Valuation of Herbicide Resistant Soybeans and An Evaluation of Incentives for Weed Resistance Management

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Roundup Ready® (RR) Soybean

- Introduced in US in 1996
- 92% of US Soybean Crop in 2008
- Problem: Glyphosate Resistant Weeds
- **Potential Solution: Add Residual Herbicide**
Questions

- What are the benefits to farmers of RR soybeans?
- How are weed resistance concerns affecting RR soybean acres and use of residual herbicides on RR soybean acres?
- How much can rebates for using residual herbicides on RR soybeans increase their use?
Early Estimates Of RR Soybean Benefits

- Partial Budget Analysis
- Profit Function Estimation

Found small or no benefit!

But why then has adoption been so rapid?
Further Research Found Non-Pecuniary Benefits Are Important

- Simplicity
- Convenience
- Flexibility
- Crop, Worker, & Environmental Safety
- Time Savings
- Compatibility With Conservation Tillage
Non-Pecuniary Benefit Affect On Farmer Decisions  
(Following Piggott & Marra 2008)

\[
\max_{x, A^B, A^{B1}} U(x) q(A^B, A^{B1})
\]

subject to

\[
P^x x = p^y f(A^{B0}, A^{B1}, A^C) - \left(r^A + r^{RR}\right) A^B - r^H A^{B1} - r^A A^C
\]

Consumption Good

Yield

Prices

Total Acres

Conventional Acres

RR Acres

Without Residual

With Residual
Non-Pecuniary Benefit Affect On Farmer Decisions  
(Following Piggott & Marra 2008)

Profit Maximizing Conditions

\[ p^y \left( \frac{\partial f}{\partial A^{B_0}} - \frac{\partial f}{\partial A^{C}} \right) = r^{RR} \]

\[ p^y \left( \frac{\partial f}{\partial A^{B_1}} - \frac{\partial f}{\partial A^{B_0}} \right) = r^H \]

Utility Maximizing Conditions

\[ p^y \left( \frac{\partial f}{\partial A^{B}} - \frac{\partial f}{\partial A^{C}} \right) + p^x \frac{\partial U}{\partial q} \frac{\partial x}{\partial U} \frac{\partial q}{\partial U} = r^{RR} \]

Non-Pecuniary Benefit of RR Acres

\[ p^y \left( \frac{\partial f}{\partial A^{B_1}} - \frac{\partial f}{\partial A^{B}} \right) + p^x \frac{\partial U}{\partial q} \frac{\partial x}{\partial U} \frac{\partial q}{\partial U} = r^H \]

Non-Pecuniary Benefit of RR Acres  
With Residual Herbicide

Partial Budgets & Profit Functions Do Not Quantify  
All of the Benefits
How can we quantify all benefits?

- Direct Elicitation
- Indirect/Contextual Elicitation
  - Model Solution: Acreage Demand
  - Why not elicit demand & calculate consumer surplus?
- Need to Determine Demand Response to Price
**U.S Soybean Grower Data**

- **Telephone Survey:** Nov. & Dec. 2007
  - 402 Growers, 317 With Complete Information, 309 Grew At Least Some RR Soybean & Were Used in Analysis
  - 10 States: AR (4%), IL (17%), IN (10%), IA (18%), MN (14%), MO (9%), NE (9%), ND (5%), OH (7%), SD (6%)

- **USDA/NASS Crop Acreage**
  - Ten-Year County Average & Standard Deviation of Yield
Surveyed Soybean Growers by County
Survey Instrument

- General Farmer & Operation Information
- 2007 Production Practices
- Weed BMP Use
- Factors Influencing Herbicide Choices
- 2008 Production Plans
  - Total Acres
  - RR Acres
  - RR Acres Treated With Residual Herbicide
- Change In 2008 Production Plans For
  - Change In RR Seed Price
  - Decrease In Residual Herbicide Cost
- Biggest Weed Management Concerns
Estimating Farmer Benefits

- Farmers asked their planned 2008 RR and conventional corn/soybean acres and RR corn/soybean acres with a residual herbicide.
- How will these acreages change if the price of RR seed changed or the price of residual herbicide changed a few dollars per acre.
- From acreage shifts to (hypothetical) price changes, derive value of RR crop using “consumer surplus”.
- “Contextually stated preferences”
  - Farmers give more reasonable results than when ask them directly: “What’s RR corn/soybeans worth to you?”
For the next few questions, please think about how your current plans for the 2008 season might change if your cost for Roundup Ready [crop] seed increased by [$] per acre.

