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Supplementary Materials for

Genetically engineered crops and pesticide use in U.S. maize and soybeans

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This PDF file includes:

- table S15. Summary statistics by adoption choice.
- References (*35–45*)

SUPPLEMENTARY TEXT

The AgroTrak® data

The data used in this study comes from AgroTrak®, a large, farm-level commercial dataset assembled by GfK Kynetec. Iowa State University acquired limited access to these proprietary data via a marketing research agreement with GfK Kynetec. Each year GfK Kynetec conducts surveys throughout the United States of randomly sampled farmers about decisions pertaining to seed and pesticide choices. The samples constructed for AgroTrak® are representative at the crop reporting district (CRD) level. Each CRD is a multi-county area identified by the National Agricultural Statistics Service of the USDA (fig. S2). Table S1 and fig. S1 contain some summary statistics of the structure of the AgroTrak® data used in this study. An important feature of the GfK dataset is that it contains repeated observations across time for a subset of the growers. Of the 38,693 farmers in the sample, over 50% were sampled 2 or more years, and more than 30% were sampled for at least 3 years.

Agrotrak® is widely considered the most comprehensive source for pesticide use data and has been used in several other studies, including Gangwal et al. (*31*), Thelin and Stone (*32*), and Mitchell (*33*). Concerning farmers' use of GE varieties, also documented in Agrotrak®, we note that estimates of GE crop variety adoption have been independently reported by the USDA (based on National Agricultural Statistics Service surveys) since 2000 (*6, 7*). This provides the opportunity for an additional external validation of some of the proprietary data used in this study. To do so, we compared state-level GE crop adoption rates reported by the USDA to state-level GE crop adoption rates computed from AgroTrak®. In the manuscript we use adoption rates for varieties that contain the GE trait(s) of interest (e.g., varieties that contain the GT trait). Some of those varieties may incidentally contain other GE traits as well, e.g., Bt traits. The USDA does not report adoption rates for maize varieties that have GE herbicide tolerance, whether alone or stacked with another GE trait (e.g., Bt). Rather, they report the adoption rate for maize varieties with GE herbicide-tolerance *only*. They also report the adoption rates for all GE varieties. As a result, we compute what we believe to be the comparable adoption rates from the GfK data. Table S14 reports the correlation between these two types of adoption rates at the state level for US maize and soybeans. Overall, they are highly correlated.

Literature Review: GE Variety Adoption and Pesticide Use

Given the breadth of the literature on GE crops and pesticide use, this section only focuses on those studies most relevant to our analysis. Somewhat more comprehensive literature reviews can be found in Carpenter (*11*), Klümper and Qaim (*12*), and Qaim (*35)*. We consider the prior literature from three different perspectives: (i) their findings, (ii) the data used, and (iii) the methods they employ. The literature relevant to our analysis for maize insecticides is discussed first.

Because Bt crops do not relate to any one particular insecticide, conclusions about their environmental impact are fairly straightforward: if they reduce insecticide use the environment is the better for it (and vice versa). Overall, most studies have found that Bt crop adopters use less insecticide than non-adopters (*11-13, 17, 35, 36*). Drawing on large number of studies Klümper and Qaim (*12*) find that these savings are on average 37%. A less studied issue has been the potential benefits reaped by non-Bt growers from Bt adopters. Results in Hutchison et al. (*25*) reveal that non-Bt growers benefited from Bt adopters through the associated suppression of the European Corn Borer population. Whether this has led to a reduction in insecticide use, however, has not been studied. A basic statistical trend in favor of this effect is that non-Bt maize adopters significantly reduced insecticide use as the adoption of Bt maize rose (*7*).

The complementary relation between GT crop varieties and glyphosate use implies a more complex characterization with respect to environmental impact. At the initial stages of the commercialization of GT crops the basic question could be reduced to whether the increase in glyphosate use exceeded the decrease in a number of more narrow-spectrum herbicides, and whether that net change was better or worse for the environment. Some early studies found that adopters of GT soybeans and/or GT maize used less herbicide than non-GT adopters (see Table 4 in Fernandez-Cornejo et al. (*7*)). In more recent years, however, that trend seems to have reversed with GT growers typically using more herbicide in terms of weight (*37*). By most environmental measures, however, that greater amount of herbicide – in particular glyphosate – was an improvement over the lesser amount used by non-adopters (*16, 18, 38*). Whether this has remained true more recently (beyond 2006) has been less studied. Moreover, the question has been complicated by the emergence of glyphosate weed resistance, which has brought back the use of some previously abandoned, narrow-spectrum herbicides (*37*). More recently, Benbrook (39) finds that GT soybeans are sprayed with significantly more herbicide than non-GT soybeans; however, certain limitations of these findings have been noted by Brookes, Carpenter, and McHughen (*40*). In brief, Benbrook (39) relies on USDA data that does not disaggregate pesticide use by GE trait, and thus his findings critically depend on somewhat arbitrary assumptions about how that use is broken down.

The most widely cited source on this issue has been a series of studies conducted by Brookes and Barfoot, the most recent of which is Brookes and Barfoot (*13*). These studies are of particular interest to our analysis because they use some of the same data that we employ. In general, they report significant reductions in herbicide use from GE crops, even during some of the more recent periods in which glyphosate weed resistance has reportedly intensified. We note two important limitations of their analysis. First, they do not control for unobserved heterogeneity across farmers: in general, they compare unconditional annual average herbicide usage rates between GE and non-GE adopters. Second, the procedure they use to compute those average rates relies in part on strong assumptions about counterfactual pesticide use. For years during which non-GE adopters comprised less than 50% of the population, rather than use observed herbicide usage rates by non-GE adopters for the counterfactual they use the rates implied by various recommended conventional herbicide programs that would achieve a level of weed control similar to that in GT crops (this method is also used, e.g., in Kleter et al. (*14*) and Johnson, Strom, and Grillo (*15*)). As we note in the paper, the usage rates implied by these programs significantly exceed average herbicide rates observed prior to the GE era (based on USDA data). The discrepancy between the recommended rates and the historically observed rates is likely due to the fact that the profit maximizing amount of herbicides for a non-GT user is less than the amount that would achieve the same level of weed control for a GT crop. In general, the appropriate counterfactual should be one in which the adoption of GT crops does not exert any indirect or direct influence on the choice (otherwise it would be part of the effect).

With regard to data, most survey-based studies use samples that are restricted to one or two years prior to 2006 (*16–18, 37, 39, 41*). Exceptions are Benbrook (*39*) and Brookes and Barfoot (*13*), but both of these studies conduct analyses that are not at the farm level. As a result, there has not yet been a farm-level, survey-based study that extends from the beginning of the GE crop era into the early stages of glyphosate weed resistance (Kathage and Qaim (*3*) conduct a multi-year farm-level analysis of Bt crops in India, but pesticide use is not one of the variables they consider).

The EIQ is one among several methods to aggregate and/or measure the environmental impact of pesticides. Various studies have employed alternative procedures or measures (*16*, *18*, *41*-*44*). Two of these aggregation procedures, however, do not explicitly capture external environmental impacts (*41*, *43*), and were thus not considered in this study. Among the remaining studies, Nelson and Bullock (*42*) use the LD50 dose for rates, Wossink and Denaux (*18*) use leaching potential, and Qaim and Traxler (*16*) break herbicides down by toxicity class. Each of these measures is to some extent captured in the various components that make-up the EIQ (e.g., leaching potential and dermal toxicity are in the consumer and farmworker components), and depending on the analysis, one may be more desirable to use than another. Below we show and discuss how some of these finer measures are impacted by GE crops.

Details for the Results Reported in the Main Text

Table S2 contain the full set of estimates for Table 1, table S3 contains the full set of estimates for Figs. 2 and 3, and table S11 contains the full set of estimates for Fig. 4, A and B.

Supplementary Results

Individual (Farmer) Random Effects

Table S4 contains results for the same specification as in table S2 (which provides details for the results of Fig. 2), but with the farmer-specific fixed effects replaced by random effects. With individual fixed effects, growers who are sampled only once and with only one plot (this accounts for 13.5% of the observations for soybeans and 6.9% of the observations for maize) do not contribute to estimating the β_t coefficients. With the random effects model, all observations contribute to estimating the β_t coefficients. The limitation of random effects is that if they are correlated with the observables then the estimated coefficients are not consistent. A comparison of table S4 with table S2 indicates that the estimated β_t coefficients are hardly affected by the choice of how one models individual heterogeneity. However, the Hausman test, which compares the difference in coefficient estimates for all variables (also reported in table S4), rejects the random effects model in favor the fixed effects model.

