

Online Appendix to The Impact of Agricultural Biotechnology on Supply and Land-Use

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A Estimated Impacts

In this online Appendix, we present the methodology for computing supply, price, land-saving, and GHG impacts of the GE technology. We also present the results in Figures A.1 – A.4 and Table A.1 that are discussed in the main text.

A.1 Supply Effect

We compute the supply effect of GE technology for the three principle GE crops as the percentage difference between observed 2010 production and two different counterfactual supplies corresponding to different assumptions about the extensive margin. Counterfactual supplies are computed country by country and then aggregated to a world figure.

We first compute the implied traditional variety yield $\widehat{y}_{it0}$ by solving

$$\begin{aligned} Q_{ct} &= y_{ct0}L_{ct0} + y_{ct1}L_{ct1} \\ &= y_{ct0} \left(L_{ct0} + (1 + \hat{\beta}) L_{ct1} \right) \\ \implies \widehat{y}_{ct0} &= \frac{Q_{ct}}{L_{ct0} + (1 + \hat{\beta}) L_{ct1}} \end{aligned} \tag{A.1}$$

where $\hat{\beta}$ represents the estimated yield effect of the GE technology for the given crop. In the estimated impacts that follow, we use both our own estimated yield impacts from section 3, and a range of other yield impacts from the literature. Assuming that production would have occurred on extensive margin lands even without the use of GE technology, then the counterfactual supply is given by

$$\widetilde{Q}_{ct} = \widehat{y}_{ct0}L_{ct} \tag{A.2}$$

We sum over country-specific counterfactual supplies to find the world total counterfactual supply $\widetilde{Q}_t$ and compute supply effect $\widetilde{s} = \frac{Q_t - \widetilde{Q}_t}{Q_t}$. If however, it is assumed that production

on the extensive margin would not have occurred without the GE technology, i.e., that GE seeds cause the increase in hectareage, then the production on the extensive margin would have to be subtracted from $\widetilde{Q}_{ct}$ to yield counterfactual supply:

$$\widetilde{\widetilde{Q}}_{ct} = \widehat{y}_{ct0} [L_{ct} - L_{ct}^{ext1}] \quad (\text{A.3})$$

where L_{ct}^{ext1} denotes the extensive margin computed in Section 4. The corresponding supply effect is defined analogously as above $\widetilde{\widetilde{s}} = \frac{Q_t - \widetilde{\widetilde{Q}}_t}{Q_t}$.

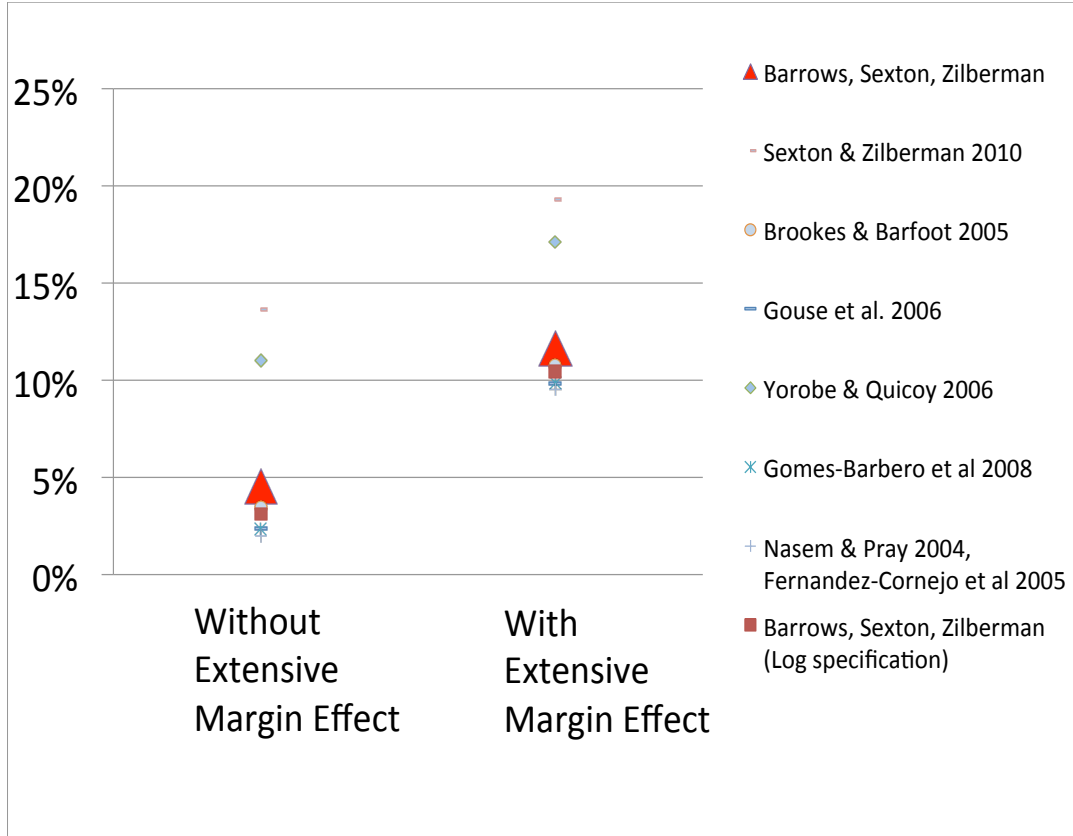
In Figures A.1 and A.2, we report world supply effect for GE corn and cotton for the year 2010 conditional on yield effects from several different studies. Supply effects based on our estimates from section 3 are denoted with large red triangles. Other markers correspond to the supply effects based on yield effects from Sexton and Zilberman (2011) along with all the studies reviewed in Qaim et al. (2009). Estimates are reported according to the extensive margin assumption. The left column, labeled “Without Extensive Margin Effect,” reports the resulting supply effects when we assume that extensive margin lands could have been profitably farmed with traditional seeds. The right column, labeled “With Extensive Margin Effect,” reports supply effects after subtracting all production on extensive margin lands. Results are discussed in the main text.

