The Role of Financial Engineering and Risk Management in Agriculture

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Outline

- I. Financial Engineering at MSU
- II. Some Examples of Financial Engineering Research
- III. The Future Role of Risk Management in Agriculture

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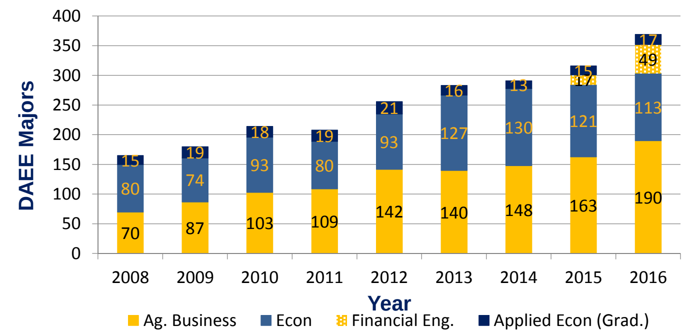
Number of DAEE Students



Second majors are those double majoring in a discipline outside the DAEE and with a second major in the DAEE. Roughly 85% of these are double majors with economics, with the remaining 15% double majors with agricultural business.

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Skills Taught in the EFIN Curriculum

- Intensive math and statistics training.
- Computer programming and software development.
- Economics and financial theory.
- Data analytics.

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Specific Topics Covered in EFIN Classes

- Option and Exotic Option pricing (Black-Scholes, Binomial Pricing, Monte Carlo Methods).
- Commodity Price Dynamics (Markov Processes, ARMA, GARCH, etc.).
- Assessment of univariate and multivariate risks (Copulas).
- Data Management and Analytics.

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Examples of Where Graduates Work?

- Agricultural Insurance.
- Asset Management.
- Manufacturing optimization.
- Graduate students in financial math.

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Example 1: Upside Grain Contracts

- Development of new forward contracts that allow for
  - Downside risk protection
  - Upside risk potential
- Prospect Theory (Kahneman and Tversky, 1976).
- Many of these contracts are offered without taking on additional risk.
- These contracts allow for contracts to be written to emulate what producers want.

"Upside-Risk" Insurance Products

- Harvest Price Products from RMA
  - Liability Established at higher of pre-planting Projected Price or Harvest Price
  - Originally proposed as private wrap-around that protected a forward contracting producer if yields fell below delivery contract levels in a year when prices increased due to a short crop.
- Private wrap-around products that potentially establish insurance liability at higher levels than RMA's product.
  - Producers pay full price plus loads on private products.

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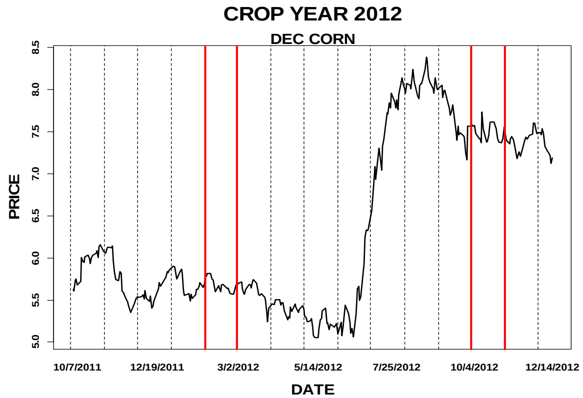
DEC CORN FUTURES PRICES



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New Generation Contracts

- Often broken into three categories
  - Automated pricing
  - Managed hedging
  - Combination contracts
- Offered by several companies, each with its own twist on the contract

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New Generation Contracts

- The contract follow predetermined pricing rules
- Often sold in set bushel increments, like futures and options, with a specified delivery period
- Some have exit clauses (depending on price)

Automated Pricing

- Examples:
  - AgriVisor – Index
  - E-Markets – Market Index Forward
  - Cargill – PacerPro or Market Ultra
  - CGB – Equalizer Traditional
  - CHS/CHI – Compass Averaging Contracts
  - CHS/CHI – Foundation Contract (Grain Seller)
  - CHS/CHI – Modified Capped Average (Grain Buyer)
  - Various companies with Minimum/Maximum Contracts

CargillAg.com

Cargill

Pacer Ultra™

How does it work?

