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

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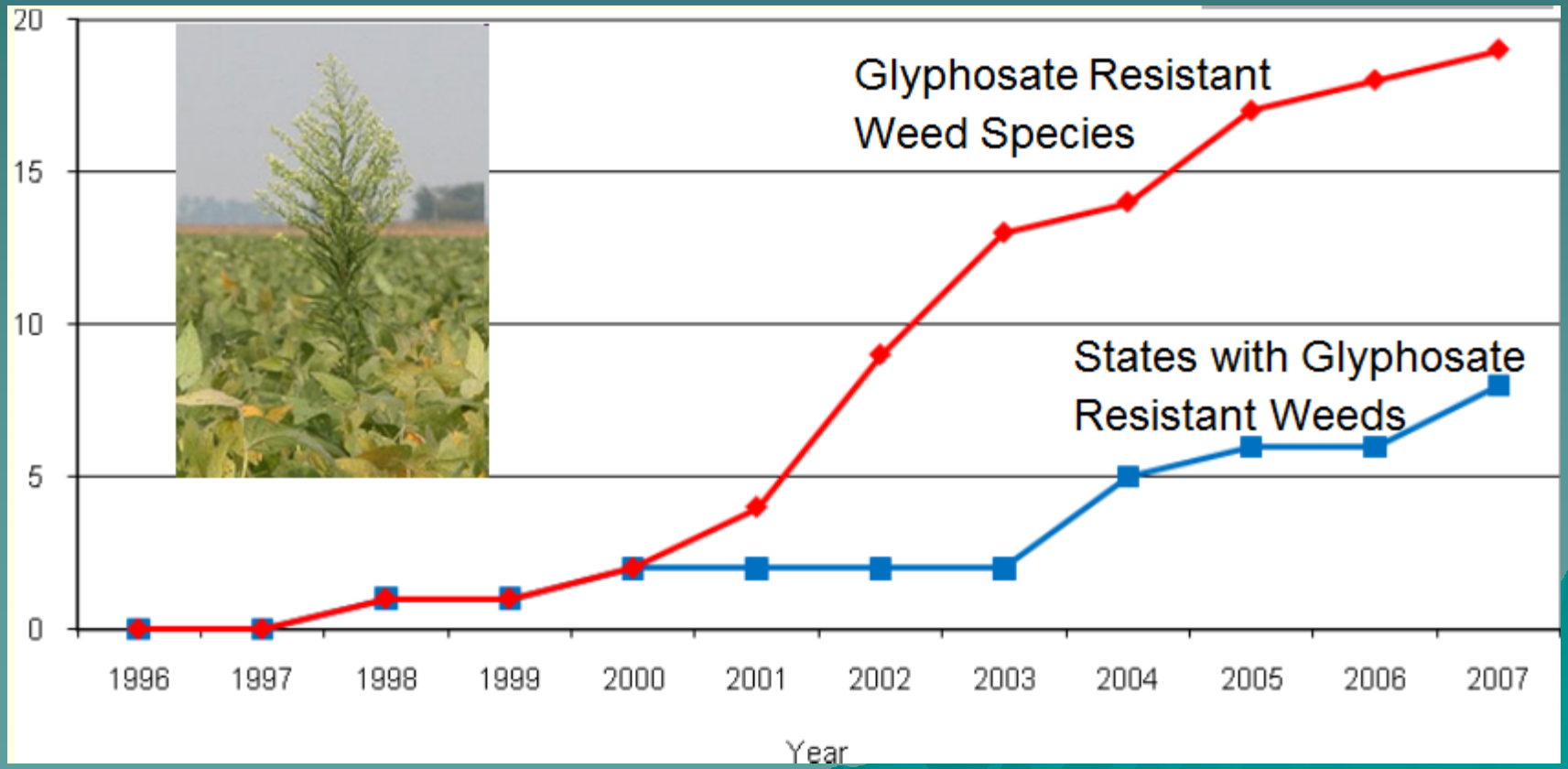
Roundup Ready® (RR) Soybean

- 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!