A.2 Price Effects

The supply effect from GE technology can be translated into price effects using a methodology from De Gorter and Zilberman (1990) and Alston et al. (1995). Suppose that without GE technology, the supply curve shifts in by a factor of η , where η corresponds to the supply effect from the previous section. In the new equilibrium:

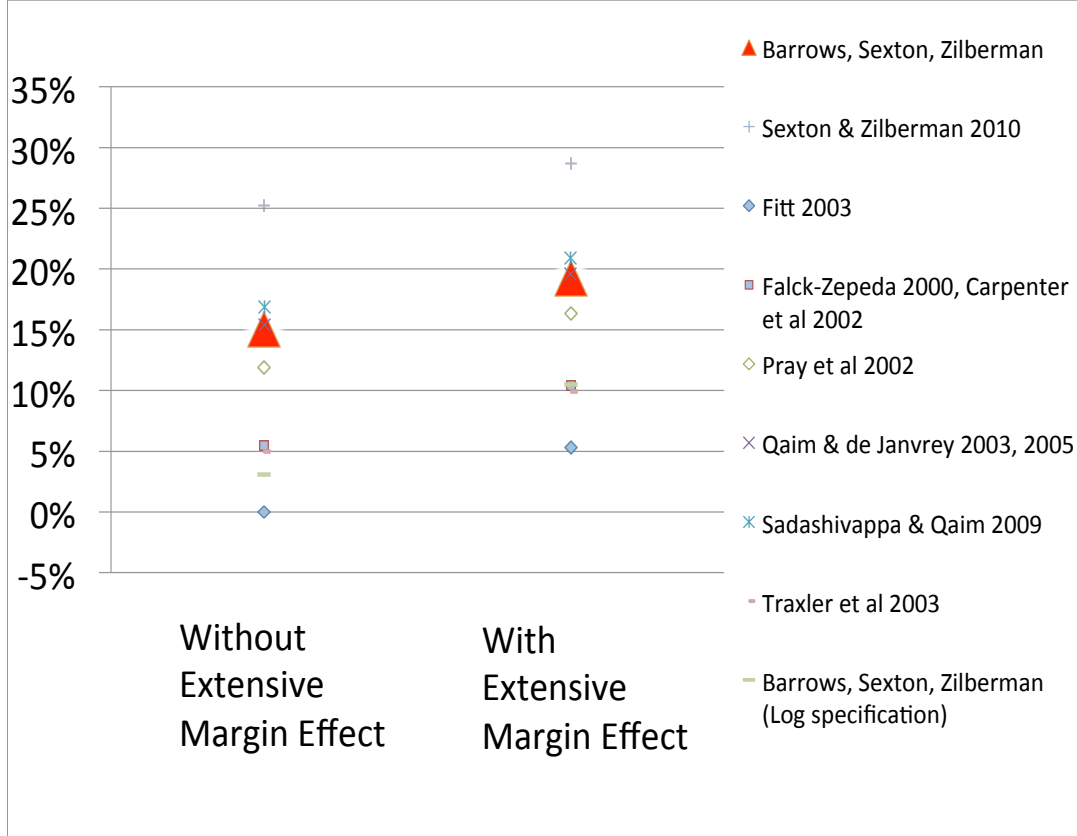
$$(1 - \eta) Q_s(p) = Q_d(p) \quad (\text{A.4})$$