As the market moves, Pacer Ultra™ uses the higher of the market close or the pre-determined floor price to establish each day's averaging points during the pricing period:

Upside Potential Contract Example

- Contract Initiation Date 6/1/2015
- Chicago Dec 2015 Corn Contract
- 6/1/2015 Dec 2015 Price = $3.69
- Contract to Deliver 15,000 bushels on 9/15/2015
- 60 Day Averaging Period = 6/15/2015 to 9/8/2015
- Effectively selling 250 bushels each day of averaging period.
- Price Floor = $3.70 (“in the money” 1 cent)
- Right to “Price Out” remaining bushels on any day in averaging period
- Cost ~ $0.26 or 26 cents per bushel
  - (Price of call option ($0.25) at K = $3.70 + the amount “in the money” ($0.01))
  - Worst case price received = $3.70 - $0.26 = $3.44

Upside Potential Contract Example

- For each day in the averaging period, the price paid to the producer for that day's "sales" of 250 bushels is maximum of $(F_t, \$3.70)$.
- If the price reaches a high enough level that the producer chooses to "price out" at that price, the producer receives the "price out" price on all remaining "unsold "bushels in the contract.

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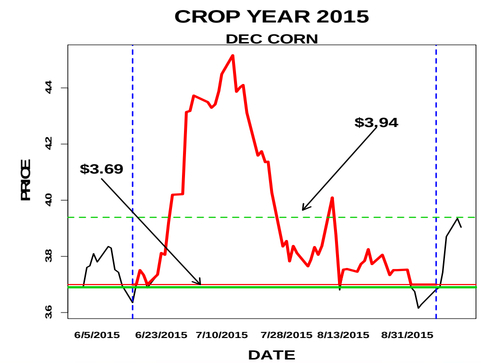
Upside Delivery Contract Example

No Early "Price Out" -- $3.94 Average $3.69 NET



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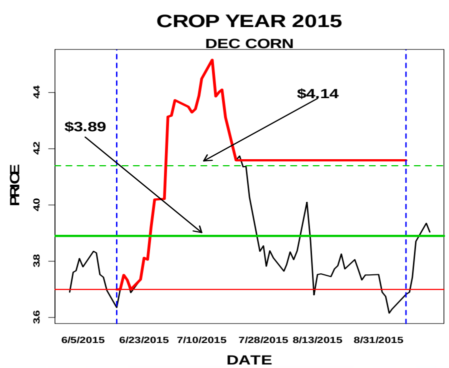
Upside Delivery Contract Example

"Price Out" on ???at $4.16 → $4.14 Average $3.89 NET



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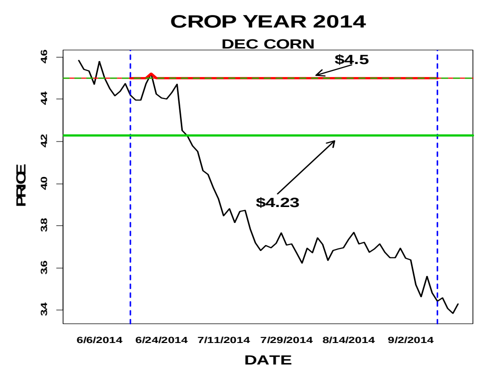
Upside Delivery Contract Example

$4.50 Price Floor → $4.50 Average $4.23 NET



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Summary of Upside Contract Specs and Outcomes

