yuetian@uoguelph.ca

Corn and soybean have been two major agricultural commodities in Ontario.

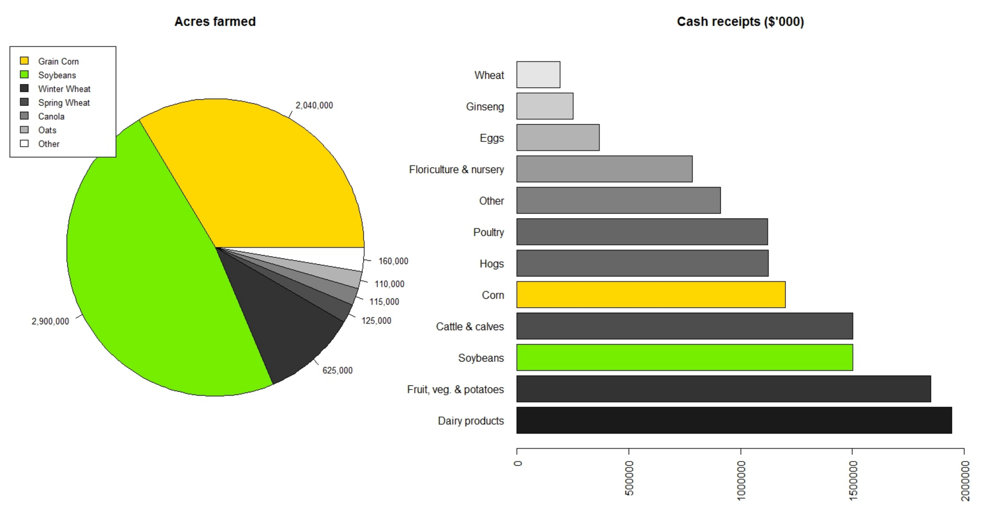

Figure 1: Ontario estimated crop area farmed and cash receipts in 2015. Source: Statistics, Ontario Ministry of Agriculture, Food And Rural Affairs (OMAFRA).

How innovation effects crop yield distributions?

Innovation does not necessarily shift the yield distribution upwards uniformly. Often innovation moves mass from one part of the distribution to another part. Moreover, the effects of technological changes could be different under changing climate. We use the Normal Distribution Mixture [1] model to capture possibly different rates of technological change.

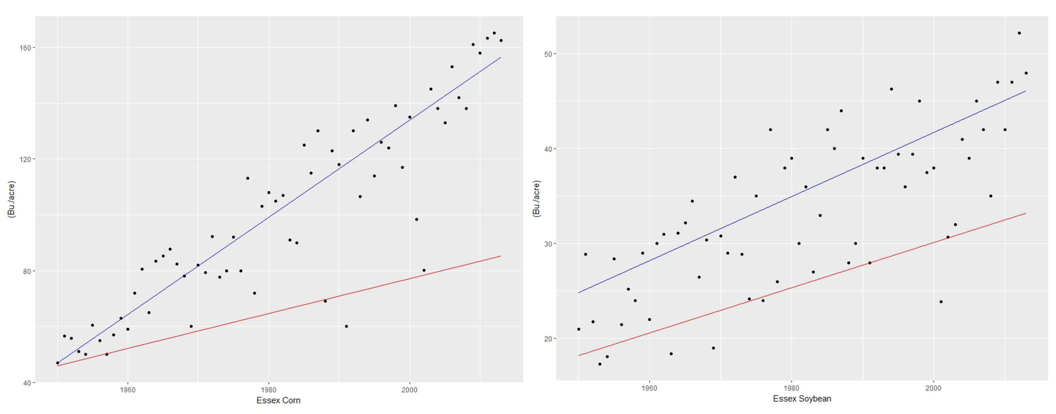

Figure 2: Essex county corn and soybean yield from 1950 to 2013. The blue line is the estimated mean of the "good" year yield realization; The "bad" years are in pink. The blue line is steeper than the red line, which indicates higher rate of technological change.