Figure A.1: Supply Effect of GE Corn



Notes: Supply effect of GE corn calculated as percentage difference between observed supply and counterfactual supply without GE technology. Estimate without extensive margin effect allow that production on the extensive margin would have occurred with the traditional technology as well. Estimates with extensive margin effect subtract all production on extensive margin in the counterfactual supply. Each point corresponds to estimates based on the yield effect from different studies in the literature. The “Barrows, Sexton, Zilberman” estimates are derived from our preferred yield estimates in Table 3 of the main text (column 4). “Barrows, Sexton, Zilberman (Log specification)” estimates are derived from the log specification in column 6 of Table 3 of the main text.

Figure A.2: Supply Effect of GE Cotton



Notes: Supply effect of GE cotton calculated as percentage difference between observed supply and counterfactual supply without GE technology. Estimate without extensive margin effect allow that production on the extensive margin would have occurred with the traditional technology as well. Estimates with extensive margin effect subtract all production on extensive margin in the counterfactual supply. Each point corresponds to estimates based on the yield effect from different studies in the literature. The “Barrows, Sexton, Zilberman” estimates are derived from our preferred yield estimates in Table 3 of the main text (column 1). “Barrows, Sexton, Zilberman (Log specification)” estimates are derived from the log specification in column 3 of Table 3 of the main text.

where $Q_s(p)$ and $Q_d(p)$ represent quantities supplied and demanded, respectively, as a function of output price p . Totally differentiating with respect to η and p , yields

$$\begin{aligned}
(1 - \eta) \frac{\partial Q_s(p)}{\partial p} dp - Q_s d\eta &= \frac{\partial Q_d(p)}{\partial p} dp \\
\implies dp \left[(1 - \eta) \frac{\partial Q_s(p)}{\partial p} - \frac{\partial Q_d(p)}{\partial p} \right] &= Q_s d\eta \\
\implies \frac{dp}{p} &= \frac{\partial \eta}{\epsilon_s - \epsilon_d}
\end{aligned} \tag{A.5}$$

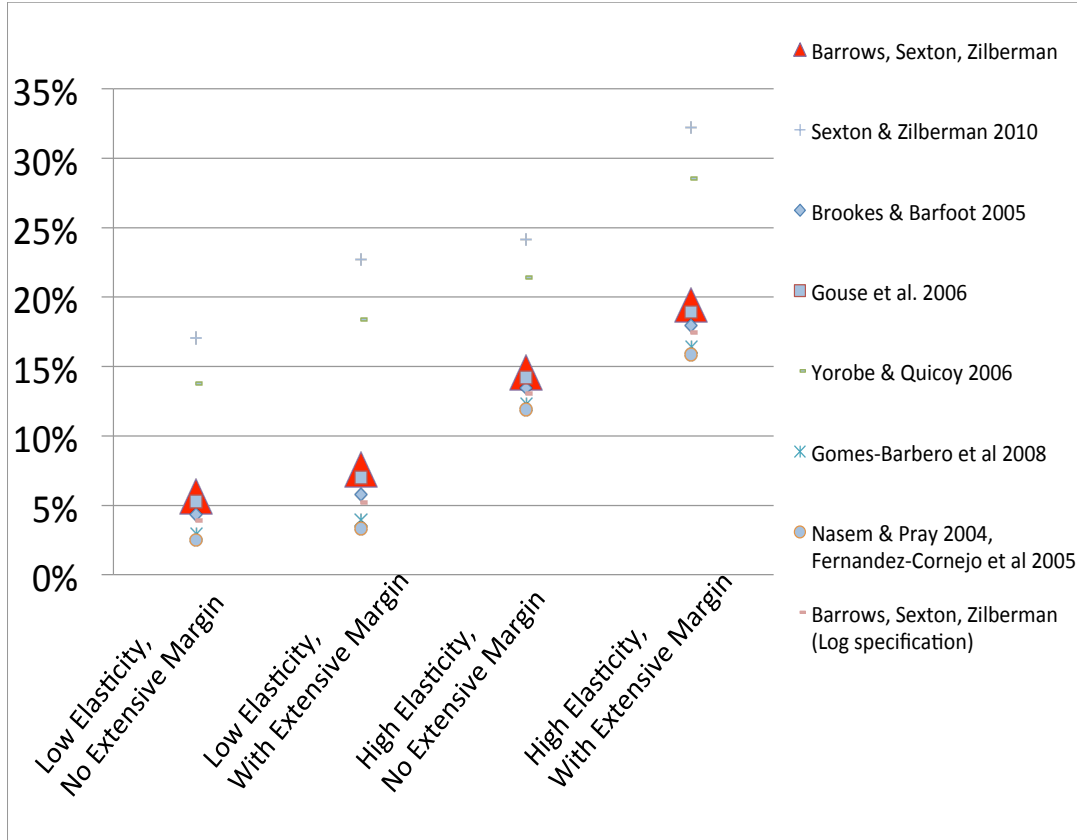
where the last line follows from setting $\eta = 0$. Equation (A.5) states that the percentage change in equilibrium price (the price effect) is equal to the supply effect divided by the difference between price elasticity of supply and price elasticity of demand. Thus, estimating the price effect simply involves scaling the supply effect from the previous section by elasticities parameters readily obtained from the literature. In our estimates, $\epsilon_s = 0.3$, a low elasticity scenario is parameterized with $\epsilon_d = -0.3$, and a high elasticity scenario uses $\epsilon_d = -0.5$.¹ For each elasticity scenario, we also vary the assumption on the extensive margin as before. For each of these 4 scenarios {low elasticity, no extensive margin ; low elasticity with extensive margin; high elasticity, no extensive margin; high elasticity, with extensive margin} price effects are computed conditional on yield estimates and plotted in Figure A.3 for corn and Figure A.4 for cotton. We discuss results in the main text.