Herbicide Prices

The results provided in table S11 indicate that both GT and non-GT adopters increased their use of glyphosate over time. These trends can in part be explained by changes in herbicide and crop output prices over time (fig. S4). In 2000, Monsanto’s patent on glyphosate expired and as a result glyphosate prices fell relative to non-glyphosate prices from 2001 onward. In addition, the commodity boom that began in the mid-2000s led to rising maize and soybean prices, which in turn encouraged the use of yield-enhancing inputs like glyphosate.

No Tillage

An additional important variable that could potentially confound our estimate for the impact of GM crops on pesticide use, is the adoption of no tillage (NT). Previous work has shown that NT and GE crops are complementary practices (*45*). NT may also use more herbicide relative to a conventional tillage operation. Thus, the greater use of herbicides observed for GE adopters may in part be attributable to the fact that they are more likely to adopt no tillage (from 1998-2009, no-till adoption increased from about 32% to 53% of land). Table S5 reports the results for soybean and maize herbicides when a binary variable for no tillage is included. We find that, although no tillage significantly increased herbicide use – by about 0.16 kg/ha in both maize and soybeans – it does not significantly alter the coefficients for the GE trait binary variable G_i.

Weed Pressure and Plot Heterogeneity

A possible alternative explanation for the estimated pattern reported in Fig. 2 is that the quantity of herbicides applied on a given plot is affected by weed pressure, and the latter may be related to the farmer’s decision to adopt a GE variety. Insofar as weed pressure on plots belonging to the same farmer is highly correlated (e.g., it is a time-invariant attribute of the given farmer’s location), the inclusion of a farmer-specific fixed effect in the estimating model provides a measure of control. However, insofar as there is additional unobserved plot-specific heterogeneity, the estimated coefficients on the GE variable G_i may reflect the impact of an implicit plot selection process.

To explore this possibility, we first investigate the sensitivity of our results to the inclusion of a set of control variables that capture the types weeds targeted by growers on each plot. Table S15 reports descriptive statistics for some major targeted weeds, separately for soybeans and maize, and for GT adopters and non-GT adopters. For the most part, there are no major differences in the frequency of weeds targeted between GT-adopters and non-GT adopters. To systematically explore the effects of weed pressure in the fixed effects regression model we add a set of indicator variables, where each variable takes the value one if the corresponding weed is targeted on that plot (and value zero otherwise). The results of this extended model are reported in table S6. It turns out that the farmer's reporting of targeting each one of these major weeds does increase the amount of herbicides applied to that plot, for both crops and for all weeds. The estimated β_t that capture the differential impact of GE variety adoption, however, are robust to the inclusion of these weed pressure control variables.

Another way to investigate the impact of plot-specific heterogeneity is to estimate the fixed effects model on the subset of growers that plant either exclusively GT or exclusively non-GT varieties (i.e., exclude all growers that plant both GT and non-GT varieties within a given year). This procedure effectively eliminates potentially confounding plot specific factors. The results of this estimation are presented in tables S7 and S8. Qualitatively, the results are largely unchanged, but there is a small change in magnitude to the estimates. For herbicides, the GT coefficient(s) are slightly smaller in both cases (they becomes less positive for soybeans and more negative for maize).

We can also test for the presence of an implicit plot selection process by using a simple model to generate predictions about the dynamics of herbicide use and compare those predictions to what we observe in the data. The following analysis illustrates.

Suppose that there is a continuum of plots, each of which is indexed by the degree of weediness $w \in [\underline{w}, \overline{w}]$, where w is distributed according to a continuous distribution function $F(w)$. Higher values of w represent higher weed pressure. Suppose that this factor was the only element in determining the sequence of GT variety adoption, and let $z \in [0,1]$ denote the GT adoption rate.

Then, for a given adoption rate $\hat{z} \in [0,1]$ there is a weediness threshold $\hat{w} \in [\underline{w}, \overline{w}]$ such that all plots with $w \geq \hat{w}$ adopt GT varieties, and plots with $w < \hat{w}$ adopt conventional varieties. The threshold $\hat{w}$ is determined by $F(\hat{w}) = 1 - \hat{z}$. Next, suppose that a plot's herbicide application rate is increasing in its weediness and also depends on the type of crop grown (GT or conventional), and represent these rates by $a_G(w)$ and $a_T(w)$ for GT and conventional (traditional) varieties, respectively.

In this setting we are interested in computing the expected (average) herbicide rate for conventional and GT varieties for any given adoption rate $\hat{z}$. Let $y_G(\hat{z})$ and $y_T(\hat{z})$ denote these average application rates. Then

$$y_G(\hat{z}) = \frac{1}{F(\overline{w}) - F(\hat{w})} \int_{\hat{w}}^{\overline{w}} a_G(w) dF(w)$$

$$y_T(\hat{z}) = \frac{1}{F(\hat{w}) - F(\underline{w})} \int_{\underline{w}}^{\hat{w}} a_T(w) dF(w)$$

The coefficients β_t from the fixed effect regression model in the main paper essentially estimate the difference $\Delta(\hat{z}) \equiv y_G(\hat{z}) - y_T(\hat{z})$ in each year as the term $\beta_t G_i$. How the foregoing conjectured adoption driver impacts these estimates cannot be established without further assumptions on the shape of the functions $a_G(w)$ and $a_T(w)$, and of the distribution function $F(w)$. To illustrate, suppose that $F(w)$ is a uniform distribution, such that $\hat{w} = \underline{w} + 1 - \hat{z}$, and that the application rates are linear in the index of weediness, that is

$$a_G(w) = \mu_G + \theta_G w$$

$$a_T(w) = \mu_T + \theta_T w$$

Then

$$y_G(\hat{z}) = \int_{\hat{w}}^{\overline{w}} \left(\mu_G + \theta_G w \right) \frac{1}{(\overline{w} - \hat{w})} dw$$

$$y_T(\hat{z}) = \int_{\underline{w}}^{\hat{w}} \left(\mu_T + \theta_T w \right) \frac{1}{(\hat{w} - \underline{w})} dw$$

Performing the integration

$$y_G(\hat{z}) = \mu_G + \frac{1}{2}\theta_G(\hat{w} + \overline{w})$$

$$y_T(\hat{z}) = \mu_T + \frac{1}{2}\theta_T(\underline{w} + \hat{w})$$

and

$$\Delta(\hat{z}) = \left(\mu_G - \mu_T \right) + \frac{1}{2}\left(\theta_G\overline{w} - \theta_T\underline{w} \right) + \frac{1}{2}\left(\theta_G - \theta_T \right)\hat{w}$$

Several cases are possible, depending on the relative magnitudes of the intercepts μ_j and the slopes θ_j , $j \in \{G,T\}$.

Testable Implication: Regardless of the relative magnitudes of parameters μ_j and θ_j, it is clear that, once the adoption rate $\hat{z}$ stops increasing, such that $\hat{w}$ is constant, then the difference in herbicide quantity used on GT and conventional plots, $\Delta(\hat{z})$, should converge to a constant. This suggests a testable implication for the estimated fixed effects regression model. For soybeans, in particular, the adoption rate $\hat{z}$ has stabilized in the last part of the sample (for the last six years, 2006-2011, this rate has hovered between 94% and 97%). Hence, if the process being investigated was the primary explanation for the estimated pattern reported in Fig. 2, we should expect the estimated parameters β_t to be constant over these years. This null hypothesis $H_0 : \beta_t = \beta$ for all $t \in [2006, 2011]$, however, is rejected by the appropriate F statistics (F-statistic of 4.90, *p*-value = 0.0002).

Additional implication – Special case 1: $\mu_G = \mu_T$ and $\theta_G = \theta_T \equiv \theta$. In this case, the average herbicide application rate on GT variety plots is greater than that on conventional variety plots, i.e., $\Delta(\hat{z}) = \frac{1}{2}\theta\left(\overline{w} - \underline{w} \right) > 0$, which would explain the paper's finding for soybeans reported in Table 1. In this case, however, the difference does not change as the adoption rate changes, which is contrary to the paper's finding that $\Delta(\hat{z})$ increases with time (which is strongly positively correlated with the adoption rate) for both soybeans and maize, as reported in Fig. 2.

