Higher Moment of Yield by N x Climate: Definition and Estimation

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This paper explores higher-moments of yield responses to nitrogen under variable climate conditions. We model the higher moments of yield distributions using a flexible functional approach.

1 Introduction

Accurate nitrogen (N) use is crucial for maximizing crop yields and profitability under variable climate conditions. Understanding how N affects yield distribution is essential for agricultural policy, especially under climate variability. Traditional analysis focuses on mean yield, but this overlooks yield variability and higher-order moments, which are critical for understanding the risk associated with nitrogen application.

2 Literature Review

2.1 Higher Moments of Yield

Studies in agricultural economics show that focusing on only the mean yield effect is limiting. Literature on higher-order moments (e.g., variance, skewness) suggests that these moments provide insights into yield risk, crucial for risk-averse decision-making (Antle, 1983).

2.2 Crop Yield Insurance and Nitrogen Use

In crop insurance, nitrogen is often considered as a factor in yield stability. Literature indicates that nitrogen can either mitigate or amplify risks associated with weather variability, with direct implications for insurance schemes.

3 Research Objectives

The primary objective of this research is to evaluate whether N application is yield-increasing or yield-decreasing under different climate conditions, particularly focusing on how N affects not only mean yield but also the variance and higher moments of yield under the different weather events.

4 Methodology

4.1 Data Structuring and Panel Data Creation

Our dataset consists of approximately 100 on-farm trials with variable nitrogen rates, seeding rates, and climate conditions.

Potential problem of making combined panel data

- Heterogeneity: Differences in soil, climate, and management practices across trials.
- Non-Panel Structure: This dataset is not inherently structured as a panel, which poses challenges.
- Solution: Using fixed effects to control for unobserved heterogeneity. Additionally, create a pseudo-panel by aggregating trial-level data into consistent nitrogen, climate, and yield variables.

4.2 Yield Response and Moment Estimation

- Estimate yield response to nitrogen using machine learning models to capture non-linear relationships.
- Estimate moments (first and higher)

$$\mu_1 = E[Q] = m(x, \beta)E[e^u] \tag{1}$$

Here, $m(x, \beta)$ represents the deterministic part of the yield response, which depends on inputs like nitrogen (x), while $E[e^u]$ represents the stochastic component.

- Nitrogen (N) and other inputs directly affect the deterministic part of the production function.
- The weather component (e^u) influences variability in yield outcomes, reflecting production risk.

The variance of yield can be expressed as:

$$\mu_2 = E[(Q - E(Q))^2] = m(x, \beta)^2(E[e^{2u}] - E[e^u]^2) \tag{2}$$

4.3 Expected Output Moments and Their Relationship to Inputs

The moments of the probability distribution of output are represented by:

$$\mu_1(x, \gamma_i) = \int Qf(Q|x)\, dQ \tag{3}$$

$$\mu_i(x, \gamma_i) = \int (Q - \mu_1)^i f(Q|x)\, dQ, \quad i > 2 \tag{4}$$

- $\mu_1(x, \gamma_i)$ is the first moment (mean yield), and $\mu_i(x, \gamma_i)$ represents higher moments.

- This approach allows for heteroskedasticity (variance depending on x) and heteroskewness (skewness depending on x), providing a more flexible representation of yield distributions under different input conditions.

4.4 Empirical Model for regressino of Yield Moments to inputs and weather

The empirical model is:

$$y_{it}^{j} = \alpha_{ij} + \beta_{j1}\text{low}_{it} + \beta_{j2}\text{S}_{it} + \beta_{j3}\text{N}_{it} + \beta_{j4}P_{it} + \beta_{j5}P_{it}^{2} + \beta_{j6}G_{it}^{2} + \beta_{j7}\text{N*P}_{it} + \beta_{j8}t + \beta_{j9}t^{2} + \epsilon_{ijt}$$

- α_{ij} is a fixed effect for field and moment.
- p_{it} capture precipitation and its quadratic effect.
- t and t^2 are time trend variables.