Trending Towards Zero: Exploring Assumptions in Estimating Dynamic Crop Supply Elasticities

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November 13, 2018

1 Introduction

Crop rotation is a common practice in the United States Corn Belt. The most common rotation in this region is between growing corn and soybeans, occasionally with some other crops. This agricultural practice is based on the agronomic feature of farm fields that alternating crops in consecutive years could decrease the pest population and maintain the productivity of the soil. Therefore, when we estimate supply elasticities of crops like corn and soybeans, we need take these dynamic features into consideration. In the paper "Crop Supply Dynamics and the Illusion of Partial Adjustment", the authors point out that, using their preferred estimation approaches, the short-run corn acreage response is more sensitive to price shocks than the long-run (5 to 10 years) counterpart. Specifically, the short-run elasticity of soybeans and corn acreage to price shocks is 37% higher than that in the long-run. These results are contrary to previous theory which predicts that producers respond more in the long-run, as it is hard to adjust equipment and human capital in the short-run. The paper utilizes a county-field level data set which gives researchers more flexibility to estimate supply elasticities than previous county level aggregated data with panel data methods.

This paper will present some extensions to Hendricks, Smith, and Sumner's 2014 paper. In section 2, we analyze the effects of time trends in estimating supply elasticities. We specify models with linear trend (as in the paper), a quadratic term trend and with no time trend in first step regressions. We find that controlling for quadratic time trend did not change regression and elasticities estimates much. The same situation also appears in the results without except for the short-run corn own price elasticity is about 20% higher than its counterparts with time trends controlled. In section 3 we explore the assumptions of zero acreage elasticities for the fields that never choose monoculture. In general, we find that the estimated values for the never-monoculture fields supports this assumption, but the results raise questions of whether the data even allows for proper estimation for these fields. We discuss potential interpretations for these fields and extensions of the model that could allow for better estimation of these elasticities.

2 Time Trends

We follow the econometric model proposed in the 2014 AJAE paper. The first step is to set up a first-order Markov model with two states, we change the subscript to 0 represents soybeans and 1 for corn.

$$\Phi_i^{11}t = Pr(c_{it} = 1 | c_{i,t-1} = 1) = \lambda_{1i} + \beta_{1i}^c p_{it}^c + \beta_{1i}^s p_{it}^s + \theta_{1i}' \mathbf{x}_i + \kappa_{1i}\mathbf{t} \tag{1}$$

$$\Phi_i^{01}t = Pr(c_{it} = 1 | c_{i,t-1} = 0) = \lambda_{0i} + \beta_{0i}^c p_{it}^c + \beta_{0i}^s p_{it}^s + \theta_{0i}' \mathbf{x}_i + \kappa_{0i}\mathbf{t} \tag{2}$$

The control variables $\mathbf{x_i}$ contains filed characteristics such as an indicator of large spring rainfall, share clay, share slit, slop, and share of county irrigated. $\mathbf{t}$ now is a vector. It could contain only linear time trend, which in the 2014 AJAE paper setting is $t = year - 1999$. We expand it to quadratic term as $\mathbf{t} = (t, t^2)'$, as well as no time trend case in which $\mathbf{t} = 0$. The estimates are presented in table 1 below. The model will allow us to recover the probabilities of transition system as $\Phi_{it}^{10} = 1 - \Phi_{it}^{11}$ and $\Phi_{it}^{00} = 1 - \Phi_{it}^{01}$. The Panel A is the regression estimates corresponding to equation (2) and the Panel B is for equation (1). Compare to linear time trend regressions, the quadratic time trend model does not change much in estimating the effects of expected effective prices. Estimates of $\beta_1^c, \beta_0^c, \beta_1^s, \beta_0^s$ are almost the same. These price effects estimates are weighted average of $\beta_{1i}^c, \beta_{0i}^c, \beta_{1i}^s, \beta_{0i}^s$ across 24 regions, which will be used to construct supply elasticites in the next step. We did not include never-monoculture region when averaging estimates. These estimates are assumed to be 0. Adding quadratic time trend only changes the intercept with a significant amount which will not affect our results of elasticities estimations. Without controlling time trend, the estimates of β_0^c, β_1^c raise to 0.082 and 0.156 respectively while $\hat{\beta}_0^s = -0.015$ and $\hat{\beta}_1^s = -0.044$ are close to their counterparts with time trend controlled.

