**Have Biotech Seeds Increased Maize Yields?**

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# Have Biotech Seeds Increased Maize Yields?

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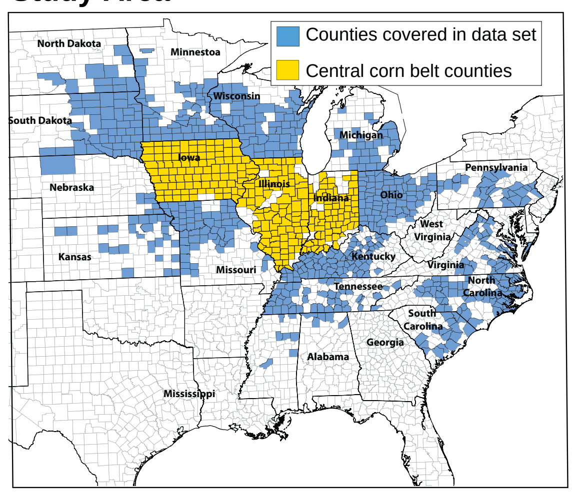
## Introduction:

Global demand for maize has grown due to market conditions and government policies. Concerns have been raised about whether the crop can meet demands for both food and fuel. In addition, there are also worries about environmental problems arising from more and more intensively managed maize acres because the crop requires high input use levels. So whether a production innovation can increase yields is crucial in determining long-run capacity to meet demands. If it does, more of the crop will be available to meet all demands and less stress need be placed on the environment. The introduction of commercial hybrid varieties dramatically improved yields during the middle twentieth century. However, whether the advent of genetic modification techniques has enhanced yields is not clear.

The matter is not straightforward. First, the introduced genetic traits have largely been targeted at pests where pesticides were already in widespread use. Thus, the new "technology package" might have offered incentives for farmers' adoption regardless of a possible yield effect. Second, any assessment of the effects of a technology on yields needs to control for random weather effects. Finally, the data show that fertilization rates have trended up in maize production over the past half century, so that this effect also needs to be controlled for.

Compared with other work that has sought to decompose maize yield trends in the United States, our study of yield trends relies on a more extensive county-level database (refer to map 1), uses more specific and detailed weather data, allows for weather non-linearities and changes in nitrogen use, and also explicitly includes the effect of farmers' adoption of GM varieties. We also address the question of whether GM yield effects differ between Central-Corn-Belt (CCB) and Non-CCB regions.

### Study Area




## Model:

The basic model estimated with our panel dataset was a fixed effect model of the form

$$y_{i,t} = \alpha_i + \beta_G G_{i,t} + \beta_E E_{i,t} + \beta_t t + \sum_{m \in \text{Jn,Jy,Au}} (\beta_{Z,m} Z_{i,m,t} + \beta_{ZZ,m} Z^2_{i,m,t}) + \beta_N N_{i,t} + \beta_A A_{i,t} + \beta_{A,t} A_{i,t}(t-32) + \varepsilon_{i,t} \quad (1)$$

Where $y_{i,t}$ is the observed average yield in county $i$ in year $t$ (in bushels per acre), $\alpha_i$ captures county-level fixed effects, and $\varepsilon_{i,t}$ is a random term. Variables have been explained in Table 1. Coefficient $\beta_{A,t}$ is intended to identify an adoption-proportional change in trend after 1996. In addition we allow for region effects, where seed companies may have stronger incentives to invest in seed for corn-dominant regions. Let $R_i = 1$ if the county is in what we refer to as the Central Corn Belt (CCB) states (Iowa, Illinois, Indiana), and let $R_i = 0$ otherwise. Please refer to Map 1. The regional model is

$$y_{i,t} = \alpha_i + \beta_G G_{i,t} + \beta_E E_{i,t} + \beta_t t + \sum_{m \in \text{Jn,Jy,Au}} \left(\beta_{Z,m} Z_{i,m,t} + \beta_{ZZ,m} Z^2_{i,m,t}\right) + \beta_N N_{i,t} + \beta_A A_{i,t} + \beta_{R,t} R_i t + \beta_{A,R} A_{i,t} R_i + \beta_{A,t} A_{i,t}(t-32) + \beta_{A,R,t} A_{i,t} R_i (t-32) + \varepsilon_{i,t}. \quad (2)$$