Additional Implication – Special case 2: $\mu_G = \mu_T = 0$ and $\theta_G \geq \theta_T$. In this case, again, the average herbicide application rate on GT variety plots is greater than that on conventional variety plots, which would explain the paper's finding for soybeans reported in Table 1. In this case, however, the difference $\Delta(\hat{z}) = \frac{1}{2}\left(\theta_G \overline{w} - \theta_T \underline{w}\right) + \frac{1}{2}\left(\theta_G - \theta_T\right)\hat{w}$ is increasing in the weediness threshold level $\hat{w}$, and therefore decreasing in the adoption rate $\hat{z}$. Hence, over time, as adoption $\hat{z}$ increases we should expect that the difference in average herbicide rates decreases, which again is contrary to the pattern uncovered for both soybeans and maize, as reported in Fig. 2.

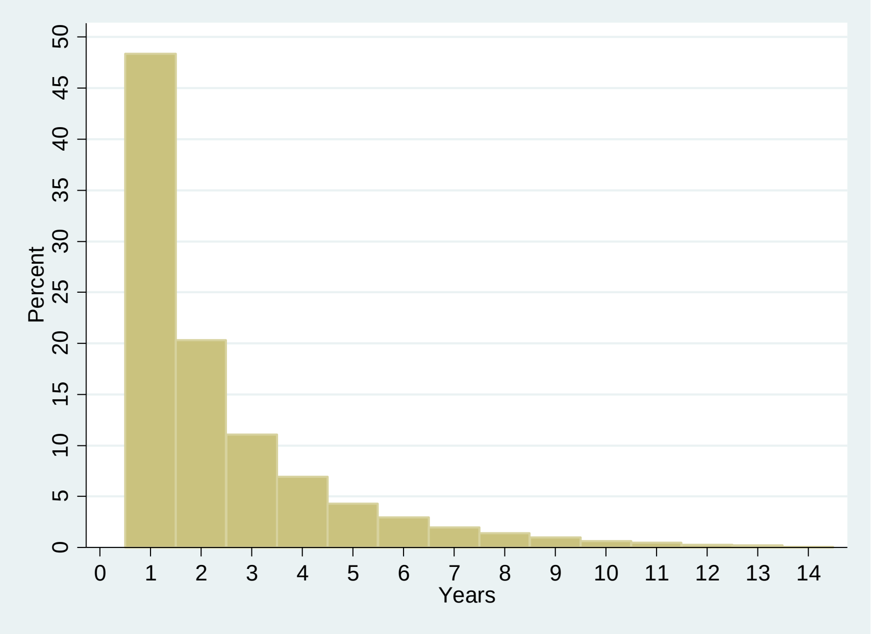

fig. S1. Number of years sampled for growers in AgroTrak data set.

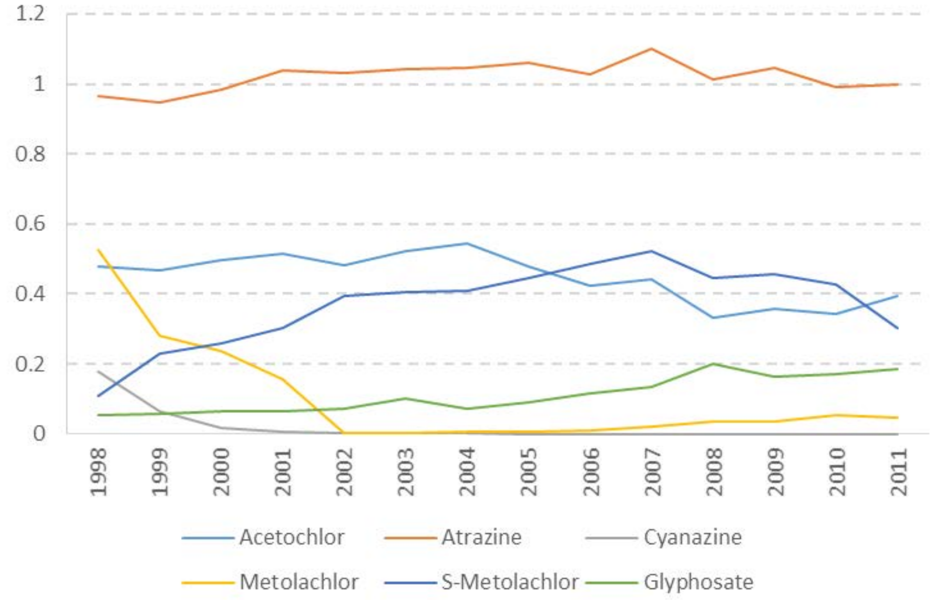

fig. S2. Maize herbicide use by non-GT adopters (selected herbicides, kg/ha).

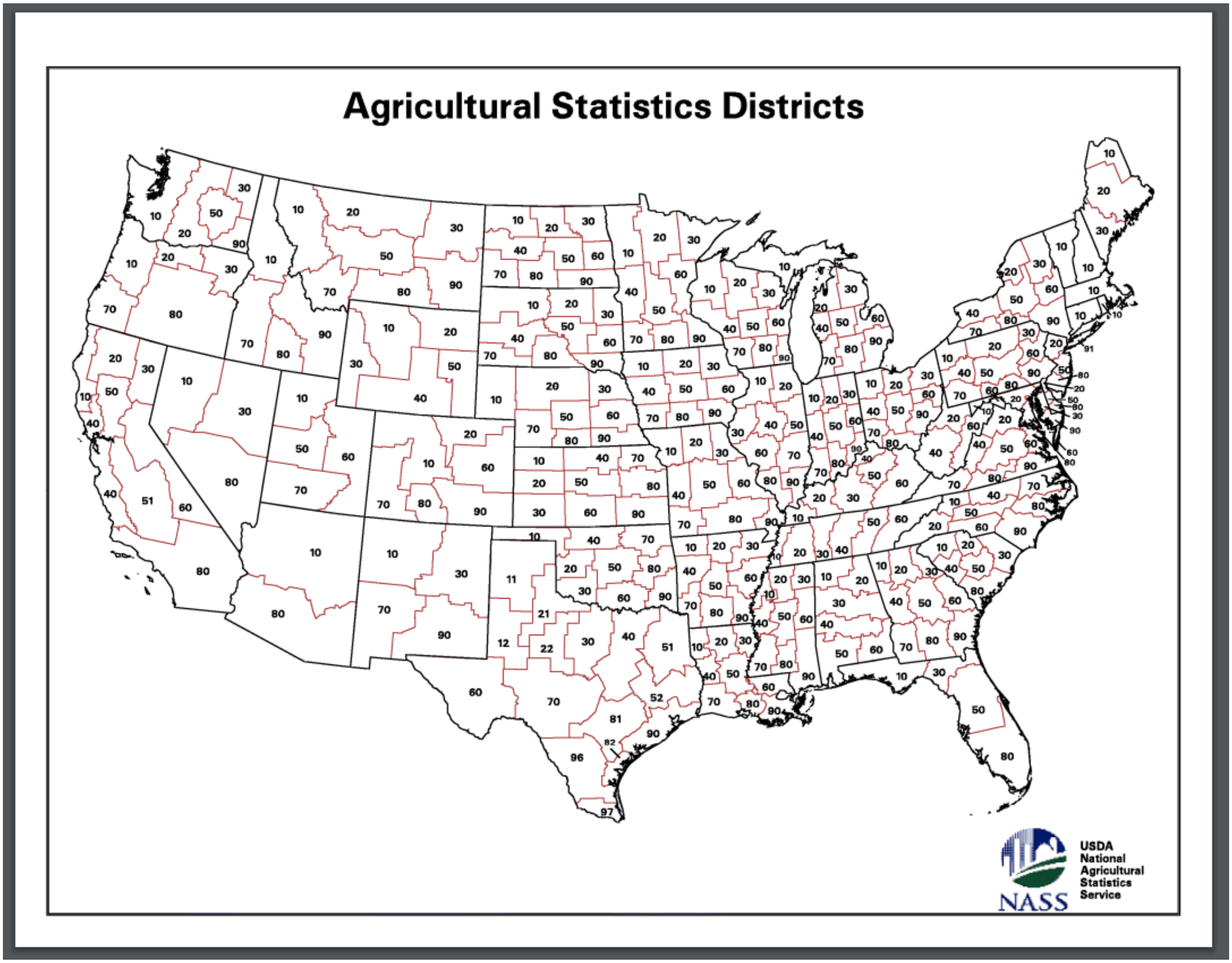

fig. S3. Crop reporting districts, National Agricultural Statistics Service, U.S. Department of Agriculture.