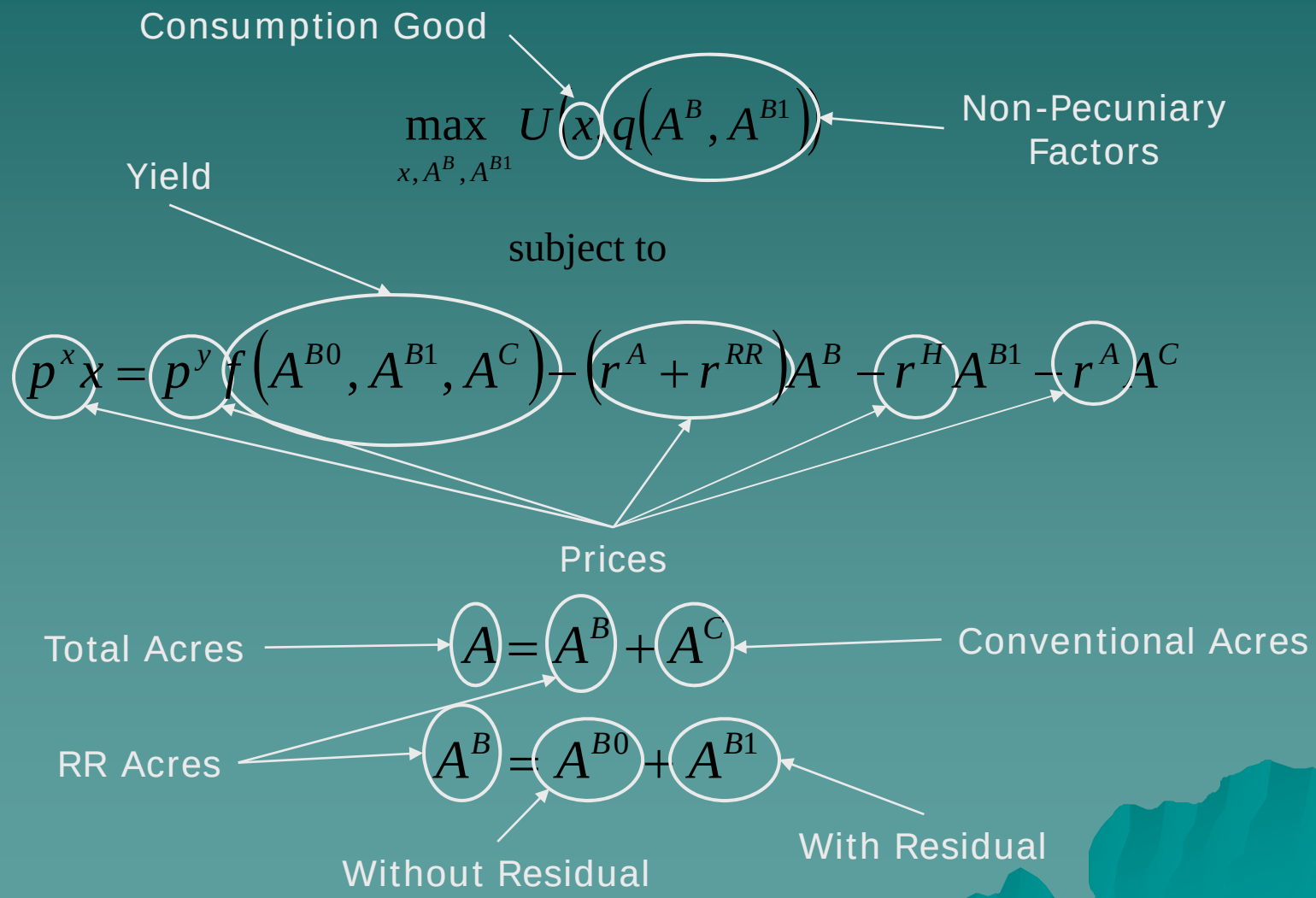
But why then has adoption been so rapid?

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)



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

Profit Maximizing Conditions

$$p^y\left(\frac{\partial f}{\partial A^{B0}}-\frac{\partial f}{\partial A^C}\right)=r^{RR}$$

$$p^y\left(\frac{\partial f}{\partial A^{B1}}-\frac{\partial f}{\partial A^{B0}}\right)=r^H$$

Utility Maximizing Conditions

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

Non-Pecuniary Benefit of RR Acres

$$p^y\left(\frac{\partial f}{\partial A^{B1}}-\frac{\partial f}{\partial A^B}\right)+p^x\frac{\partial U}{\partial q}\frac{\partial x}{\partial U}\frac{\partial q}{\partial A^{B1}}=r^H$$

