Estimation of the Dynamics of Crop Acreage Response to Price: Rotations and Aggregation

Nathan P. Hendricks,[1] Daniel A. Sumner, [2] and Aaron Smith, [2]

1) Agricultural Economics, Kansas State University; 2) Agricultural & Resource Economics, University of California, Davis

Overview

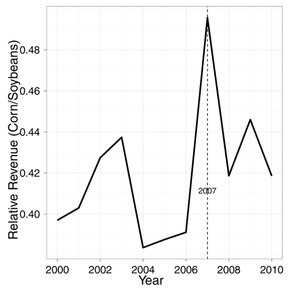
At least since the seminal work of Nerlove (1958), conventional wisdom among economists has held that long-run supply response to price is larger than short-run response to price for crops. This result followed from a theory of "partial adjustment," where farmers are able to only gradually adjust to a new optimal crop production after a change in prices. A large empirical literature conforms with this theory.

We argue that the opposite is true for crops that are grown in rotation. Farmers that adjust their planting decision in response to price changes have an incentive to switch back to the previous crop to capture agronomic benefits associated with crop rotations. Hence, the long-run response to price is smaller than the short-run response to price. We confirm this model result with econometric estimates from a novel set of field-level crop data derived from satellite imagery that covers Iowa, Illinois, and Indiana. The difference between our field-level estimates those using more aggregate data are explained by biases that arise from aggregating heterogeneous dynamic responses.

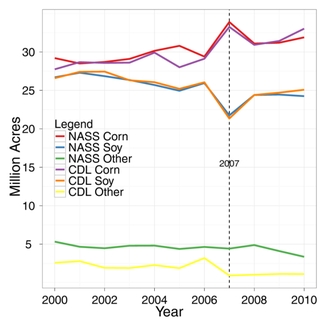
Data

Crops	Cropland Data Layer: Illinois (1999-2010), Iowa & Indiana (2000-2010)
Revenue	Futures plus expected basis plus expected loan deficiency payment
Field boundaries	Common Land Unit GIS data Layer from the Farm Service Agency
Soils	SSURGO database
April-May Precip	PRISM Climate Group

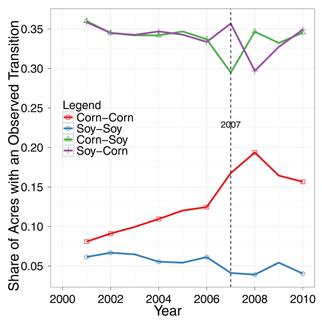
Relative Revenue



Aggregate Crop Acreage



Aggregate Crop Transitions



Conceptual Model

Incentives to rotate crops:

1. Yield boost, holding fertilizer and other inputs constant.
2. Reduction in input use (e.g., nitrogen carry-over).

One-year memory: For each field it is optimal to plant continuous corn, corn-soybeans, or continuous soybeans.

Two-year memory: It may also be optimal to plant corn-corn-soybeans or soybeans-soybeans-corn.

When prices change, some rotations change and the farmer will plant the crop that begins the new rotation immediately (assuming the new prices are expected to be permanent).

Why is the long-run response smaller than the short-run response?

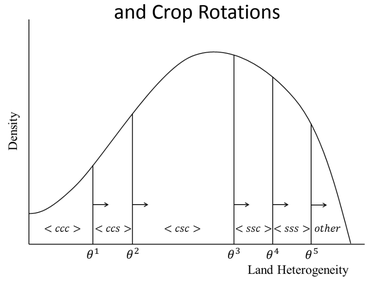
- Farmers that adjust their planting decision have an incentive to switch back to the previous crop to capture rotation benefits.

Example 1: If the price of corn increases, some land previously in continuous soybeans switches to a corn-soybean rotation. It is optimal to plant corn first and many of these fields will switch back to soybeans in the second year so corn acreage will fall, even if corn prices remain high.

Example 2: If the price of corn increases, some farmers may find it optimal to plant corn after corn on some land that was previously in a corn-soybean rotation. In the second year, it is optimal for some of these farmers to plant soybeans again to obtain the rotation incentives. Again, corn acreage will decrease in the second year, even if corn prices remain high.