A.3 Land-Use Saving Effects

Lastly, we estimate land-use saving effects and the corresponding GHG emissions savings due to GE technology. We compute saved hectares as the difference between observed hectareage in 2010 and counterfactual hectareage that would be needed to produce the same output without the GE supply effects.

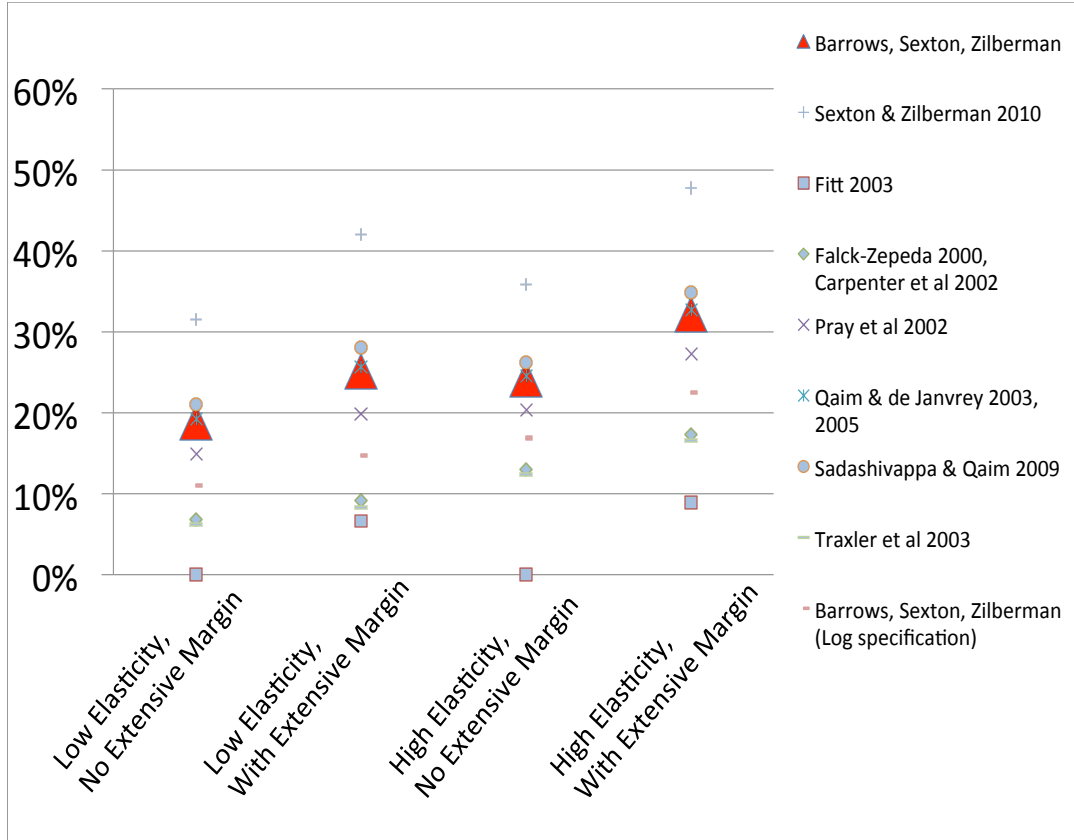
¹Roberts and Schlenker (2010) suggest that supply elasticities vary between 0.08 and 0.13 for supply of grain calories and demand elasticities vary between -0.05 and -0.08. Thus, the magnitude of the price effect should be greater than five times the magnitude of the supply effect, which are greater than the impacts estimated here.