Non-Pecuniary Benefit of RR Acres With Residual Herbicide

Partial Budgets & Profit Functions Do Not Quantify All of the Benefits

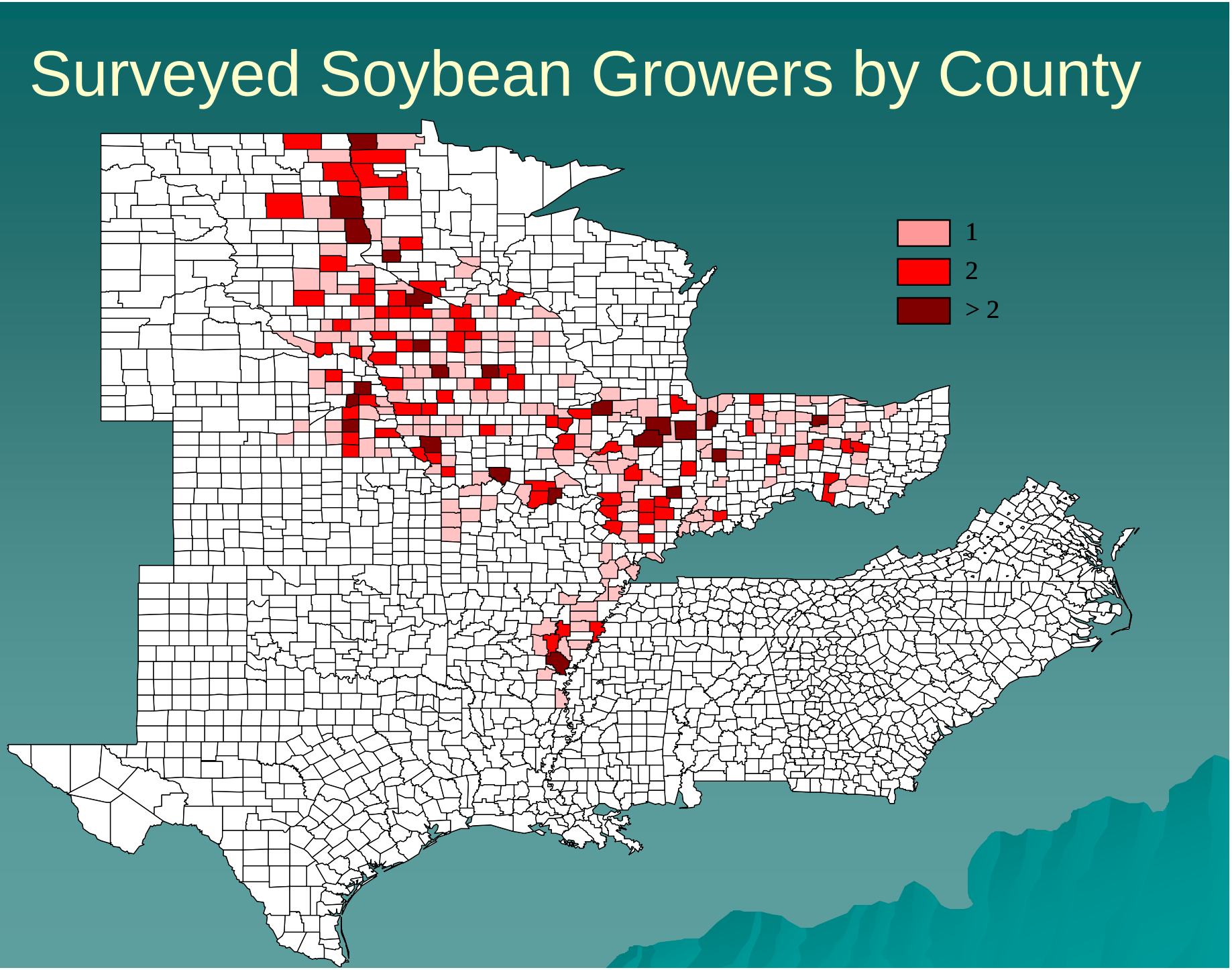
How can we quantify all benefits?

