Testing for Complementarity: Glyphosate Tolerant Soybeans and Conservation Tillage

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Background

- Positive environmental impacts associated with the widespread adoption of glyphosate tolerant (GT) crops is a hotly debated hypothesis.
- Anecdotal and correlational evidence suggest that GT crops and conservation tillage (CT) are complements – GT crops provide more efficient post-emergent weed control, which potentially reduces the need for tillage.
- However, previous research has been inconclusive on whether GT crops complement CT for two reasons:
  - A lack of longitudinal, farm-level data.
  - Previously employed empirical frameworks do not distinguish between true complementarity and the correlation induced by unobservable factors (e.g., farmer education).

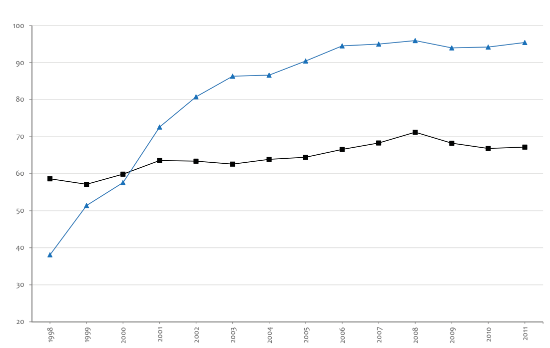
Objectives

In this paper we address the limitations of existing studies by:

- Developing a structural discrete choice framework of joint soybean-tillage adoption.
- Applying our model to a large, unbalanced farm-level dataset that covers the 1998-2011 period.

Importantly, we allow unobserved returns across tillage and seed practices to be correlated. This allows us to explicitly identify whether GT soybeans and CT are complements.

Figure 1: Convservation Tillage and GT Soybean Adoption Rates in the US



Model Basics

- We develop a mixed logit discrete choice model of joint soybean-tillage adoption.
- Each grower chooses the soybean-tillage system with the greatest per acre return.
- The choice set consists of four soybean-tillage systems :
  - Conventional Soybeans and Intensive Tillage (CV,IT)
  - Glyphosate Tolerant Soybeans and Intensive Tillage (GT,IT)
  - Conventional Soybeans and Conservation Tillage (CV,CT)
  - Glyphosate Tolerant Soybeans and Conservation Tillage (GT,CT)

Empirical Framework

The latent, per-acre returns to each system for grower *i* at time *t* on field *f* are specified as:

$$\pi_{itf}(CV,IT) = 0$$

$$\pi_{itf}(GT,IT) = x_{ift}'\beta^{GT} + v_i^{GT} + \varepsilon_{itf}^{GT}$$

$$\pi_{itf}(CV,CT) = z_{ift}'\beta^{CT} + v_i^{CT} + \varepsilon_{itf}^{CT}$$

$$\pi_{itf}(GT,CT) = \pi_{itf}(GT,IT) + \pi_{itf}(CV,CT) + \gamma + \xi_{itf}$$

- x_{ift} and z_{ift} are vectors of factors that affect the per acre returns to GT soybeans and CT (e.g., farm size).
- $(v_i^{GT}, v_i^{CT}) \sim N(0, \Sigma)$
- $\varepsilon_{itf}^{GT}, \varepsilon_{itf}^{CT}$, and ξ_{itf} are mean zero, IID Gumbel

Theory of Complementarity

To test for whether GT Soybeans and CT are complements we rely on the theory of supermodularity, which states that the two practices complement if

$$\gamma \equiv [\pi\,(\mathrm{GT,CT}) - \pi(\mathrm{GT,IT})] - [\pi(\mathrm{CV,CT}) - \pi(\mathrm{CV,CT})] \geq 0.$$

That is, GT soybeans and CT are complements if the increase in returns from using CT with GT soybeans exceeds the increase in returns from using CT with CV soybeans.

Empirical Test for Complementarity

From the empirical framework

$$\gamma + \xi_{itf} = [\pi_{itf}(\mathrm{GT},CT) - \pi_{itf}(GT,IT)] - [\pi_{itf}(CV,CT) - \pi_{itf}(CV,IT)] - \pi_{itf}(CV,IT)]$$

- Since $E[\xi_{itf}] = 0,\ \gamma$ measures mean complementarity.
- If $\gamma > 0$, GT soybeans and CT are, on average, complements.

Data

- We employ farm-level seed and tillage data from the survey company GfK.
- In total, our sample contains 82,056 farm-field-year observations across 235 crop reporting districts in 31 states. In any given year, about 43% of sampled growers are re-sampled the next year.
- The seed and tillage data are supplemented with data on soil erodibility (source: NRI), drought severity (source: NCDC), fuel prices (source: USDA-NASS), and soybean futures prices (source: CBOT).

Table 1: System shares for U.S. Soybean Growers (percent of total observations).

System	1998-2001	2002-2006	2007-2011	1998-2011
(CV,IT)	20.73	6.34	2.26	10.18
(GT,IT)	21.53	30.41	29.38	27
(CV,CT)	20.3	6.63	3.01	10.35
(GT,CT)	37.44	56.61	65.34	52.47

Table 2: Simulated Maximum Likelihood Results. GT Soybean variable esitmates represent their impact on GT soybean adoption. CT variable estimates represent their impact on conservation tillage adoption.

Variables	Coefficient	Standard Error
GT Soybean Variables:		
Seed Price	-0.3271***	(0.01480)
Herbicide Price	-0.9733***	(0.14272)
Farm Size	0.1184***	(0.02992)
Trend	0.4427***	(0.00717)
CT Variables:		
Farm Size	0.2861***	(0.03090)
Fuel Price	0.0126***	(0.00100)
Palmer Drought Index	-0.0193***	(0.00447)
Erodibility Index	0.0787***	(0.00430)
Complementarity Estimate:		
γ	0.5106***	(0.02948)

Notes: ***Significant at 1%. **Significant at 5%.

Table 3: Conservation Tillage Predicted Adoption Rates. This table provides predicted share results from simulating adoption rates without GT soybeans included in the choice set.

	With GT	Without GT	
Period	Option	Option	Difference
1998-2000	56.8	52.65	4.15
2001-2003	59.96	53.97	5.99
2004-2007	64.91	58.31	6.60
2008-2011	67.75	60.94	6.82

Notes: values are in percent of total soybean acres.

Conclusions

- GT soybeans and Conservation Tillage are, on average, complementary practices (>0 and highly significant).
- Conservation Tillage adoption rates have been higher by as much 10% (7 percentage points) as a result of the availability GT soybeans.
- Larger farms are more likely to adopt both GT soybeans and CT.
- Drought-like conditions, greater erodibility, and higher fuel prices are associated with a greater likelihood of adopting CT.