22a. If the cost for Roundup Ready [crop] seed increased by [$] per acre, would you plan to plant Roundup Ready [crop] next year in 2008?


22c. [If RR less than 100% of crop acres >> ask:] And, given this price change, how many acres of conventional herbicide [crop] would you plan to plant in 2008? That is, [crop] that is not Roundup Ready or LibertyLink or AgriSure?

Randomly assigned $2, $4 or $6/Acre Increase

Randomly assigned $1, $2, $3, or $4/Acre Decrease
250 acres

$2/ac

Consumer Surplus

RR Acres

Seed Price

$2/ac

Δ50 ac

Area A + B + C = \frac{1}{2} \times 250 \times 10 = $1250 or $5/ac

Reported acreage at hypothetical higher price

Don’t need to know current price, just how they respond to a price change

Current acreage at current price

Area A + B is “Consumer Surplus” with linear demand

Dollar value a farmer gets from RR crop

C

250 acres

Δ50 ac

A

B

Δ$2/ac

RR Acres
Lower bound on CS based on raw data

Estimated average CS with linearity

Estimated Lower bound on CS without linearity
Descriptive Statistics: Mean (St. Dev.)

- Planned Soybean Acres: 607 (433)
- Planned RR Soybean Acres: 594 (437)
  - 98% Of All Soybean Acres
  - 0.0% No RR Acres, 93.5% Only RR Acres
  - 30.3% Used Residual, 63.1% No Residual,
    23.9% Applied Residual To All Acres

- Controls
  - Education (Years): 13.9 (1.8)
  - Experience Farming (Years): 29.1 (10.5)
  - 2007 Crop Acres: 1,274 (839)
  - County Average Yield (bu/ac): 41.0 (5.9)
  - County Average Yield CV: 0.135 (0.04)
  - Concerned About Weed Resistance: 0.54
### Acreage Changes with Price Changes

#### RR Acres

<table>
<thead>
<tr>
<th>RR Cost Δ</th>
<th>% Growers</th>
<th>Acres</th>
<th>% Total Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>+2/A</td>
<td>9.7</td>
<td>63.9</td>
<td>8.6</td>
</tr>
<tr>
<td>+4/A</td>
<td>16.2</td>
<td>61.2</td>
<td>8.7</td>
</tr>
<tr>
<td>+6/A</td>
<td>28.4</td>
<td>105</td>
<td>17.9</td>
</tr>
</tbody>
</table>

#### RR Acres With Residual

<table>
<thead>
<tr>
<th>Residual Cost Δ</th>
<th>% growers</th>
<th>Acres</th>
<th>% Total Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1/A</td>
<td>18.0</td>
<td>78.5</td>
<td>10.6</td>
</tr>
<tr>
<td>-2/A</td>
<td>23.5</td>
<td>93.1</td>
<td>12.0</td>
</tr>
<tr>
<td>-3/A</td>
<td>19.5</td>
<td>83.6</td>
<td>12.3</td>
</tr>
<tr>
<td>-4/A</td>
<td>20.6</td>
<td>64.8</td>
<td>11.4</td>
</tr>
</tbody>
</table>

No grower said they would increase RR acres with an increase in the RR seed price or decrease RR acres with a residual with a decrease in the residual herbicide price.
Empirical Strategy

- Jointly Estimate 2 RR Acres & 3 RR Acres with Residual equations, with censoring
- Seemingly Unrelated Interval Regression
  - STATA xtintreg
    - Uses Quadrature to Approximate Integrals
    - Restricted Error Covariance Matrix: RR and RR w/ residual independent, homoscedastic, RR w/ residual had same covariance
  - STATA Custom Simulated ML Program
    - Use Geweke-Hajivassiliou-Keane Method to Approximate Integrals
    - Estimates Unrestricted & Restricted Error Covariance Matrix
## Selected Coefficient Estimates (t-statistics) for RR Acres