- 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

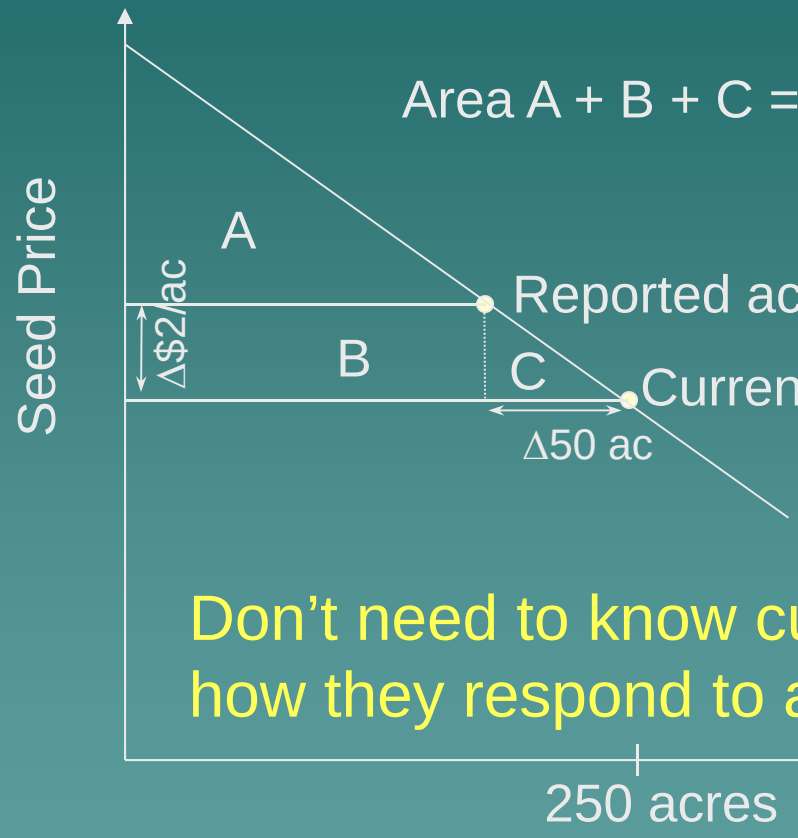
Estimating Farmer Benefits

- 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?"

Telephone Survey Script

- 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?
- 22b. **[If "yes" in Q.22a >> ask:]** How many acres of Roundup Ready **[crop]** would you plan to plant next year? Remember, you earlier indicated that you currently plan to plant **[Q.17]** acres of Roundup Ready **[crop]** 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

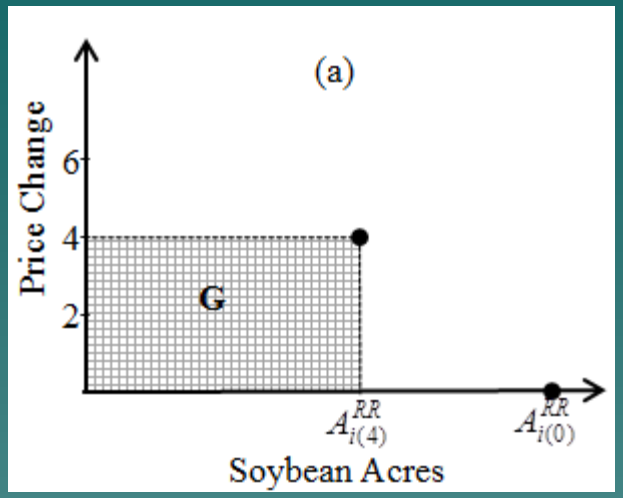
Consumer Surplus



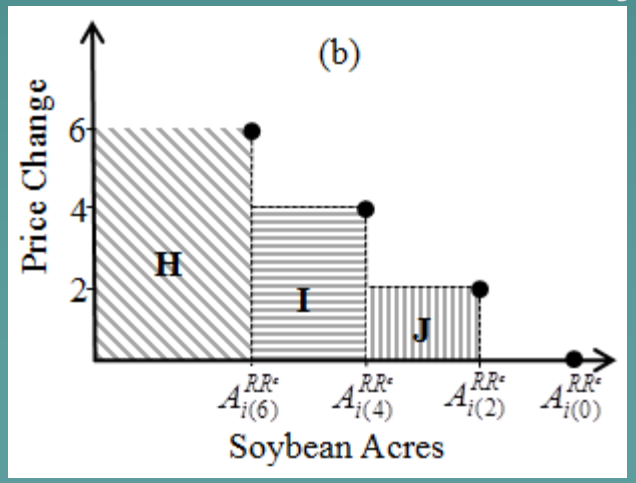
Area A + B is "Consumer Surplus" with linear demand