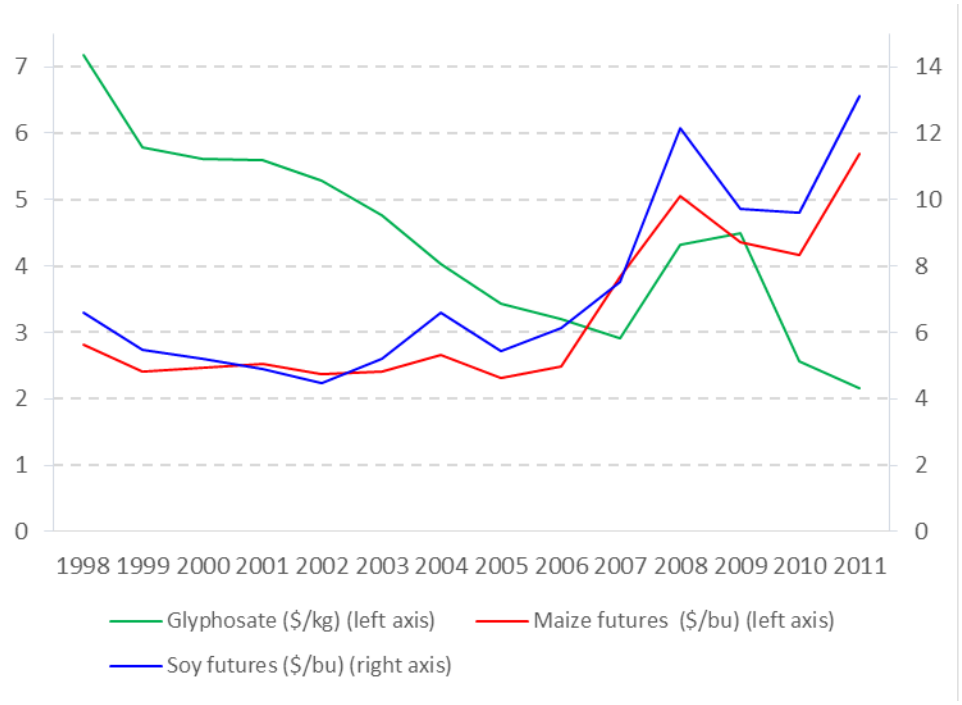

fig. S4. Trends in glyphosate and expected crop output prices, 1998–2011.

table S1. Summary statistics for AgroTrak data set.

	Annual Averages	
	Maize	Soybeans
Number of growers	5,424	5,029
Number of plots per farmer	1.77	1.23
Number of CRDs	248	197
Number of states	41	29
Number of herbicide a.i.	48	42
Number of insecticide a.i.	27	-

table S2. Full results corresponding to Table 1.

	Soybean Herbicides		Maize Herbicides		Maize Insecticides	
	a.i. kg/ha	EIQ kg/ha	a.i. kg/ha	EIQ kg/ha	a.i. kg/ha	EIQ kg/ha
G_t	0.3021***	0.0045	-0.0329*	-0.2590***	-0.0129***	-0.0122***
	(0.0097)	(0.0122)	(0.0150)	(0.0156)	(0.0014)	(0.0014)
1999	-0.1314***	-0.1569***	-0.2692***	-0.2731***	-0.0265***	-0.0368***
	(0.0161)	(0.0197)	(0.0302)	(0.0314)	(0.0064)	(0.0075)
2000	-0.0946***	-0.1156***	-0.3318***	-0.3458***	-0.0267**	-0.0417***
	(0.0171)	(0.0212)	(0.0327)	(0.0335)	(0.0082)	(0.0090)
2001	-0.1029***	-0.1423***	-0.3925***	-0.3924***	-0.0485***	-0.0652***
	(0.0175)	(0.0213)	(0.0329)	(0.0339)	(0.0074)	(0.0086)
2002	-0.1419***	-0.2218***	-0.4725***	-0.4817***	-0.0486***	-0.0674***
	(0.0178)	(0.0212)	(0.0343)	(0.0352)	(0.0092)	(0.0098)
2003	-0.0819***	-0.1791***	-0.4910***	-0.5078***	-0.0575***	-0.0731***
	(0.0188)	(0.0218)	(0.0355)	(0.0366)	(0.0084)	(0.0097)
2004	-0.0780***	-0.1868***	-0.5340***	-0.5382***	-0.0796***	-0.1024***
	(0.0185)	(0.0218)	(0.0362)	(0.0372)	(0.0083)	(0.0096)
2005	-0.0661***	-0.1760***	-0.5603***	-0.5570***	-0.0928***	-0.1158***
	(0.0191)	(0.0222)	(0.0386)	(0.0394)	(0.0083)	(0.0094)
2006	-0.1246***	-0.2382***	-0.5583***	-0.5691***	-0.1265***	-0.1478***
	(0.0193)	(0.0223)	(0.0398)	(0.0410)	(0.0083)	(0.0093)
2007	-0.0005	-0.1224***	-0.4703***	-0.4855***	-0.1441***	-0.1643***
	(0.0208)	(0.0237)	(0.0416)	(0.0428)	(0.0100)	(0.0105)
2008	0.1127***	-0.0180	-0.3675***	-0.3857***	-0.1323***	-0.1505***
	(0.0210)	(0.0237)	(0.0409)	(0.0418)	(0.0085)	(0.0096)
2009	0.1520***	0.0265	-0.3346***	-0.3500***	-0.1304***	-0.1513***
	(0.0203)	(0.0235)	(0.0405)	(0.0415)	(0.0082)	(0.0094)
2010	0.2421***	0.1142***	-0.2922***	-0.3282***	-0.1436***	-0.1647***
	(0.0212)	(0.0239)	(0.0400)	(0.0409)	(0.0088)	(0.0098)
2011	0.2994***	0.1698***	-0.2641***	-0.3137***	-0.1400***	-0.1580***
	(0.0220)	(0.0249)	(0.0433)	(0.0442)	(0.0095)	(0.0103)
Constant	1.1297***	1.4439***	2.8727***	2.9758***	0.1890***	0.2060***
	(0.0142)	(0.0173)	(0.0272)	(0.0278)	(0.0063)	(0.0074)
N	86,736	86,736	134,264	134,264	134,264	134,264
R^2	0.067	0.028	0.022	0.027	0.039	0.051

Notes: Standard errors (in parentheses) are clustered at the farmer level. Model includes time fixed effects, CRD-specific time trends and individual fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

table S3. Full results corresponding to Figs. 2 and 3.

