Dynamic Crop Rotation with Field-Level Heterogeneity: Estimating Yields and Profits

Relevance of the Topic

Crop rotation is important for agricultural productivity and environmental outcomes across a diverse range of agricultural systems within the United States. For example, when farmers plant corn consecutively instead of rotating with soybeans, they deplete soil nitrogen and must apply additional fertilizer, contributing to nutrient runoff, eutrophication, and hypoxic zones. Policies ranging from biofuel mandates to conservation programs interact with rotation decisions. Evaluating the impacts of such policies on supply, rotation behavior, and the environment requires understanding how unobserved field-level heterogeneity shapes crop choices and yields.

A key complication is that fields differ in their suitability for corn versus soybeans, and farmers select crops based on this private information. This selection generates two empirical challenges. First, observed yields are endogenously determined by crop choice. Second, the response to policies depends on the joint distribution of corn and soybean productivity across fields. Consider a rotation subsidy: its supply impact depends on (i) how many fields switch crops (extensive margin), (ii) the productivity of switchers relative to non-switchers (selection effect), and (iii) what happens to yields when fields switch (rotation effect). A naive analysis that ignores selection will mispredict supply response because marginal switchers are not average fields, they are selected on comparative advantage, which under certain conditions also predicts absolute advantage.

We develop and estimate a dynamic structural model of crop rotation that addresses these challenges and identifies all three effects. Our approach makes three contributions.

First, we explicitly model unobserved field-level heterogeneity in crop-specific productivity. We allow fields to have separate corn and soybean productivity that may be correlated, generating a distribution of comparative advantage across fields. We characterize when fields that plant more corn also have higher absolute productivity in both crops, not just comparative advantage in corn. This distinction matters for policy: it determines whether marginal switchers are better or worse than average.

Second, we jointly estimate the yield process and the dynamic crop choice model. The yield equations identify the rotation effect on output, while the choice model identifies the profit function, including the cost savings from rotation. By estimating both jointly, we can separately identify these components—a decomposition not possible with yield or choice data alone. This distinction matters for policy: yield boosts increase production, while input cost savings provide environmental benefits without necessarily raising output.

Third, we combine satellite-derived crop choices and yields at the field level. This granularity is essential for understanding selection: aggregate or county-level data cannot reveal which fields are marginal or how their productivity differs from the average.

Research Methodology

We use remotely-sensed, field-level data on crop choice and yields for approximately one million fields in Illinois, Iowa, and Indiana over 2005–2019. We link these to field-specific

prices constructed from futures and local basis at nearby grain elevators.

We estimate yield equations with field fixed effects to recover rotation effects on yields and the distribution of field-level productivity in corn and soy, (θ_c, θ_s). We present estimates that heterogeneity in yields is present even at county levels, implying coarse spatial controls are not sufficient to capture variation in field quality. We derive conditions under which selection on comparative advantage (the difference in productivity, $\Delta\theta \equiv \theta_c - \theta_s$) also implies selection on absolute advantage: both conditional expectations $E[\theta_c|\Delta\theta]$ and $E[\theta_s|\Delta\theta]$ are both increasing in comparative advantage when the variance of corn productivity exceeds that of soy and the correlation lies in a specific range. We verify these conditions hold empirically: fields in the upper tail of relative corn productivity plant corn more frequently, but these fields also have above-average soy productivity.

Our reduced-form estimates confirm statistically and economically significant rotation effects on yields and substantial heterogeneity in field productivity. The correlation between corn and soy fixed effects is positive but well below one, indicating scope for comparative advantage to drive specialization. We also document that a substantial fraction of fields are "always rotators" who maintain a strict corn-soy rotation regardless of price movements. Our static choice model rationalizes this pattern: when the rotation benefit is large relative to the variance of idiosyncratic cost shocks, rotation incentives dominate price signals.

We estimate a dynamic discrete choice model where farmers choose crops to maximize expected discounted profits, accounting for how current choices affect future productivity through rotation. The state space includes prices, lagged crop choice, and unobserved field type. We integrate over the distribution of field heterogeneity using Gauss-Hermite quadrature and estimate via simulated maximum likelihood.

Potential for Generating Discussion

This paper should generate discussion on several fronts.We contribute to the literature on dynamic discrete choice estimation with continuous outcomes and unobserved heterogeneity. Our identification argument—using the covariance structure of estimated fixed effects to recover structural parameters—may be applicable to other crops and other settings with selection on unobservables.

Policy evaluation in this setting requires understanding three distinct margins: how many fields switch (extensive margin response to incentives), how productive switchers are (selection effect determined by the distribution of heterogeneity and current market conditions), and what happens to yields when they switch (rotation effect). These questions are answered by different parts of the model: the choice probabilities, the joint distribution of heterogeneity, and the yield equations, but the parameters are linked. A structural model is necessary to combine them coherently for counterfactual analysis.

Finally, our characterization of the productivity distribution addresses a gap in the crop supply literature. Long-run supply responses to price changes depend on which fields are marginal and our estimates reveal how field quality varies across the margin of rotation versus specialization.