In table 2, we present our acreage elasticities estimates. The long-run and short-run price elasticities are calculated based on the equation (3) and (4) below. Notice that since we suppose never-monoculture fileds do not respond to prices, $\beta_{1i}^c, \beta_{0i}^c, \beta_{1i}^s, \beta_{0i}^s$ are all zero for these fields. Thus, the corresponding long-run probability of corn for these fields is $\Phi_{it}^1 = \frac{1}{2}$ according to equation (5). From equation (4), we can also know that the elasticity estimates will be smaller than it would have been if we only focus on monoculture fields.

$$\frac{\partial C_{LR}}{\partial p_{it}^c} = \sum_i a_i \frac{\partial \Pi_{it}^1}{\partial p_{it}^c} \tag{3}$$

$$\frac{\partial C_{SR}}{\partial p_{it}^c} = \sum_i a_i (c_{i,t-1}\beta_{1i}^c + (1 - c_{i,t-1})\beta_{2i}^c) \tag{4}$$

$$\Pi_{it}^1 = \frac{\Phi_{it}^{21}}{\Phi_{it}^{21} + (1 - \Phi_{it}^{11})} \tag{5}$$

Table 1: Regression Estimates Among Different Time Trends

	Specifications		
	Linear	Quadratic	No Trend
Panel A: Previously Soybeans (t=0)			
Intercept	0.669	0.697	0.651
Expected Corn Price	0.072	0.070	0.082
Expected Soy Price	−0.018	−0.019	−0.015
Share Clay	0.033	0.033	0.037
Share Slit	0.004	0.004	0.002
Slope	−0.008	−0.008	−0.008
Large Spring Rainfall	−0.043	−0.043	−0.054
Share Irrigated	0.310	0.320	0.375
Trend	0.005	−0.003	
Trend Squared		0.001	
Panel B: Previously Corn (t=1)			
Intercept	0.372	0.286	0.343
Expected Corn Price	0.119	0.119	0.156
Expected Soy Price	−0.043	−0.040	−0.044
Share Clay	−0.313	−0.314	−0.317
Share Slit	−0.045	−0.045	−0.045
Slope	−0.002	−0.002	−0.002
Large Spring Rainfall	−0.007	−0.0004	−0.010
Share Irrigated	0.251	0.276	0.256
Trend	0.013	0.041	
Trend Squared		−0.002	

As before, since the expected price estimates do not change much by adding quadratic time trend, our estimates for short-run and long-run elasticities are very close to the baseline model with linear time trend. For corn acreage own price elasticities, without time trend model yields much higher elasticities than the other two models. To be more specific, no time trend controlled short-run corn acreage own price elasticity is 20% higher than it's counterparts. The corn acreage cross price elasticities are similar across models. On the contrary, since estimates of β_{1i}^s and β_{0i}^s are close to time trend models, the own price elasticities for soybeans are comparable among three models. Due to the differences in β_{1i}^c and β_{0i}^c, the cross price elasticities of soybeans differ from time trend models in both long-run and short-run.

The results from table 1 and table 2 indicate that linear trend has already capture the time variation and adding quadratic time trend is not necessary. Without controlling time trends, the corn acreage own price elasticities are significant higher in both short-run and long-run while soybeans acreage own price elasticities remain similar as before. The heterogeneity of acreage price elasticity between corn and soybeans is interesting and deserves further investigation.

Table 2: Aggregated Acreage Elasticities Across Trend Specifications

	Specifications		
	Linear	Quadratic	No Trend
Panel A: Corn Acreage Elasticities			
Own-Price			
Short-run	0.395	0.392	0.503
Long-run	0.285	0.283	0.363
Cross-Price			
Short-run	−0.307	−0.295	−0.299
Long-run	−0.221	−0.213	−0.215
Panel B: Soybeans Acreage Elasticities			
Own-Price			
Short-run	0.360	0.346	0.351
Long-run	0.259	0.250	0.253
Cross-Price			
Short-run	−0.464	−0.460	−0.590
Long-run	−0.335	−0.332	−0.426
$\frac{\varepsilon_{LR}-\varepsilon_{SR}}{\varepsilon_{LR}}$	−0.387	−0.385	−0.385

3 Never-Monoculture Assuptions

3.1 Results

In the original paper Hendricks, Smith, and Sumner separate field observations into those which planted monoculture at least once and those which never planted monoculture, choosing always to rotate corn and soybeans throughout the observed time period. For the fields that never chose monoculture, it was assumed that the acreage elasticity was equal to zero, given that the fields appeared to never react to changes in the price of corn or soybeans. Additionally, it was assumed that they would continue in their rotational pattern, i.e. the probability of planting corn in the next year was equal to 1 if the field was planted to soybeans in the previous year and 0 if it was previously planted to corn.