	Soybean Herbicides		Maize Herbicides		Maize Insecticides	
	a.i. kg/ha	EIQ kg/ha	a.i. kg/ha	EIQ kg/ha	a.i. kg/ha	EIQ kg/ha
G_i × 1998	0.1714***	-0.1487***	-0.5527***	-0.7993***	0.0011	0.0059
	(0.0201)	(0.0247)	(0.1121)	(0.1143)	(0.0079)	(0.0099)
G_i × 1999	0.2089***	-0.1067***	-0.3574***	-0.5778***	0.0130*	0.0138*
	(0.0196)	(0.0245)	(0.0636)	(0.0670)	(0.0063)	(0.0067)
G_i × 2000	0.2422***	-0.0472	-0.4363***	-0.6754***	-0.0022	-0.0033
	(0.0196)	(0.0253)	(0.0639)	(0.0664)	(0.0073)	(0.0074)
G_i × 2001	0.3017***	0.0112	-0.1933***	-0.3796***	-0.0011	-0.0030
	(0.0215)	(0.0271)	(0.0507)	(0.0523)	(0.0072)	(0.0070)
G_i × 2002	0.3060***	0.0094	-0.2228***	-0.4464***	-0.0169*	-0.0195**
	(0.0236)	(0.0293)	(0.0468)	(0.0479)	(0.0079)	(0.0072)
G_i × 2003	0.4444***	0.1512***	-0.2060***	-0.4706***	-0.0067	-0.0072
	(0.0293)	(0.0356)	(0.0441)	(0.0453)	(0.0065)	(0.0068)
G_i × 2004	0.4280***	0.1139**	-0.1027*	-0.3618***	-0.0114	-0.0085
	(0.0303)	(0.0388)	(0.0418)	(0.0426)	(0.0060)	(0.0062)
G_i × 2005	0.3977***	0.1014*	-0.1210**	-0.3701***	-0.0082*	-0.0101**
	(0.0317)	(0.0395)	(0.0376)	(0.0387)	(0.0039)	(0.0039)
G_i × 2006	0.3936***	0.1403**	-0.0442	-0.2569***	-0.0081*	-0.0062
	(0.0381)	(0.0474)	(0.0347)	(0.0359)	(0.0039)	(0.0036)
G_i × 2007	0.4525***	0.1768**	0.0190	-0.2131***	-0.0168**	-0.0149**
	(0.0512)	(0.0642)	(0.0385)	(0.0404)	(0.0063)	(0.0053)
G_i × 2008	0.5399***	0.2915***	0.2301***	0.0247	-0.0337***	-0.0304***
	(0.0521)	(0.0652)	(0.0395)	(0.0410)	(0.0039)	(0.0037)
G_i × 2009	0.4917***	0.2304***	0.1438***	-0.0639	-0.0277***	-0.0248***
	(0.0442)	(0.0545)	(0.0406)	(0.0423)	(0.0034)	(0.0033)
G_i × 2010	0.6428***	0.3760***	0.2973***	0.0894	-0.0207***	-0.0218***
	(0.0492)	(0.0587)	(0.0436)	(0.0458)	(0.0032)	(0.0033)
G_i × 2011	0.6604***	0.4262***	0.3639***	0.1535**	-0.0191***	-0.0182***
	(0.0552)	(0.0638)	(0.0567)	(0.0590)	(0.0038)	(0.0040)
1999	-0.1306***	-0.1548***	-0.2637***	-0.2684***	-0.0301***	-0.0398***
	(0.0217)	(0.0278)	(0.0303)	(0.0315)	(0.0063)	(0.0074)

2000	-0.1090***	-0.1439***	-0.3171***	-0.3307***	-0.0268***	-0.0408***
	(0.0232)	(0.0300)	(0.0330)	(0.0338)	(0.0078)	(0.0087)
2001	-0.1534***	-0.2067***	-0.3869***	-0.3914***	-0.0488***	-0.0642***
	(0.0255)	(0.0324)	(0.0330)	(0.0341)	(0.0072)	(0.0084)
2002	-0.1961***	-0.2856***	-0.4606***	-0.4707***	-0.0451***	-0.0625***
	(0.0279)	(0.0353)	(0.0348)	(0.0358)	(0.0102)	(0.0103)
2003	-0.2537***	-0.3635***	-0.4758***	-0.4870***	-0.0568***	-0.0714***
	(0.0327)	(0.0402)	(0.0364)	(0.0376)	(0.0088)	(0.0098)
2004	-0.2391***	-0.3423***	-0.5312***	-0.5289***	-0.0775***	-0.1004***
	(0.0336)	(0.0433)	(0.0374)	(0.0387)	(0.0082)	(0.0093)
2005	-0.2023***	-0.3221***	-0.5452***	-0.5354***	-0.0920***	-0.1133***
	(0.0349)	(0.0439)	(0.0407)	(0.0417)	(0.0084)	(0.0092)
2006	-0.2600***	-0.4231***	-0.5640***	-0.5803***	-0.1263***	-0.1475***
	(0.0409)	(0.0513)	(0.0420)	(0.0435)	(0.0086)	(0.0094)
2007	-0.1931***	-0.3444***	-0.5116***	-0.5236***	-0.1392***	-0.1595***
	(0.0533)	(0.0674)	(0.0473)	(0.0493)	(0.0117)	(0.0115)
2008	-0.1648**	-0.3513***	-0.5801***	-0.6146***	-0.1168***	-0.1359***
	(0.0538)	(0.0679)	(0.0490)	(0.0508)	(0.0087)	(0.0096)
2009	-0.0771	-0.2454***	-0.4894***	-0.5200***	-0.1187***	-0.1404***
	(0.0472)	(0.0588)	(0.0495)	(0.0513)	(0.0083)	(0.0094)
2010	-0.1305*	-0.2965***	-0.5914***	-0.6436***	-0.1362***	-0.1555***
	(0.0515)	(0.0622)	(0.0531)	(0.0555)	(0.0089)	(0.0099)
2011	-0.0902	-0.2886***	-0.6317***	-0.6957***	-0.1335***	-0.1510***
	(0.0569)	(0.0667)	(0.0638)	(0.0661)	(0.0095)	(0.0103)
Constant	1.1812***	1.5043***	2.8851***	2.9887***	0.1865***	0.2028***
	(0.0164)	(0.0205)	(0.0273)	(0.0279)	(0.0063)	(0.0072)
N	86,736	86,736	134,264	134,264	134,264	134,264
R^2	0.071	0.032	0.026	0.031	0.040	0.051

Notes: Standard errors (in parentheses) are clustered at the farmer level. Model includes time fixed effects, CRD-specific time trends and individual fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

table S4. Random effects replace farmers fixed effects (compare to table S3).

	Soybean Herbicides		Maize Herbicides		Maize Insecticides	
	a.i. kg/ha	EIQ kg/ha	a.i. kg/ha	EIQ kg/ha	a.i. kg/ha	EIQ kg/ha
G_i × 1998	0.1605***	-0.1726***	-0.6704***	-0.9345***	-0.0050	-0.0028
	(0.0174)	(0.0212)	(0.0988)	(0.1002)	(0.0078)	(0.0099)
G_i × 1999	0.1987***	-0.1288***	-0.4138***	-0.6418***	0.0120	0.0124
	(0.0174)	(0.0218)	(0.0599)	(0.0634)	(0.0063)	(0.0068)
G_i × 2000	0.2313***	-0.0804***	-0.5255***	-0.7775***	-0.0042	-0.0055
	(0.0176)	(0.0228)	(0.0571)	(0.0594)	(0.0073)	(0.0074)
G_i × 2001	0.2918***	-0.0152	-0.2572***	-0.4587***	-0.0066	-0.0090
	(0.0195)	(0.0248)	(0.0472)	(0.0489)	(0.0072)	(0.0070)
G_i × 2002	0.3100***	-0.0016	-0.3153***	-0.5534***	-0.0220**	-0.0228**
	(0.0217)	(0.0271)	(0.0428)	(0.0440)	(0.0085)	(0.0077)
G_i × 2003	0.4439***	0.1348***	-0.2640***	-0.5426***	-0.0100	-0.0114
	(0.0267)	(0.0334)	(0.0409)	(0.0421)	(0.0059)	(0.0065)
G_i × 2004	0.4122***	0.0868*	-0.1892***	-0.4618***	-0.0114	-0.0087
	(0.0276)	(0.0357)	(0.0383)	(0.0393)	(0.0059)	(0.0061)
G_i × 2005	0.3837***	0.0659	-0.1734***	-0.4345***	-0.0086*	-0.0107**
	(0.0295)	(0.0377)	(0.0346)	(0.0356)	(0.0040)	(0.0039)
G_i × 2006	0.4106***	0.1454***	-0.0765*	-0.3003***	-0.0078*	-0.0057
	(0.0338)	(0.0431)	(0.0324)	(0.0337)	(0.0034)	(0.0032)
G_i × 2007	0.5277***	0.2459***	0.0294	-0.2124***	-0.0166***	-0.0143**
	(0.0460)	(0.0579)	(0.0360)	(0.0379)	(0.0047)	(0.0045)
G_i × 2008	0.6226***	0.3620***	0.2556***	0.0437	-0.0299***	-0.0277***
	(0.0486)	(0.0613)	(0.0372)	(0.0387)	(0.0037)	(0.0035)
G_i × 2009	0.5368***	0.2529***	0.1929***	-0.0210	-0.0250***	-0.0229***
	(0.0420)	(0.0526)	(0.0388)	(0.0405)	(0.0032)	(0.0032)
G_i × 2010	0.6821***	0.3950***	0.3742***	0.1615***	-0.0194***	-0.0211***
	(0.0458)	(0.0557)	(0.0415)	(0.0436)	(0.0030)	(0.0033)
G_i × 2011	0.6875***	0.4305***	0.4794***	0.2663***	-0.0175***	-0.0169***
	(0.0498)	(0.0581)	(0.0528)	(0.0550)	(0.0035)	(0.0038)
N	86,736	86,736	134,264	134,264	134,264	134,264
R^2	0.065	0.025	0.012	0.016	0.019	0.024
Hausman test	607.4***	641.2***	2,615 ***	3,004***	3,164***	4,335***

Notes: Standard errors (in parentheses) are clustered at the farmer level. Model includes time fixed effects and CRD-specific time trends. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

table S5. Model estimates with the no-till binary variable included.