<table>
<thead>
<tr>
<th></th>
<th>Restricted</th>
<th></th>
<th>Unrestricted</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>xtingreg</td>
<td>SML</td>
<td>SML</td>
<td></td>
</tr>
<tr>
<td><strong>RR Seed Price</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$2 Increase</td>
<td>-598***</td>
<td>-598***</td>
<td>-146</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3.79)</td>
<td>(3.79)</td>
<td>(0.41)</td>
<td></td>
</tr>
<tr>
<td>$4 Increase</td>
<td>-662***</td>
<td>-661***</td>
<td>-187</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(4.69)</td>
<td>(4.69)</td>
<td>(0.55)</td>
<td></td>
</tr>
<tr>
<td>$6 Increase</td>
<td>-1,042***</td>
<td>-1,042***</td>
<td>-588*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(6.37)</td>
<td>(6.37)</td>
<td>(1.79)</td>
<td></td>
</tr>
<tr>
<td><strong>Joint Price Tests</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Effect - ( \chi^2(3) )</td>
<td>47.44***</td>
<td>47.48***</td>
<td>8.16**</td>
<td></td>
</tr>
<tr>
<td>Constant Effect - ( \chi^2(2) )</td>
<td>7.48**</td>
<td>7.49**</td>
<td>6.53**</td>
<td></td>
</tr>
<tr>
<td>Linear Effect - ( \chi^2(2) )</td>
<td>3.13</td>
<td>3.14</td>
<td>1.40</td>
<td></td>
</tr>
<tr>
<td><strong>2007 Crop Acres</strong></td>
<td>0.332***</td>
<td>0.332***</td>
<td>0.387***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3.88)</td>
<td>(3.87)</td>
<td>(4.07)</td>
<td></td>
</tr>
<tr>
<td><strong>Resistance Concerns</strong></td>
<td>130</td>
<td>129</td>
<td>79.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.87)</td>
<td>(0.87)</td>
<td>(0.54)</td>
<td></td>
</tr>
</tbody>
</table>

*** Significant at 1%. ** Significant at 5%. * Significant at 10%.
### Selected Coefficient Estimates (t-statistics) for RR Acres with Residual

<table>
<thead>
<tr>
<th>Residual Herbicide Price</th>
<th>Restricted xtingreg</th>
<th>SML</th>
<th>Unrestricted SML</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1$ Decrease</td>
<td>564***</td>
<td>564***</td>
<td>465***</td>
</tr>
<tr>
<td></td>
<td>(5.09)</td>
<td>(5.08)</td>
<td>(3.12)</td>
</tr>
<tr>
<td>$2$ Decrease</td>
<td>516***</td>
<td>516***</td>
<td>557***</td>
</tr>
<tr>
<td></td>
<td>(5.36)</td>
<td>(5.36)</td>
<td>(4.28)</td>
</tr>
<tr>
<td>$3$ Decrease</td>
<td>514***</td>
<td>514***</td>
<td>537***</td>
</tr>
<tr>
<td></td>
<td>(5.03)</td>
<td>(5.02)</td>
<td>(4.01)</td>
</tr>
<tr>
<td>$4$ Decrease</td>
<td>570***</td>
<td>570***</td>
<td>496***</td>
</tr>
<tr>
<td></td>
<td>(5.01)</td>
<td>(5.01)</td>
<td>(3.32)</td>
</tr>
</tbody>
</table>

**Joint Price Tests**

<table>
<thead>
<tr>
<th></th>
<th>Restricted xtingreg</th>
<th>SML</th>
<th>Unrestricted SML</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Effect - $\chi^2(4)$</td>
<td>76.17***</td>
<td>76.08***</td>
<td>36.34***</td>
</tr>
<tr>
<td>Constant Effect - $\chi^2(3)$</td>
<td>0.27</td>
<td>0.27</td>
<td>0.30</td>
</tr>
<tr>
<td>Linear Effect - $\chi^2(3)$</td>
<td>17.31***</td>
<td>17.29***</td>
<td>9.34**</td>
</tr>
</tbody>
</table>

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### Selected Coefficient Estimates (t-statistics) for RR Acres with Residual

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<td></td>
<td>xtingreg</td>
<td>SML</td>
<td></td>
<td>SML</td>
</tr>
<tr>
<td>$2 Increase</td>
<td>-81.2</td>
<td>-81.1</td>
<td>-83.2*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.83)</td>
<td>(0.83)</td>
<td>(1.65)</td>
<td></td>
</tr>
<tr>
<td>$4 Increase</td>
<td>-100</td>
<td>-100</td>
<td>-109*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.08)</td>
<td>(1.07)</td>
<td>(1.83)</td>
<td></td>
</tr>
<tr>
<td>$6 Increase</td>
<td>-51.2</td>
<td>-51.3</td>
<td>-116**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.54)</td>
<td>(0.54)</td>
<td>(2.24)</td>
<td></td>
</tr>
<tr>
<td><strong>Joint Price Tests</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Effect - $\chi^2(3)$</td>
<td>1.87</td>
<td>1.86</td>
<td>6.52*</td>
<td></td>
</tr>
<tr>
<td>Constant Effect - $\chi^2(2)$</td>
<td>0.15</td>
<td>0.15</td>
<td>0.31</td>
<td></td>
</tr>
<tr>
<td>Linear Effect - $\chi^2(2)$</td>
<td>0.66</td>
<td>0.66</td>
<td>0.99</td>
<td></td>
</tr>
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<tbody>
<tr>
<td></td>
<td>xtingreg</td>
<td>SML</td>
</tr>
<tr>
<td>County Yield Average</td>
<td>88.6***</td>
<td>88.4***</td>
</tr>
<tr>
<td></td>
<td>(3.63)</td>
<td>(3.63)</td>
</tr>
<tr>
<td>County Yield CV</td>
<td>7,897**</td>
<td>7,867**</td>
</tr>
<tr>
<td></td>
<td>(2.35)</td>
<td>(2.35)</td>
</tr>
<tr>
<td>Resistance Concerns</td>
<td>797***</td>
<td>795***</td>
</tr>
<tr>
<td></td>
<td>(3.49)</td>
<td>(3.48)</td>
</tr>
</tbody>
</table>