### Table 1: Explanation of Variables Used

| Variable | Explanation |
|---|---|
| $y_{i,t}$ | Corn yield (in bushels per acre) for the $i$th county at time $t$. |
| $G_{i,t}$ | Season growing degree days for the $i$th county at time $t$. It is used to capture the beneficial effect of normal heat on corn yield. |
| $E_{i,t}$ | Season excess heat degree days for the $i$th county at time $t$. It is used to capture the damaging effect of overheat on corn yield. |
| $Z_{i,m,t}$ | Palmer index for the $i$th county, in month $m$ and year $t$. Palmer index is a measure of moisture stress, where low (drought) and high (waterlog) $Z$ values are bad for crop yields. Here $m = \text{Jn}$ , $m = \text{Jy}$ and $m = \text{Au}$ are for June, July and August. |
| $N_{i,t}$ | The number of units of commercial nitrogen used per acre for the $i$th county in year $t$. |
| $A_{i,t}$ | Share of acres that have adopted GM varieties for $i$th county in year $t$. Values $A_{i,t} = 0$ and $A_{i,t} = 1$ refer to no adoption and full adoption, respectively. |
| $t$ | Time trend. Time index $t$ is initialized at $t = 0$ so that $t = 32$ in 1996, the year that genetically modified corn seed is assumed to have become available. |
| $R_i$ | CCB region dummy. $R_i = 1$ if the county is in a Central Corn Belt (CCB) state (Iowa, Illinois, Indiana), and $R_i = 0$ otherwise. |

### Table 2: List of Models Used In the Analysis

| Model | Characteristics | Explanation |
|---|---|---|
| M1 | Baseline | No GMO yield effect; or $\beta_A = \beta_{A,t} = 0$ in (1) |
| M2 | Adoption shift | GMO yield effect is characterized as a shift; or $\beta_{A,t} = 0$ in (1) |
| M3 | Adoption trend | GMO yield effect is characterized as a trend; or $\beta_A = 0$ in (1) |
| M4 | Region + M1 | Extend M1 by adding CCB regional dummy |
| M5 | Region + M2 | Extend M2 by adding CCB regional dummy |
| M6 | Region + M3 | Extend M3 by adding CCB regional dummy |

### Table 3: Results based on M2 and M5

| Variable | M2 (Adoption shift) | M5 (Region + M2) |
|---|---|---|
| $t$ | 1.247 | 1.215 |
| $R_i t$ | | 0.037 |
| $G_{i,t}$ | 0.0045 | 0.0048 |
| $E_{i,t}$ | -0.168 | -0.167 |
| $Z_{i,Jn,t}$ | 0.118 | 0.152 |
| $Z^2_{i,Jn,t}$ | -0.257 | -0.265 |
| $Z_{i,Jy,t}$ | 3.709 | 3.667 |
| $Z^2_{i,Jy,t}$ | -0.579 | -0.573 |
| $Z_{i,Au,t}$ | 1.431 | 1.431 |
| $Z^2_{i,Au,t}$ | -0.243 | -0.245 |
| $N_{i,t}$ | 0.126 | 0.138 |
| $A_{i,t}$ | 17.33 | 12.69 |
| $A_{i,t} R_i$ | | 18.57 |
| Adjusted $R^2$ | 0.8104 | 0.8134 |

*Note:* All coefficients are statistically significant at the 1% level.

## Results and Findings:

By different assumptions of GMO effects, we used six models for analysis. The different assumptions of six models are listed in the Table 2.

All coefficients on all models are of the hypothesized signs. We select the best model among basic models M1-M3, and also the best model among regional models M4-M6. According to all standard selection criteria, the best models are M2 and M5 and are reported in Table 3.

## Conclusion:

The marginal effects of growing degree days, excess heat degree days, moisture stress and nitrogen use are statistically significant and consistent with intuition. M2 and M5 give similar estimated marginal effects. In addition, the estimated time trend was 1.22 bu./ac. inside CCB and 1.25 bu./ac. outside the CCB. For the GM effect, complete adoption was estimated to increase yield by 31.3 bu./ac. inside the CCB and by 12.7 bu./ac. outside the CCB.