	Soybean Herbicides		Maize Herbicides	
	a.i. kg/ha	EIQ kg/ha	a.i. kg/ha	EIQ kg/ha
No Till	0.1600^{***}	0.1408^{***}	0.1531^{***}	0.1240^{***}
	(0.0081)	(0.0090)	(0.0162)	(0.0168)
$G_i \times 1998$	0.1609^{***}	-0.1580^{***}	-0.5588^{***}	-0.8043^{***}
	(0.0201)	(0.0247)	(0.1117)	(0.1140)
$G_i \times 1999$	0.1986^{***}	-0.1158^{***}	-0.3606^{***}	-0.5804^{***}
	(0.0195)	(0.0245)	(0.0635)	(0.0670)
$G_i \times 2000$	0.2334^{***}	-0.0549^{*}	-0.4394^{***}	-0.6779^{***}
	(0.0196)	(0.0254)	(0.0639)	(0.0664)
$G_i \times 2001$	0.2906^{***}	0.0014	-0.1989^{***}	-0.3841^{***}
	(0.0215)	(0.0271)	(0.0506)	(0.0523)
$G_i \times 2002$	0.2956^{***}	0.0003	-0.2238^{***}	-0.4472^{***}
	(0.0236)	(0.0293)	(0.0468)	(0.0479)
$G_i \times 2003$	0.4346^{***}	0.1426^{***}	-0.2095^{***}	-0.4734^{***}
	(0.0292)	(0.0356)	(0.0440)	(0.0452)
$G_i \times 2004$	0.4197^{***}	0.1066^{**}	-0.1102^{**}	-0.3678^{***}
	(0.0302)	(0.0387)	(0.0417)	(0.0425)
$G_i \times 2005$	0.3862^{***}	0.0913^{*}	-0.1244^{***}	-0.3728^{***}
	(0.0317)	(0.0395)	(0.0376)	(0.0387)
$G_i \times 2006$	0.3803^{***}	0.1286^{**}	-0.0458	-0.2583^{***}
	(0.0382)	(0.0475)	(0.0347)	(0.0359)
$G_i \times 2007$	0.4488^{***}	0.1736^{**}	0.0172	-0.2146^{***}
	(0.0511)	(0.0641)	(0.0385)	(0.0405)
$G_i \times 2008$	0.5298^{***}	0.2826^{***}	0.2272^{***}	0.0223
	(0.0522)	(0.0653)	(0.0395)	(0.0410)
$G_i \times 2009$	0.4801^{***}	0.2201^{***}	0.1404^{***}	-0.0666
	(0.0443)	(0.0547)	(0.0406)	(0.0423)
$G_i \times 2010$	0.6341^{***}	0.3683^{***}	0.2922^{***}	0.0853
	(0.0491)	(0.0588)	(0.0435)	(0.0458)
$G_i \times 2011$	0.6420^{***}	0.4100^{***}	0.3578^{***}	0.1486^{*}
	(0.0548)	(0.0634)	(0.0568)	(0.0591)
N	86,736	86,736	134,264	134,264
R^2	0.079	0.037	0.028	0.032

Notes: Standard errors (in parentheses) are clustered at the farmer level. Model includes time fixed effects, CRD-specific time trends and individual fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

table S6. Impact of GE variety adoption on herbicide use (kg/ha of active ingredient). Model includes indicator variables for major targeted weeds.

	Soybean Herbicides		Maize Herbicides	
	a.i. kg/ha	a.i. kg/ha	a.i. kg/ha	a.i. kg/ha
G_i	0.3176***		-0.0245	
	(0.0096)		(0.0147)	
G_i × 1998		0.1976***		-0.4943***
		(0.0199)		(0.1097)
G_i × 1999		0.2275***		-0.2978***
		(0.0194)		(0.0618)
G_i × 2000		0.2571***		-0.3906***
		(0.0195)		(0.0624)
G_i × 2001		0.3192***		-0.1674***
		(0.0213)		(0.0497)
G_i × 2002		0.3146***		-0.1845***
		(0.0233)		(0.0461)
G_i × 2003		0.4562***		-0.1727***
		(0.0289)		(0.0430)
G_i × 2004		0.4366***		-0.0790
		(0.0299)		(0.0414)
G_i × 2005		0.4097***		-0.1075**
		(0.0313)		(0.0370)
G_i × 2006		0.3999***		-0.0455
		(0.0379)		(0.0342)
G_i × 2007		0.4483***		0.0160
		(0.0491)		(0.0378)
G_i × 2008		0.5417***		0.2177***
		(0.0508)		(0.0394)
G_i × 2009		0.5019***		0.1317**
		(0.0430)		(0.0405)
G_i × 2010		0.6548***		0.2733***
		(0.0475)		(0.0426)
G_i × 2011		0.6530***		0.3260***
		(0.0544)		(0.0564)

Cocklebur	0.0672***	0.0654***	0.1168***	0.1149***
	(0.0086)	(0.0086)	(0.0188)	(0.0188)
Foxtail	0.1005***	0.0990***	0.2935***	0.2888***
	(0.0079)	(0.0079)	(0.0157)	(0.0157)
Lambsquarters	0.0617***	0.0599***	0.1070***	0.1030***
	(0.0091)	(0.0091)	(0.0169)	(0.0169)
Pigweed	0.0728***	0.0718***	0.1876***	0.1848***
	(0.0090)	(0.0090)	(0.0163)	(0.0163)
Ragweed	0.0517***	0.0514***	0.1334***	0.1302***
	(0.0094)	(0.0093)	(0.0183)	(0.0183)
Velvetleaf	0.0306***	0.0290**	0.1573***	0.1549***
	(0.0089)	(0.0088)	(0.0168)	(0.0168)
Waterhemp	0.0831***	0.0839***	0.0767***	0.0752**
	(0.0107)	(0.0107)	(0.0233)	(0.0233)
Morningglory	0.0797***	0.0775***	0.2045***	0.2028***
	(0.0144)	(0.0144)	(0.0313)	(0.0313)
Johnson grass	0.0857***	0.0871***	0.0641*	0.0687*
	(0.0152)	(0.0152)	(0.0294)	(0.0294)
N	86,736	86,736	134,264	134,264
R^2	0.080	0.083	0.043	0.046

Notes: Standard errors (in parentheses) are clustered at the farmer level. Model includes time fixed effects, CRD-specific time trends and individual fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

table S7. Model excludes growers that plant both GE and non-GE varieties within a given year (compare with Table 1).

	Soybean Herbicides		Corn Herbicides		Corn Insecticides	
	a.i. kg/ha	EIQ kg/ha	a.i. kg/ha	EIQ kg/ha	a.i. kg/ha	EIQ kg/ha
G_i	0.2559^{***}	-0.0515^{*}	-0.0956^{**}	-0.3480^{***}	-0.0106	-0.0101
	(0.0189)	(0.0226)	(0.0295)	(0.0308)	(0.0070)	(0.0069)
N	71,239	71,239	108,327	108,327	62,265	62,265
R^2	0.060	0.037	0.027	0.032	0.030	0.042

Notes: Standard errors (in parentheses) are clustered at the farmer level. Model includes time fixed effects, CRD-specific time trends and individual fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

table S8. Model excludes growers that plant both GE and non-GE varieties within a given year (compare with table S3).