We chose to investigate the validity of these assumptions, and the effect they have on the results presented in the paper. First, we estimated transition probabilities and acreage elasticities for fields which chose monoculture at least once using the same procedure as in Hendricks, Smith, and Sumner. Then, we applied this procedure to the fields which never chose monoculture. We present the estimated coefficients in Columns 3 through 6 of Table 3. In addition, we calculate the weighted average of the coefficients across the monoculture and never-monoculture fields, which are displayed in Columns 1 and 2. The coefficient estimates in Columns 3 and 4 are identical to those presented in Table 3 in Hendricks, Smith, and Sumner.

In examining the estimated coefficients for the never-monoculture fields, the first thing to note is that the assumptions made by Hendricks, Smith, and Sumner are not unwarranted. The displayed results in Table 3 are rounded, so it is worth pointing out that the estimated coefficients in Column 5 are exactly zero, while the estimated coefficients in column 6 are nonzero, but are essentially also zero.[1] Note also that the estimated intercept when corn was previously planted is zero, while the intercept when soybeans were previously planted is 1, thus supporting the assumption about the probability of planting corn in the next year.

We find similar support for these assumptions when examining the estimated acreage elasticities presented in Table 4. Column 1 presents the results from the paper using the assumed values for never-monoculture elasticities and transition probabilities. Column 2 then presents the combined results from estimating both monoculture fields and never-monoculture fields.

[1]When written in scientific notation, the estimates are multiplied by between e^{-15} and e^{-18}.

Table 3: Average Coefficients of Transition Probabilities

	Combined Results		Monoculture At Least Once		Never-Monoculture	
	Previously Corn (1)	Previously Soybeans (2)	Previously Corn (3)	Previously Soybeans (4)	Previously Corn (5)	Previously Soybeans (6)
Expected Corn Price	0.081	0.049	0.119	0.072	0	0
Expected Soybean Price	−0.029	−0.012	−0.043	−0.018	0	0
Large Spring Rainfall	−0.005	−0.029	−0.007	−0.043	0	0
Share Clay	−0.212	0.023	−0.313	0.033	0	0
Share Silt	−0.03	0.002	−0.045	0.004	0	0
Slope	−0.001	−0.005	−0.002	−0.008	0	0
Trend	0.009	0.003	0.013	0.005	0	0
Share Irrigated	0.17	0.21	0.251	0.31	0	0
Intercept	0.252	0.776	0.372	0.669	0	1

Note: Columns 1 and 2 present a weighted average estimate of the results in Columns 3 and 5 and Columns 4 and 6 respectively.

As should be expected given the coefficients presented in Table 3, the estimated acreage elasticities for never-monoculture fields are approximately zero.

Table 4: Aggregate Acreage Elasticities for Assumed Never-Monoculture versus Estimated Never-Monoculture

	Estimates with Assumption (From Paper) (1)	Combined Results (Monoculture and Never) (2)	Estimates for Monoculture (3)	Estimates for Never-Monoculture (4)
Panel A: Corn Acreage Elasticities				
Own-Price				
Short-run	0.395	0.395	0.583	0
Long-run	0.285	0.285	0.421	0
Cross-Price				
Short-run	−0.307	−0.307	−0.452	0
Long-run	−0.221	−0.221	−0.326	0
Panel B: Soybeans Acreage Elasticities				
Own-Price				
Short-run	0.36	0.36	0.531	0
Long-run	0.259	0.259	0.383	0
Cross-Price				
Short-run	−0.464	−0.464	−0.685	0
Long-run	−0.335	−0.335	−0.494	0
$\frac{\varepsilon_{LR}-\varepsilon_{SR}}{\varepsilon_{LR}}$	−0.387	−0.387	−0.387	−1

Note: Column 1 is estimated as in the paper, with assumed zero values for the never-monoculture elasticities. Column 2 uses the estimated never-monoculture elasticities presented in Column 4 to produce a combined estimate.