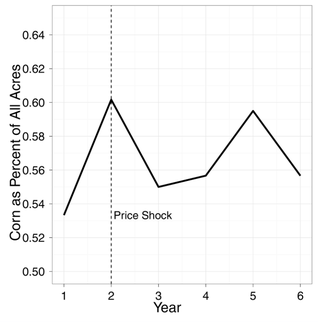
Numerical Illustration with Two-Year Memory

Illustration of Land Heterogeneity and Crop Rotations

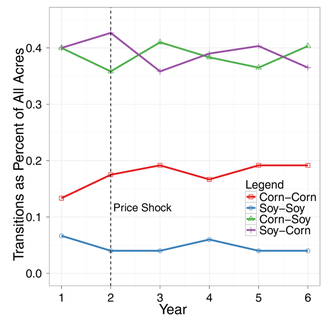


Assume there is a permanent increase in the price of corn relative the price of soybeans. A permanent shift in the land types planted to each crop rotation implies the dynamics of crop acreage and crop transitions shown below.

Corn Acreage Dynamics from a Permanent Price Shock



Crop Transition Dynamics from a Permanent Price Shock



Econometric Model

Rotational Margin: Estimate linear second-order Markov transition probabilities for transitions between corn and soybeans. Define four states: state 1 $(c_{it} = 1, c_{i,t-1} = 1)$, state 2 $(c_{it} = 0, c_{i,t-1} = 1)$, state 3 $(c_{it} = 1, c_{i,t-1} = 0)$, state 4 $(c_{it} = 0, c_{i,t-1} = 0)$. The probability of transitioning between these states is estimated with reduced form linear probability models.

$$P_{11} = Prob(c_{it} = 1 | c_{i,t-1} = 1, c_{i,t-2} = 1) = p_{it}\beta_{1g} + x_i\theta_{1g} + \delta_{1g} precip_{it} + \kappa_{1g} t + \alpha_{1g}$$
$$P_{23} = Prob(c_{it} = 1 | c_{i,t-1} = 0, c_{i,t-2} = 1) = p_{it}\beta_{2g} + x_i\theta_{2g} + \delta_{2g} precip_{it} + \kappa_{2g} t + \alpha_{2g}$$
$$P_{31} = Prob(c_{it} = 1 | c_{i,t-1} = 1, c_{i,t-2} = 0) = p_{it}\beta_{3g} + x_i\theta_{3g} + \delta_{3g} precip_{it} + \kappa_{3g} t + \alpha_{3g}$$
$$P_{43} = Prob(c_{it} = 1 | c_{i,t-1} = 0, c_{i,t-2} = 0) = p_{it}\beta_{4g} + x_i\theta_{4g} + \delta_{4g} precip_{it} + \kappa_{4g} t + \alpha_{4g}$$

The long-run probability of being in state j is denoted π_j and is the solution to the following system of equations:

$$\sum_{m=1}^{4} P_{mj}\pi_m = \pi_j \quad \forall j,$$
$$\sum_{j=1}^{4} \pi_j = 1,$$

The long-run probability of planting corn is $Prob(c_{it} = 1) = \pi_1 + \pi_3,$ and the long-run marginal effect is calculated as the derivative of the closed form solution.

Extensive Margin: Estimate linear first-order transition probabilities for transitions between corn or soybeans and other crops.

We define groups of similar fields in different regions, yet maintain a sufficient number of observations within each group to obtain consistent estimates specific to each group of fields. First, we divide the fields into groups by the history of observed transitions during the sample period. Next, we divide these groups by Major Land Resource Areas from NRCS. We further divide these groups of fields according to the soil taxonomy only if there are a sufficient number of observations to further divide the group.

Econometric Results

Aggregate Corn Acreage Elasticities Using Field-level Data

	Rotational	Extensive	Total
Price of Corn			
Short-run	0.39	0.004	0.39
Long-run	0.31	0.006	0.31
Price of Soybeans			
Short-run	-0.30	0.002	-0.30
Long-run	-0.24	0.003	-0.24

Aggregate Corn Acreage Elasticities Using County-level Data and Fixed Effects

	Total
Price of Corn	
Short-run	0.35
Long-run	0.37
Price of Soybeans	
Short-run	-0.42
Long-run	-0.44

Why would estimates with aggregate data give a different result?

1. Fixed effects estimates of dynamic panels with heterogeneous coefficients and autocorrelated regressors (or autocorrelated common factors) give biased estimates of average coefficients. This bias can increase if aggregate data are used instead of individual data.
2. Aggregate data are likely to have a different dynamic structure than disaggregate data.