Year	2012	2014	2015
60-Day Averaging Period	6/15/2012 – 9/10/2012	6/16/2014 – 9/9/2014	6/15/2015 – 9/8/2018
Futures Price at Initiation (June 1)	5.10	4.59	3.69
Contract Price Floor	5.10	4.50	3.70
Price at End of Averaging Period	7.82	3.43	3.91
Strike of call option	5.10	4.50	3.70
Cost of option	0.41	0.36	0.25
In the moneyness	0.00	-0.09	+0.01
Total Premium rate	0.41	0.27	0.26
Augmented Average	7.46	4.50	3.94
Effective Price	7.05	4.23	3.69

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Upside Delivery Contract Example
Buyer's Perspective

- Costs must cover buyer's cost to hedge risk
- Commonly little or no initial per bushel charge except for cost of call option.
- Buyers can hedge by:
  - long call and short futures 15,000 bushels on day 0
  - Close out 250 bushels of option position each day of averaging period. (Sell 250 bushels calls each day)
  - Close out futures position on delivery date.

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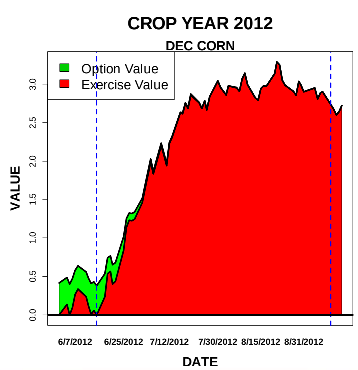
Buyer Hedge Profits

(4.3 Cents – Average Profit)



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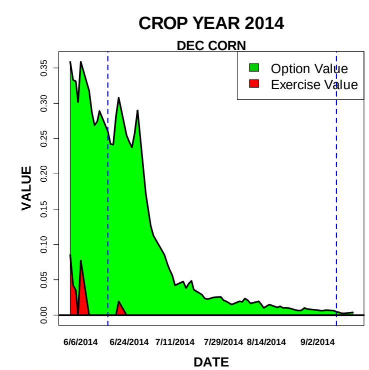
Buyer Hedge Profits

(7 Cents Average Profit)



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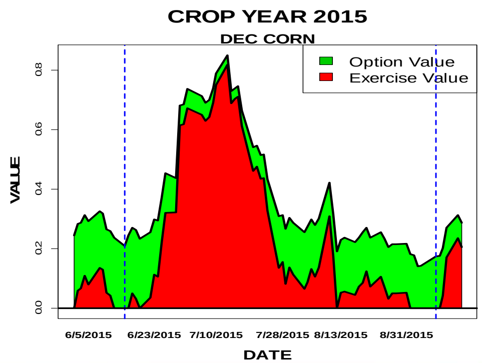
Buyer Hedge Profits

(14 Cents - Average Profit Per Bushel)



Simulated 2017 Corn Price Data

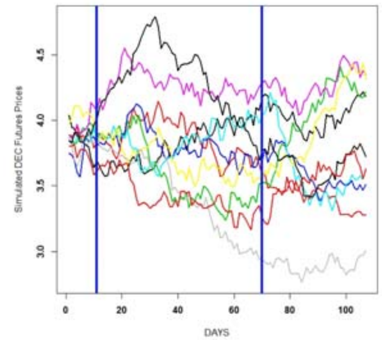


Figure 3. First 10 out of 10,000 trajectory simulations for corn price movements, assuming contract specifications from a 2017 corn contract.

Simulated Payoff from Option Strategies for Closing Option Accounts

Strategy	Mean	5%	25%	50%	75%	95%
Exercised	15.5	0.0	0.3	6.5	23.7	59.1
Sold	30.5	7.7	16.1	26.3	40.4	67.9
Profit (Sold – Exercised)	15.0	6.4	11.7	15.7	18.8	21.3

Note: Profits are expressed as the difference between selling and exercising a call option an every day since exercising the option would result in a perfect hedge for the upside grain contract.