Innovations in seed technologies have led to more plants per acre. Consequently, there is greater demand for precipitation. As a result, we may expect to see precipitation thresholds increasing over time.

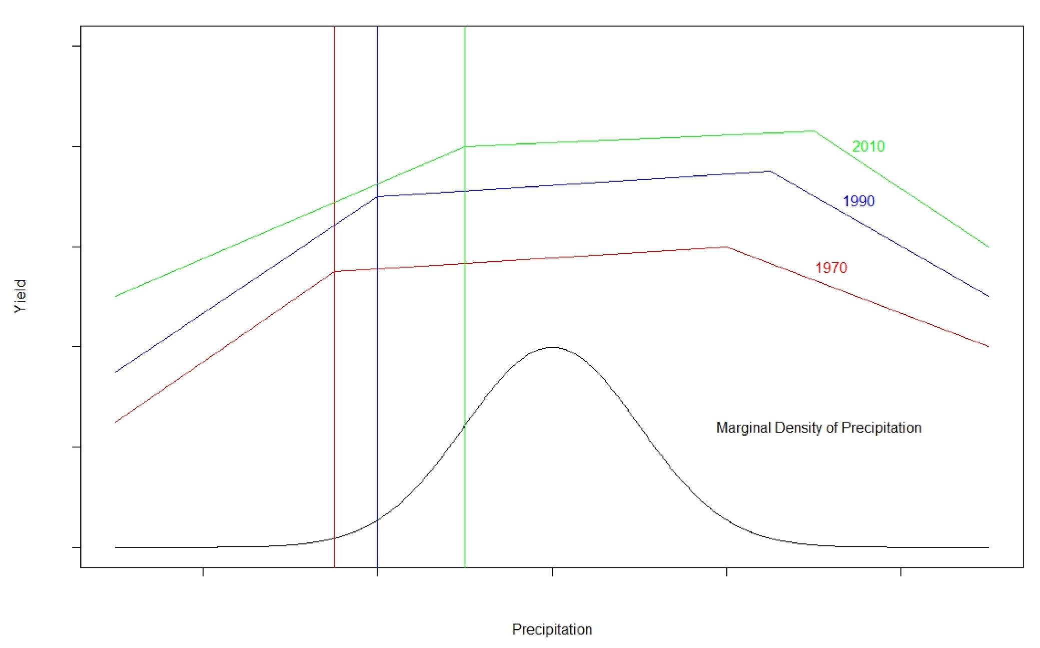

Figure 3: Changing climate thresholds. The three vertical lines denotes the precipitation thresholds at there different periods of time. After reaching these precipitation thresholds (i.e. plants get enough water for growing.), the yield per acre rises slowly. Notice that the precipitation thresholds increases through time.

Conceptual framework

The following two models investigate yield-climate relationship. Equation (1) and (3) are estimated using least squares with county fixed effects; Equation (2) is estimated using Expectation-Maximization algorithm.

Model I: Yield & climate

$$y_{i,t} = f(Grow.length_{i,t}, Trend, Climate\ variables_{i,t}) \quad (1)$$

where *i* denotes county and *t* = {1,...,64}.

Model II: Probability of "Bad" year & climate

$$y_{i,t} \sim \lambda_i N_i(\alpha_l + \beta_l * t, \sigma_l) + (1-\lambda_i) N_i(\alpha_u + \beta_u * t, \sigma_u) \quad (2)$$

where λ_i denotes the probability of "Bad" year. $\lambda_i \in [0,1]$.

$$\lambda_{i,t} = f(Grow.length_{i,t}, Trend, Climate\ variables_{i,t}) \quad (3)$$

where $\lambda_{i,t}$ is calculated from Equation (2).

Climate variables

- Growing degree days (GDD) measures the duration of temperature that is good for the growth of a particular plant.
- Harmful degree days (HDD) measures the duration of temperature that is too high for the growth of a particular plant.
- Precipitation means water vapor that falls under gravity. Prec.JA means the precipitation from the beginning of July to the end of August, which is when plants need a lot of water.
- Vapour pressure deficit (VPD) is the difference between the amount of moisture in the air and how much moisture the air can hold.