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Summary

- RR acres, own price effect: negative, non-constant across prices, could be linear
  - Larger farms have larger own price effects
  - No effect from concern about resistance
- RR acres w/ residual, residual price effect: negative, could be constant across prices, not linear
- RR acres w/ residual, own price effect: negative, could be constant across prices, could be linear
  - Larger own price effects if: More productive county, Riskier county, Concern about resistance
With 69.6 million acres of RR soybean planted in 2008, our raw data implies benefits of at least $225 million, while our linear estimates imply benefits of $1.2 billion.
### Potential For Rebates To Increase Residual Herbicide Use

<table>
<thead>
<tr>
<th>Variable</th>
<th>Observed: No Rebate</th>
<th>Estimated: No Rebate</th>
<th>Estimated: Change With $1 Rebate</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR Acres Treated with a Residual Herbicide (Average Acres)</td>
<td>180</td>
<td>176</td>
<td>92.0</td>
</tr>
<tr>
<td></td>
<td>[142, 212]</td>
<td>[57.4, 127.6]</td>
<td></td>
</tr>
<tr>
<td>RR Acres Treated with a Residual Herbicide (% RR Soybean Acres)</td>
<td>30.3</td>
<td>30.1</td>
<td>15.7</td>
</tr>
<tr>
<td></td>
<td>[24.4, 36.2]</td>
<td>[9.8, 21.8]</td>
<td></td>
</tr>
<tr>
<td>All RR Acres Treated with a Residual Herbicide (% Growers)</td>
<td>23.9</td>
<td>26.2</td>
<td>17.3</td>
</tr>
<tr>
<td></td>
<td>[20.7, 31.7]</td>
<td>[12.0, 23.0]</td>
<td></td>
</tr>
<tr>
<td>No RR Acres Treated with a Residual Herbicide (% Growers)</td>
<td>63.1</td>
<td>60.8</td>
<td>-11.3</td>
</tr>
<tr>
<td></td>
<td>[54.7, 66.7]</td>
<td>[-17.2, -5.50]</td>
<td></td>
</tr>
</tbody>
</table>

Effects estimated using model with non-positive own-price effects imposed and Monte Carlo simulation with 10,000 replications.
Summary & Conclusions

- What are the benefits to farmers of RR soybeans?
  - Surveyed farmers expected benefits of at least $3.23 per acre in 2008.
  - Our best estimate of these benefits was $17.02 per acre.
  - To the extent our sample was representative, our best estimate implies $1.2 billion in expected benefits in 2008.
Summary & Conclusions

- How are weed resistance concerns affecting RR soybean acres and use of residual herbicides on RR soybean acres?
  - While a slight majority of surveyed farmers expressed concerns about weed resistance going into the 2008 growing season, this did not appear to dissuade their plans to use RR soybeans.
  - Alternatively, these concerns did persuade them to plan to treat more of their RR acres with residual herbicides.
Summary & Conclusions

- How much can rebates for residual herbicides on RR soybeans increase use?
  - Our best estimate suggest a small rebate ($1/A) would have increased residual herbicide use on RR acres by about 50% in 2008
  - These estimates also suggest that substantially higher rebates (> $4/A) would be needed to further increase residual herbicide use
  - Consistent with Monsanto increasing its 2011 $3/A rebate to $10/A in 2012
More Work To Be Done

- More Explicit Theoretical Links For Econometric Model
- Incorporate More Information Into Estimates
- Explore Other Strategies to Promote Sustainable Use of RR Soybean & Other RR Crops
- Revisit these questions and others since the severity of the glyphosate resistant weed problem has only continued to grow since 2008
Acknowledgments

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Thank You For Your Attention!
Questions or Comments?