Upside-Risk Delivery Contracts

- Numerous other contracts exist with increased complexity but customizable to meet needs and desires of producer.
- Potential for significant upside while truncating downside risk.
- Comes at a cost --- prices must increase sufficiently to cover hedging costs.
- Competition is providing incentives for grain buyers to innovate to compete.
- Producers can obtain sophisticated products not available in the traded exchanges while also benefiting from the buyer’s lower transaction costs.

Example 2: Weather Derivative Crop Insurance

- Coupling weather and production data to accurately predict yields at a low cost.
- Abundance of weather data.
- Developing availability of production and land-use data.
- May result in insurance that reduces moral hazard and administrative costs.

Steps to Develop Crop Weather Derivative

- Characterize and estimate functional form to relate weather and yields.
- Simulate farm-level performance of proposed program.
- Compute total cost of administering derivative program.
- Compare derivative product to existing Revenue Protection policy.

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Weather and Yield Data

- Weather station data collected through NOAA's Daily Global Historical Climatology Network (GHCN) dataset.
  - Data are aggregated to the county level.
  - For counties with less than 3 stations, nearest stations are used.
  - Monthly Growing Degree Days (GDD) and Total Precipitation are computed.
- County-level detrended yields.
- All variables are standardized as Z-score.
- Top 5 production states for corn, cotton, soybeans, and wheat.

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Yield Regression

The following indices were computed for the county, agricultural district, and state:

$$IP_{Git} = GDD_{Git} * (-PRCP_{Git})$$
$$IS_{Git} = GDD_{Git} - PRCP_{Git}$$

where

$$GDD_{dit} = max\left(\frac{T_{min} + T_{max}}{2} - 50, 0\right)$$
$$GDD_{Git} = max\left[\frac{\left(\sum_{d=1}^{D} GDD_{dit}\right) - mean(GDD_{Gi})}{std(GDD_{Gi})}, 0\right]$$
$$PRCP_{Git} = min\left[\frac{\left(\sum_{d=1}^{D} PRCP_{dit}\right) - mean(PRCP_{di})}{std(PRCP_{di})}, 0\right]$$

for G =two-month time period, i =county, d =day, t =year.

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Yield Regression

$$Y_{it} = \beta_0 + \beta_1 IS_{Git} + \beta_2 IS_{Git}^2 + \beta_3 IP_{Git} + \beta_4 IP_{it} + \beta_5 IP_{it}^2 + \beta_6 IP_{At} + \beta_7 IP_{At}^2 + \beta_8 IP_{St} + \beta_9 IP_{St}^2 + e_{it}$$

- Y_{it} is the standardized yield deviations for county i in year t.
- Regressions run separately by state.
- i =county, A =Agricultural district, S =State.

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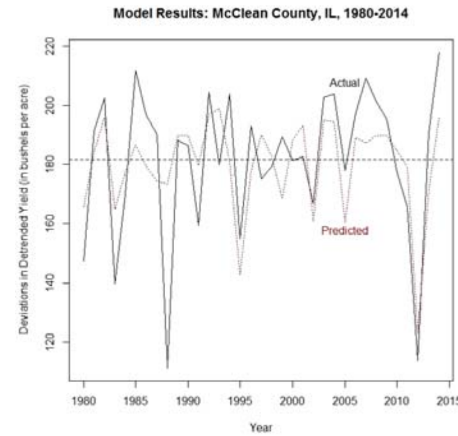

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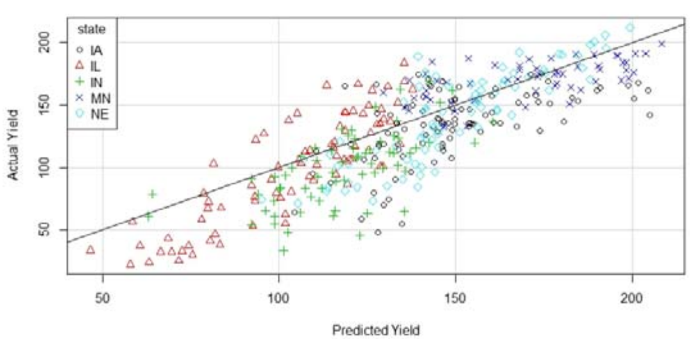
Ability to Predict Corn Yields



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Simulated Insurance Prem. and Rev.