3.2 Remaining Questions

While these results clearly support the assumptions made by Hendricks, Smith, and Sumner, they do raise questions about how the results are presented in the paper. In Hendricks, Smith, and Sumner Table 2 presents the results that are

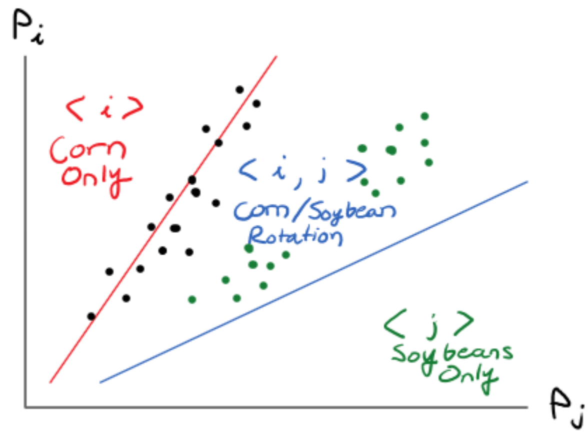

Figure 1: Rotation vs. Monoculture Regions

Note: Black points represent monoculture fields, green points represent never-monoculture fields.

displayed here in Table 4, Column 1, which combines estimates across the monoculture and never-monoculture fields. In contrast, Table 3 in Hendricks, Smith, and Sumner displays the same results as in Columns 3 and 4 of Table 3 here, the estimated coefficients from only the monoculture fields. One would think that in order to compare the results effectively, Table 3 in Hendricks, Smith, and Sumner should display the combined results presented here in Table 3, Columns 1 and 2, which also average across all fields in the sample.

This averaging process additionally raises questions about how to interpret these results. Consider the own-price, short-run corn acreage elasticity. Hendricks, Smith, and Sumner report this as 0.395, averaged across the nonzero elasticities for monoculture fields and the zero elasticities for the never-monoculture fields. In Table 4, Column 3 we see that this same elasticity for the monoculture fields only is 0.583. Is it realistic to assume that the never-monoculture fields are different enough to allow for assumed acreage elasticities of zero, but not different enough to average with the mononculture fields? In other words, is it possible that farmers who choose to rotate every year and farmers that choose monoculture from time to time are different enough to justify reporting different elasticities? It is unclear why these farmers differ in their decision making process, but examining these results separately does seem to indicate that averaging across these farmer types may not be appropriate.

Another concern is that the data itself may not allow for accurate estimation of never-monoculture elasticities. Using the same procedure as with the monoculture fields requires estimating separate elasticities for when corn was planted previously and when soybeans were planted previously. Since the never-monoculture fields will always plant the opposite in the next year, this means that there is no variation in the dependent variable in these regressions. This means that the estimating procedure essentially builds in the assumption of zero acreage elasticities for these fields by construction. Consider the figure described by Hennessy (2006). The monoculture fields are those observations that straddle the boundary between the corn/soybean rotation and corn only, while the never-monoculture observations all lie between the red and blue lines in Figure 1. While these points are never observed outside of the corn/soybean rotation region, this does not imply that they do not move in response to changes in the price. Indeed, this merely suggests that price movements must be more substantial in order for movement outside of this region to occur. This estimation problem exists primarily due to the lack of a relevant counterfactual for these fields.

3.3 Potential Extensions

Given the issues associated with estimating acreage elasticities for the never-monoculture fields, there are several ways in which this research could be further explored. First, it could be possible to estimate or search for a counterfactual for the never-monoculture fields. Second, the decisions by the never-monoculture farmers could be approached as a censoring problem, with censoring at zero.

These two approaches speak to two possible explanations for the acreage elasticities of the never-monoculture farmers. In one case, it could be that the farmers need an even larger change in price in order to be convinced to switch to monoculture, suggesting a very inelastic, but nonzero, elasticity. This could be explored by attempting to use the models estimated for the monoculture fields to predict transition probabilities for the never-monoculture fields with larger price changes.

On the other hand, if the elasticities are censored at zero, then it is possible that these farmers actually choose to move in the opposite direction of most, moving further into the corn/soybean rotation region while other farmers move to monoculture. While this may sound unlikely, it could be worth exploring with different techniques.

4 Conclusion

In this paper, we have tried to extend the 2014 AJAE paper in two directions, namely different time trends and zero responds from never-monoculture fields. In section 2, we scrutinize the effects of adding quadratic time trend as well as disregarding the time trend. The results suggest that linear trend control has already capture most of the time variation and adding a quadratic time trend is unnecessary. We also find support for the assumptions made by Hendricks, Smith, and Sumner with respect to the fields which always choose to rotate. However, this has raised questions of whether this estimation method is even appropriate for use with these fields. We suggest that the fields that choose monoculture and the fields that always choose rotation be considered separately. We also suggest that further exploration may be necessary to properly explore the decision making process for the never-monoculture fields.