	Soybean Herbicides		Corn Herbicides		Corn Insecticides	
	a.i. kg/ha	EIQ kg/ha	a.i. kg/ha	EIQ kg/ha	a.i. kg/ha	EIQ kg/ha
$G_i \times 1998$	0.0602	-0.2774***	-0.9996***	-1.2646***	0.0011	0.0036
	(0.0364)	(0.0422)	(0.2887)	(0.2933)	(0.0351)	(0.0468)
$G_i \times 1999$	0.1358***	-0.1985***	-0.8637***	-1.1141***	-0.0180	-0.0322
	(0.0340)	(0.0412)	(0.1609)	(0.1738)	(0.0292)	(0.0327)
$G_i \times 2000$	0.1690***	-0.1425***	-0.5778***	-0.8486***	0.0099	0.0272
	(0.0319)	(0.0389)	(0.1182)	(0.1211)	(0.0231)	(0.0271)
$G_i \times 2001$	0.2276***	-0.0860	-0.4668***	-0.6952***	0.0704	0.0540
	(0.0365)	(0.0455)	(0.0921)	(0.0948)	(0.0679)	(0.0576)
$G_i \times 2002$	0.2509***	-0.0591	-0.3760***	-0.6292***	0.0010	-0.0110
	(0.0379)	(0.0475)	(0.0774)	(0.0784)	(0.0245)	(0.0218)
$G_i \times 2003$	0.4036***	0.1162*	-0.2470***	-0.5122***	-0.0129	-0.0054
	(0.0459)	(0.0558)	(0.0661)	(0.0670)	(0.0225)	(0.0229)
$G_i \times 2004$	0.3770***	0.0740	-0.1321*	-0.3954***	0.0157	0.0217
	(0.0452)	(0.0580)	(0.0605)	(0.0619)	(0.0382)	(0.0407)
$G_i \times 2005$	0.4047***	0.1211*	-0.1272*	-0.3910***	-0.0052	-0.0099
	(0.0456)	(0.0554)	(0.0596)	(0.0608)	(0.0155)	(0.0178)
$G_i \times 2006$	0.3448***	0.0967	-0.1408*	-0.3775***	-0.0082	-0.0060
	(0.0578)	(0.0715)	(0.0567)	(0.0586)	(0.0129)	(0.0120)
$G_i \times 2007$	0.4456***	0.1756*	-0.1416*	-0.4053***	-0.0198	-0.0215
	(0.0666)	(0.0809)	(0.0644)	(0.0679)	(0.0226)	(0.0190)
$G_i \times 2008$	0.5352***	0.2680**	0.1822**	-0.0579	-0.0336***	-0.0244*
	(0.0656)	(0.0827)	(0.0645)	(0.0669)	(0.0101)	(0.0095)
$G_i \times 2009$	0.5135***	0.2473**	0.0409	-0.1995**	-0.0255*	-0.0211
	(0.0638)	(0.0789)	(0.0671)	(0.0702)	(0.0113)	(0.0119)
$G_i \times 2010$	0.6811***	0.3947***	0.2575***	0.0086	-0.0201	-0.0251*
	(0.0662)	(0.0799)	(0.0721)	(0.0748)	(0.0117)	(0.0126)
$G_i \times 2011$	0.6311***	0.3868***	0.2363**	-0.0250	-0.0196	-0.0199
	(0.0762)	(0.0840)	(0.0894)	(0.0930)	(0.0124)	(0.0122)
N	71,239	71,239	108,327	108,327	62,265	62,265
R^2	0.064	0.042	0.030	0.034	0.030	0.043

Notes: Standard errors (in parentheses) are clustered at the farmer level. Model includes time fixed effects, CRD-specific time trends and individual fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

table S9. Model excludes farmers that never used pesticides (on any of their plots) (compare with Table 1).

	Soybean Herbicides		Corn Herbicides		Corn Insecticides	
	a.i. kg/ha	EIQ kg/ha	a.i. kg/ha	EIQ kg/ha	a.i. kg/ha	EIQ kg/ha
G_i	0.3023***	0.0045	-0.0331*	-0.2594***	-0.0140***	-0.0131***
	(0.0097)	(0.0122)	(0.0150)	(0.0157)	(0.0015)	(0.0016)
N	85,932	85,932	132,824	132,824	106,256	106,256
R^2	0.067	0.028	0.022	0.028	0.042	0.055

Notes: Standard errors (in parentheses) are clustered at the farmer level. Model includes time fixed effects, CRD-specific time trends and individual fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

table S10. Model excludes farmers that never used pesticides (on any of their plots) (compare with table S3).

	Soybean Herbicides		Corn Herbicides		Corn Insecticides	
	a.i. kg/ha	EIQ kg/ha	a.i. kg/ha	EIQ kg/ha	a.i. kg/ha	EIQ kg/ha
G_i × 1998	0.1709^{***}	-0.1499^{***}	-0.5537^{***}	-0.8029^{***}	-0.0037	0.0015
	(0.0202)	(0.0247)	(0.1132)	(0.1154)	(0.0116)	(0.0145)
G_i × 1999	0.2093^{***}	-0.1071^{***}	-0.3598^{***}	-0.5817^{***}	0.0179^{*}	0.0191^{*}
	(0.0197)	(0.0247)	(0.0640)	(0.0674)	(0.0089)	(0.0096)
G_i × 2000	0.2422^{***}	-0.0477	-0.4366^{***}	-0.6761^{***}	-0.0049	-0.0064
	(0.0197)	(0.0255)	(0.0640)	(0.0664)	(0.0103)	(0.0105)
G_i × 2001	0.3021^{***}	0.0109	-0.1931^{***}	-0.3796^{***}	-0.0008	-0.0032
	(0.0217)	(0.0274)	(0.0507)	(0.0524)	(0.0098)	(0.0095)
G_i × 2002	0.3071^{***}	0.0101	-0.2228^{***}	-0.4468^{***}	-0.0224^{*}	-0.0254^{*}
	(0.0239)	(0.0297)	(0.0469)	(0.0480)	(0.0110)	(0.0100)
G_i × 2003	0.4472^{***}	0.1539^{***}	-0.2061^{***}	-0.4709^{***}	-0.0078	-0.0084
	(0.0298)	(0.0363)	(0.0441)	(0.0453)	(0.0085)	(0.0088)
G_i × 2004	0.4301^{***}	0.1159^{**}	-0.1027^{*}	-0.3623^{***}	-0.0126	-0.0090
	(0.0309)	(0.0396)	(0.0419)	(0.0427)	(0.0071)	(0.0073)
G_i × 2005	0.3982^{***}	0.1021^{*}	-0.1210^{**}	-0.3703^{***}	-0.0079	-0.0097^{*}
	(0.0323)	(0.0402)	(0.0377)	(0.0387)	(0.0043)	(0.0043)
G_i × 2006	0.3981^{***}	0.1458^{**}	-0.0440	-0.2571^{***}	-0.0067	-0.0044
	(0.0392)	(0.0488)	(0.0348)	(0.0360)	(0.0042)	(0.0039)
G_i × 2007	0.4569^{***}	0.1827^{**}	0.0189	-0.2137^{***}	-0.0145^{*}	-0.0124^{*}
	(0.0541)	(0.0678)	(0.0387)	(0.0406)	(0.0067)	(0.0056)
G_i × 2008	0.5433^{***}	0.2981^{***}	0.2311^{***}	0.0258	-0.0337^{***}	-0.0303^{***}
	(0.0557)	(0.0697)	(0.0400)	(0.0415)	(0.0041)	(0.0038)
G_i × 2009	0.4907^{***}	0.2305^{***}	0.1439^{***}	-0.0638	-0.0273^{***}	-0.0242^{***}
	(0.0465)	(0.0573)	(0.0412)	(0.0430)	(0.0035)	(0.0034)
G_i × 2010	0.6425^{***}	0.3776^{***}	0.3024^{***}	0.0952^{*}	-0.0195^{***}	-0.0206^{***}
	(0.0529)	(0.0632)	(0.0447)	(0.0470)	(0.0033)	(0.0034)
G_i × 2011	0.6602^{***}	0.4295^{***}	0.3697^{***}	0.1599^{**}	-0.0185^{***}	-0.0176^{***}
	(0.0579)	(0.0669)	(0.0588)	(0.0611)	(0.0039)	(0.0041)
N	85,932	85,932	132,824	132,824	106,256	106,256
R^2	0.072	0.032	0.026	0.031	0.043	0.055

Notes: Standard errors (in parentheses) are clustered at the farmer level. Model includes time fixed effects, CRD-specific time trends and individual fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

table S11. Full set of results corresponding to Fig. 4.