Scenario	FP Premium Per Acre	Premium Subsidy Per Acre[a]	Average Total Rev. Per Acre	95% CI Rev. Per Acre	COV Total Rev Per Acre
Corn					
No Insurance	——	——	739	[257; 1,286]	0.36
RP Insurance	15.46	22.27	761	[528; 1,271]	0.28
Free Index RP	0.00	15.56	755	[333; 1,289]	0.33
Soybeans					
No Insurance	——	——	480	[150; 871]	0.39
RP Insurance	10.06	14.91	495	[328; 861]	0.31
Free Index RP	0.00	8.86	488	[176; 873]	0.37

Note: All insurance premiums assume a 70% coverage rate. 2016 RMA Base prices are assumed.
[a] Simulations are based on a representative farmer in each included county/crop combination.

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Simulated Insurance Prem. and Rev.

Scenario	FP Premium Per Acre	Premium Subsidy Per Acre[a]	Average Total Rev. Per Acre	95% CI Rev. Per Acre	COV Total Rev Per Acre
Winter Wheat					
No Insurance	——	——	265	[31; 564]	0.54
RP Insurance	10.37	14.92	280	[175; 553]	0.40
Free Index RP	0.00	10.00	275	[61; 566]	0.49
Cotton					
No Insurance	——	——	420	[37; 992]	0.69
RP Insurance	21.14	30.42	451	[263; 971]	0.50
Free Index RP	0.00	33.23	452	[84; 994]	0.57

Note: All insurance premiums assume a 70% coverage rate. 2016 RMA Base prices are assumed.
[a] Simulations are based on a representative farmer in each included county/crop combination.

Simulated Insurance Prem. and Rev.

Indicator	Corn	Soybeans	Wheat	Cotton
Average Premium Subsidy Per Acre (70% Coverage Level)[a]				
RP Insurance	22.27	14.91	14.92	30.42
Free Index RP	15.56	8.86	10.00	33.23
% Reduction with Free Index RP	30.13	40.58	32.98	9.24
2016 RMA Enrolled Acres (M)	82.15	73.26	42.81	9.44
Estimated Cost of RMA RP ($B)[b]	2.88	1.72	1.01	0.45
Cost of Free Index RP ($B)[c]	1.47	0.75	0.49	0.36
Savings ($B)	1.41	0.98	0.51	0.09
Change in Downside Risk Protection (%)	-37	-46	-65	-52

Note: All insurance premiums assume a 70% coverage rate on RP policies. 2016 RMA Base prices are assumed.
[a] Simulations are based on a representative farmer in each included county/crop combination.
[b] Figures based on simulated RP premium rates applied to all enrolled acres and include average A&O and underwriting gains as a percent of total premium. Average A&O and underwriting gains, as a percentage of total premium, are based on historical averages shown in table 8 and are respectively 12% and 15%.
[c] Figures based on simulated Free Index RP premium rates applied to all enrolled acres and include average A&O expenses as a percent of total premium.

Use of Index Insurance

- Methods still have plenty of room for improvement.
  - Triangulation between weather stations to improve data at a point.
  - More disaggregated production/land-use data needed.
- Index can be computed more accurately at any point to reduce basis risk.
- Index insurance can be offered at a substantially lower price than individual insurance products.