Figure A.3: Price Effect of GE Corn



Notes: Price effect of GE corn calculated as percentage difference between observed price and counterfactual price without GE technology. Estimate without extensive margin effect allow that production on the extensive margin would have occurred with the traditional technology as well. Estimates with extensive margin effect subtract all production on extensive margin in the counterfactual supply. “Low elasticity” scenario sets elasticity of demand to -0.3, “high elasticity” scenario sets elasticity of demand to -0.5. Each point corresponds to estimates based on the yield effect from different studies in the literature. The “Barrows, Sexton, Zilberman” estimates are derived from our preferred yield estimates in Table 3 of the main text (column 4). “Barrows, Sexton, Zilberman (Log specification)” estimates are derived from the log specification in column 6 of Table 3 of the main text.

Figure A.4: Price Effect of GE Cotton



Notes: Price effect of GE cotton calculated as percentage difference between observed price and counterfactual price without GE technology. Estimate without extensive margin effect allow that production on the extensive margin would have occurred with the traditional technology as well. Estimates with extensive margin effect subtract all production on extensive margin in the counterfactual supply. “Low elasticity” scenario sets elasticity of demand to -0.3, “high elasticity” scenario sets elasticity of demand to -0.5. Each point corresponds to estimates based on the yield effect from different studies in the literature. The “Barrows, Sexton, Zilberman” estimates are derived from our preferred yield estimates in Table 3 of the main text (column 1). “Barrows, Sexton, Zilberman (Log specification)” estimates are derived from the log specification in column 3 of Table 3 of the main text.

Table A.1: Land-Use Saving Effects in 2010

	(1)	(2)	(3)
	2010 Harvested Area	Area Saved	GHG Saved
	<i>(Millions of Ha)</i>	<i>(Millions of Ha)</i>	<i>(Gt)</i>
Cotton	32	6	0.07
Corn	160	5	0.06
Soybeans	102	2	0.03
Total	294	13	0.15

Notes: 2010 Harvested Area are world aggregate from FAO Stat. “Area Saved” in column 2 represents the difference between observed area (column 1) and counterfactual area needed to meet observed 2010 demand without the intensive margin yield impact of GE. Column 3 multiplies “Area Saved” by a constant *GHG*/Ha/yr value of 11.7 metric tonnes, taken from the land-use literature (Searchinger et al., 2008).

Formally, counterfactual hectarage without considering the extensive margin effect is computed as

$$\widetilde{L}_{ct} = \frac{Q_{ct}}{\widehat{y_{ct0}}} \quad (\text{A.6})$$

Country-specific hectarages are aggregated to the world level and observed 2010 hectarage is subtracted to compute world hectarage savings

$$\widetilde{L}_t = \sum_c \left(\widetilde{L}_{ct} - L_{ct} \right) \quad (\text{A.7})$$

Estimates are reported by crop in the second column of Table A.1 and discussed in the main text. In the last column of Table A.1, we translate land-use savings into *Gt* of averted GHG emissions by multiplying the hectares saved by GHG emissions per hectare of land-use change per year.

References

- Alston, J. M., Norton, G. W., Pardey, P. G. et al. (1995), *Science under scarcity: principles and practice for agricultural research evaluation and priority setting.*, Cornell University Press.
- De Gorter, H. and Zilberman, D. (1990), ‘On the political economy of public good inputs in agriculture’, *American Journal of Agricultural Economics* **72**(1), 131–137.
- Qaim, M. et al. (2009), ‘The economics of genetically modified crops.’, *Annual Review of Resource Economics* **1**, 665–694.
- Roberts, M. J. and Schlenker, W. (2010), Is agricultural production becoming more or less sensitive to extreme heat? evidence from us corn and soybean yields, Technical report, National Bureau of Economic Research.
- Searchinger, T., Heimlich, R., Houghton, R., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D. and Yu, T. (2008), ‘Use of us croplands for biofuels increases greenhouse gases through emissions from land-use change’, *Science* **319**(5867), 1238–1240.
- Sexton, S. and Zilberman, D. (2011), How agricultural biotechnology boosts food supply and accomodates biofuels, Technical report, National Bureau of Economic Research.