Dollar value a farmer gets from RR crop

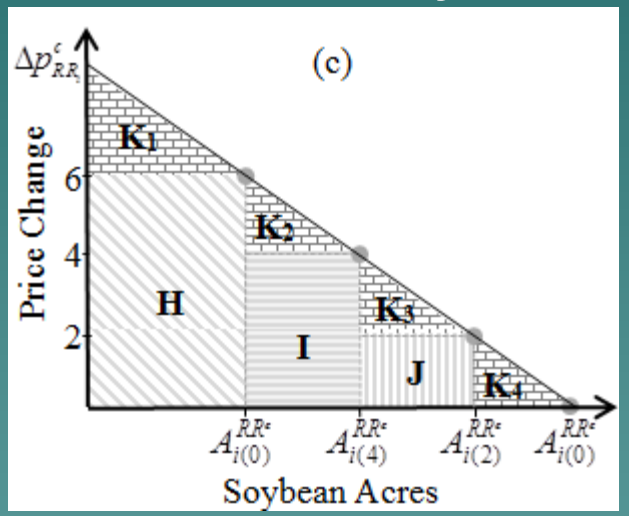
Lower bound on CS based on raw data



Estimated Lower bound on CS without linearity



Estimated average CS with 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

RR Cost Δ	% Growers	Acres	% Total Acres
+2/A	9.7	63.9	8.6
+4/A	16.2	61.2	8.7
+6/A	28.4	105	17.9

RR Acres With Residual

Residual Cost Δ	% growers	Acres	% Total Acres
-1/A	18.0	78.5	10.6
-2/A	23.5	93.1	12.0
-3/A	19.5	83.6	12.3
-4/A	20.6	64.8	11.4

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

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

*** Significant at 1%. ** Significant at 5%. * Significant at 10%.

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

	Restricted		Unrestricted
	xtingreg	**SML**	**SML**
Residual Herbicide Price			
$1 Decrease	564***	564***	465***
	(5.09)	(5.08)	(3.12)
$2 Decrease	516***	516***	557***
	(5.36)	(5.36)	(4.28)
$3 Decrease	514***	514***	537***
	(5.03)	(5.02)	(4.01)
$4 Decrease	570***	570***	496***
	(5.01)	(5.01)	(3.32)
Joint Price Tests			
No Effect - $\chi^2(4)$	76.17***	76.08***	36.34***
Constant Effect - $\chi^2(3)$	0.27	0.27	0.30
Linear Effect - $\chi^2(3)$	17.31***	17.29***	9.34**

*** Significant at 1%. ** Significant at 5%. * Significant at 10%.

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

	Restricted		Unrestricted
	xtingreg	**SML**	**SML**
RR Seed Price			
$2 Increase	-81.2	-81.1	-83.2*
	(0.83)	(0.83)	(1.65)
$4 Increase	-100	-100	-109*
	(1.08)	(1.07)	(1.83)
$6 Increase	-51.2	-51.3	-116**
	(0.54)	(0.54)	(2.24)
Joint Price Tests			
No Effect - $\chi^2(3)$	1.87	1.86	6.52*
Constant Effect - $\chi^2(2)$	0.15	0.15	0.31
Linear Effect - $\chi^2(2)$	0.66	0.66	0.99

*** Significant at 1%. ** Significant at 5%. * Significant at 10%.

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

	Restricted		Unrestricted
	xtingreg	**SML**	**SML**
County Yield Average	88.6***	88.4***	84.8***
	(3.63)	(3.63)	(3.53)
County Yield CV	7,897**	7,867**	8,052**
	(2.35)	(2.35)	(2.37)
Resistance Concerns	797***	795***	811***
	(3.49)	(3.48)	(3.58)

*** Significant at 1%. ** Significant at 5%. * Significant at 10%.

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

Consumer Surplus Per RR Soybean Acre: Mean [Confidence Interval]

CS Lower Bound	Mean	Lower	Upper
Raw Data	$3.23		
Estimated without linearity	$4.41	$1.93	$5.14
Average CS	**Mean**	**Lower**	**Upper**
Estimated with linearity	$17.02	$9.44	$27.48

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

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

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

Support for this project was provided by the Arizona, Minnesota, and Wisconsin Experiment Stations, Harvest Choice (www.harvestchoice.org), and Monsanto. The authors gratefully acknowledge the helpful comments and data collection efforts of Michelle Obermeier-Starke, John Soteres, and other researchers at Monsanto. All conclusions and any remaining errors are the authors'.

Thank You For Your Attention!
Questions or Comments?