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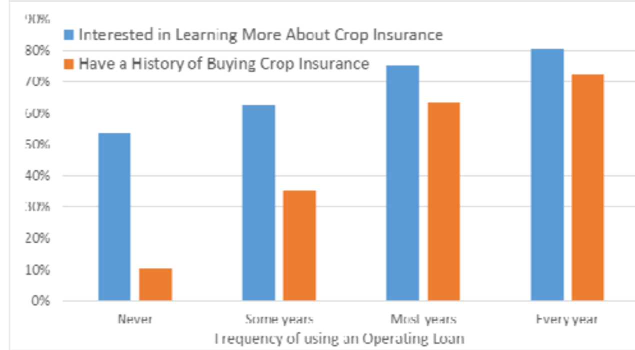
The Future Role of Risk Management in Agriculture

1. Continued relationship between lending and risk management
   – Debt-to-Asset ratios positively related to crop insurance participation (Bekkerman, Belasco, and Watson, 2015).
   – Use of operating loans are a primary determinant for crop insurance participation (Belasco, working paper)

Operating Loans and Crop Insurance



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Logit Regression Results: Crop Insurance Participation.

Variable	Estimate	Standard Error	T Value	P value
Any Certified Organic Acres	1.359	0.573	2.374	0.018
Percentage of Certified Acres	-0.007	0.006	-1.114	0.265
Adjusted Gross Income (in $10,000s)	0.012	0.006	2.033	0.042
Amount of Acres (in 1,000 Acres)	0.262	0.178	1.474	0.141
Different Number of Products Produced	-0.015	0.009	-1.607	0.108
Organic Experience (in years)	-0.015	0.016	-0.945	0.345
Farming Experience (in years)	0.027	0.013	2.155	0.031
Is an Operating Loan Commonly Used?	1.359	0.295	4.601	0.000
High Value or Specialty Crops	-0.693	0.328	-2.112	0.035
Hogs	-1.232	0.546	-2.255	0.024

Note: Other variables include an intercept, Willingness to Pay for crop insurance, other crop types. Grains/Legumes are excluded crop.

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The Future Role of Risk Management in Agriculture

2. Better methods and access to weather/production data should allow for reduction of basis risk in index insurance products
   – Pasture, Rangeland, and Forage insurance.
   – Livestock Forage Protection program.
   – Crop index insurance product (Belasco, Cooper, and Smith, working paper)
      • Weather station data can be triangulated to provide unique weather outcomes at a point.
      • More production data needed to refine regressions.

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The Future Role of Risk Management in Agriculture

3. Constant fiscal pressure to reduce administrative costs on crop insurance without reducing benefits to farmers/ranchers.
   - Index products are heavily used on other countries due to reduced cost of delivery.
   - Individual insurance eliminates most basis risk, but comes with a high administrative cost.
   - Returns going to insurance company reinsurers constantly under fire.

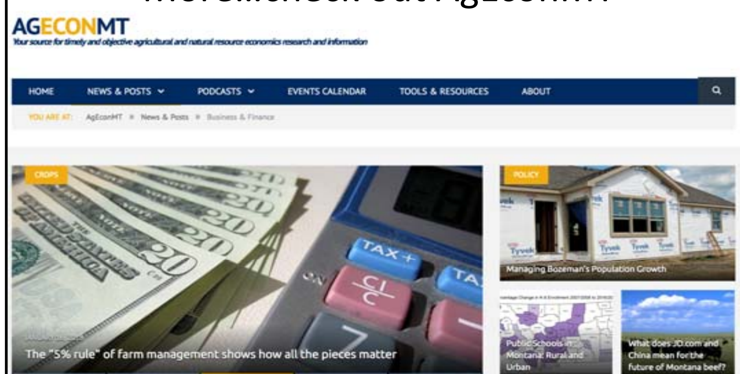
The Future Role of Risk Management in Agriculture

4. Continued development new exotic insurance and marketing products.
   - Privately developed "wrapper" products used with RMA products.
   - Upside risk products.
   - Lower priced crop insurance products.

The Future Role of Risk Management in Agriculture

5. Future farm bills will take longer than expected to complete.

For More Details on These Issues and More…check out AgEconMT



Thank you for your time.

Questions, comments, feedback?

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