	Soybeans		Maize	
	Glyphosate (kg/ha)	Non-Glyphosate (kg/ha)	Glyphosate (kg/ha)	Non-Glyphosate (kg/ha)
G_i × 1998	0.8772^{***}	-0.7057^{***}	0.7651^{***}	-1.3178^{***}
	(0.0117)	(0.0176)	(0.0263)	(0.1114)
G_i × 1999	0.8686^{***}	-0.6596^{***}	0.6808^{***}	-1.0382^{***}
	(0.0111)	(0.0175)	(0.0240)	(0.0659)
G_i × 2000	0.8481^{***}	-0.6059^{***}	0.7547^{***}	-1.1910^{***}
	(0.0115)	(0.0183)	(0.0261)	(0.0644)
G_i × 2001	0.8908^{***}	-0.5891^{***}	0.6197^{***}	-0.8130^{***}
	(0.0131)	(0.0192)	(0.0206)	(0.0512)
G_i × 2002	0.8831^{***}	-0.5771^{***}	0.7607^{***}	-0.9835^{***}
	(0.0151)	(0.0200)	(0.0195)	(0.0461)
G_i × 2003	0.9882^{***}	-0.5438^{***}	0.8892^{***}	-1.0952^{***}
	(0.0185)	(0.0241)	(0.0179)	(0.0427)
G_i × 2004	1.0075^{***}	-0.5795^{***}	0.8695^{***}	-0.9722^{***}
	(0.0188)	(0.0251)	(0.0172)	(0.0395)
G_i × 2005	0.9548^{***}	-0.5572^{***}	0.8060^{***}	-0.9270^{***}
	(0.0188)	(0.0266)	(0.0153)	(0.0361)
G_i × 2006	0.8344^{***}	-0.4408^{***}	0.6953^{***}	-0.7394^{***}
	(0.0223)	(0.0333)	(0.0142)	(0.0333)
G_i × 2007	0.8794^{***}	-0.4268^{***}	0.7490^{***}	-0.7300^{***}
	(0.0351)	(0.0408)	(0.0134)	(0.0375)
G_i × 2008	0.9715^{***}	-0.4316^{***}	0.7085^{***}	-0.4784^{***}
	(0.0338)	(0.0438)	(0.0148)	(0.0385)
G_i × 2009	0.9671^{***}	-0.4754^{***}	0.7104^{***}	-0.5666^{***}
	(0.0283)	(0.0370)	(0.0147)	(0.0389)
G_i × 2010	1.1295^{***}	-0.4868^{***}	0.6920^{***}	-0.3947^{***}
	(0.0321)	(0.0380)	(0.0173)	(0.0431)
G_i × 2011	1.1278^{***}	-0.4674^{***}	0.6898^{***}	-0.3260^{***}
	(0.0370)	(0.0434)	(0.0222)	(0.0547)

1999	-0.0229*	-0.1077***	0.0008	-0.2645***
	(0.0091)	(0.0200)	(0.0054)	(0.0300)
2000	0.0249*	-0.1339***	0.0175**	-0.3347***
	(0.0104)	(0.0217)	(0.0067)	(0.0326)
2001	0.0484***	-0.2018***	0.0267***	-0.4136***
	(0.0121)	(0.0234)	(0.0067)	(0.0326)
2002	0.0876***	-0.2837***	0.0381***	-0.4988***
	(0.0148)	(0.0249)	(0.0071)	(0.0344)
2003	0.0787***	-0.3324***	0.0534***	-0.5292***
	(0.0179)	(0.0282)	(0.0076)	(0.0359)
2004	0.0781***	-0.3173***	0.0523***	-0.5835***
	(0.0182)	(0.0292)	(0.0079)	(0.0369)
2005	0.1427***	-0.3450***	0.0743***	-0.6194***
	(0.0185)	(0.0306)	(0.0098)	(0.0392)
2006	0.2103***	-0.4702***	0.1221***	-0.6861***
	(0.0224)	(0.0367)	(0.0100)	(0.0413)
2007	0.2855***	-0.4785***	0.1576***	-0.6692***
	(0.0349)	(0.0438)	(0.0109)	(0.0465)
2008	0.2996***	-0.4644***	0.2279***	-0.8080***
	(0.0334)	(0.0465)	(0.0135)	(0.0485)
2009	0.3118***	-0.3889***	0.2174***	-0.7068***
	(0.0285)	(0.0405)	(0.0137)	(0.0481)
2010	0.2371***	-0.3676***	0.2891***	-0.8805***
	(0.0323)	(0.0408)	(0.0166)	(0.0526)
2011	0.2493***	-0.3395***	0.3312***	-0.9628***
	(0.0370)	(0.0457)	(0.0210)	(0.0620)
Constant	0.1476***	1.0336***	0.0625***	2.8226***
	(0.0079)	(0.0150)	(0.0061)	(0.0270)
N	86,736	86,736	134,264	134,264
R^2	0.357	0.238	0.440	0.108

Notes: Standard errors (in parentheses) are clustered at the farmer level. Model includes time fixed effects, CRD-specific time trends and individual fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

table S12. GE adoption rates (% of planted hectares), 1998–2011.

Year	Bt Maize	GT Maize	GT Soybeans
1998	11%	3%	37%
1999	19%	6%	57%
2000	18%	8%	63%
2001	19%	13%	74%
2002	23%	15%	83%
2003	26%	19%	88%
2004	30%	28%	90%
2005	40%	40%	91%
2006	46%	51%	94%
2007	59%	71%	96%
2008	66%	84%	96%
2009	69%	88%	95%
2010	69%	90%	95%
2011	71%	91%	97%

Notes: these adoption rates are those represented in Fig. 1A

table S13. Pesticide rates (kg/ha), 1998–2011.

Year	Maize Insecticides	Maize Herbicides	Soybean Herbicides
1998	0.203	2.848	1.248
1999	0.172	2.514	1.197
2000	0.174	2.532	1.228
2001	0.139	2.498	1.279
2002	0.146	2.372	1.250
2003	0.133	2.392	1.339
2004	0.119	2.310	1.356
2005	0.081	2.344	1.367
2006	0.056	2.285	1.292
2007	0.055	2.464	1.441
2008	0.052	2.560	1.600
2009	0.051	2.525	1.609
2010	0.039	2.624	1.726
2011	0.053	2.652	1.862

Notes: these rates are calculated by adding up the total amount of active ingredients used in each year and dividing by the total number of hectares planted to the corresponding crop.

table S14. Correlation between state-level GE adoption rates from USDA and GfK data.

	Maize	Soybeans
All GE Varieties	0.987	0.901
GT Only Varieties	0.956	0.901

Notes: see supplementary text.

table S15. Summary statistics by adoption choice.

	Soybeans		Maize	
Variable	non-GT	GT	non-GT	GT
Weed Targeted				
Cocklebur	37.7%	28.2%	30.2%	24.7%
Foxtail	57.0%	48.3%	60.5%	57.3%
Lamb's Quarters	26.3%	23.1%	29.1%	32.0%
Pigweed	27.8%	23.0%	27.3%	26.6%
Ragweed	28.3%	24.2%	25.6%	24.1%
Velvet Leaf	26.0%	25.8%	34.0%	34.6%
Water Hemp	16.9%	19.6%	17.0%	21.4%
Morning Glory	14.6%	10.7%	7.5%	6.5%
Johnson Grass	11.2%	11.0%	7.5%	7.8%
Hectares Grown	198.5	204.6	175.9	217.9

Notes: Entries for Weed Targeted represent the fraction of all plots that report targeting the given weed. In some cases the listed weed may encompass multiple related individual species (for example, ‘Foxtail’ includes Giant Foxtail, Yellow Foxtail, and Green Foxtail). Entries for Hectares Grown represent the average number of hectares, per farmer, allocated to the given crop (farmers who grow both GT and non-GT varieties contribute to both average values).