Data

- 32 and 6 county-level corn and soybean yield data are collected from Ontario annual provincial agricultural production statistics reports from 1950 to 2013.
- The length of growing season for corn and soybean are calculated by choosing OMAFRA's recommended start date on May 10^{th} and end date on the first day after September that the minimum temperature is lower than -2°.
- GDD, HDD, VPD and precipitation are calculated and annualized using daily Environment Canada weather station observations of precipitation and minimum and maximum temperature.

Preliminary Results

Table 1: Estimation results: yield-climate relationship.

	Dependent variable:			
	Yield		Prob.lower	
	Soybean	Corn	Soybean	Corn
Grow.Length	0.071***	0.327***	-0.004**	-0.008***
	(0.026)	(0.032)	(0.002)	(0.001)
GDD	3.004***	9.759***	-0.167***	-0.242***
	(0.666)	(0.832)	(0.041)	(0.020)
HDD	-7.968	-101.784***	0.302	2.280***
	(13.778)	(14.257)	(0.843)	(0.343)
Trend	-0.232	0.536***	0.006	0.006
	(0.158)	(0.169)	(0.010)	(0.004)
Prec.	0.394	-0.087	-0.057	0.008
	(0.728)	(0.868)	(0.045)	(0.021)
Prec.JA	-1.500**	-3.540***	0.044	0.021
	(0.694)	(0.870)	(0.042)	(0.021)
Prec.JA*Trend	0.105***	0.243***	-0.003***	-0.003***
	(0.020)	(0.023)	(0.001)	(0.001)
VPD	-0.577	-3.879	0.298	0.124
	(5.498)	(6.202)	(0.337)	(0.149)
VPD.JA	-12.963***	-2.966	0.400	0.215*
	(4.222)	(4.618)	(0.258)	(0.111)
VPD.JA*Trend	0.175**	0.113	0.001	0.0004
	(0.077)	(0.079)	(0.005)	(0.002)
Obs.	384	2,048	384	2,048
R^2	0.727	0.821	0.205	0.138
Adjusted R^2	0.716	0.817	0.173	0.120
F Statistic	97.948***	920.237***	9.511***	32.017***
Note:		*p<0.1; **p<0.05; ***p<0.01		

Marginal effects

	Model:			
	Yield		Prob.lower	
	Soybean	Corn	Soybean	Corn
Trend	0.313***	1.323***	0.015**	0.014***
(p-value)	(0.000)	(0.000)	(0.018)	(0.000)
Prec.JA	1.913***	4.358***	-0.054***	-0.077***
	(0.000)	(0.000)	(0.003)	(0.000)
VPD.JA	-7.28***	0.707	0.433	0.228**
	(0.009)	(0.999)	(0.126)	(0.031)
Note:		*p<0.1; **p<0.05; ***p<0.01		

Table 2: Marginal effects for interacted terms.

Findings

1. Rates of technological change differ in the "good" years and "bad" years. The rate of technological change tends to be higher in the upper component than it is in the lower one.
2. The probability of "bad" harvest is statistically increasing over time.
3. Yields are becoming more susceptible to precipitation shortfalls over time.

Implications of findings

1. Different rates of technological change and increasing probability of lower yield realization jointly may put a financial burden on Business Risk Management programs.
2. Producers do not appear to be adopting risk-reducing technologies but rather using subsidized crop insurance to take care of the lower tail; this is optimal in many cases.
3. Co-insurance may create greater incentives for producers to adopt more risk reducing technologies.

Forthcoming Research

Our analysis will be extended to consider innovation and climate effects on yield volatilities for both upper and lower tails of the yield distribution. Potential findings would be important to Ontario Business Risk Management programs and crop insurance policies.

[1] Normal mixture model is commonly estimated using the Expectation-Maximization algorithm.