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# Simulating Crop Insurance Demand Under Prospect Theory

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# Why Prospect Theory?

Expected utility bad at predicting observed crop insurance buyup behavior.

- Babcock, Choi & Feinerman (JARE, 1993)

Prospect theory may do a better job.

- Babcock (AJAE, 2015):
  - "narrow framing" aspect drives most accurate demand predictions, where farmers view crop insurance as standalone investment or lottery (ignoring hedge).

 $v(x) = (x-r)^{1-\sigma}$  if  $x \ge r$ , else  $-\lambda(r-x)^{(1-\sigma)}$ 

$$\pi(p) = \frac{p^{\gamma}}{\left(p^{\gamma} + (1-p)^{\gamma}\right)^{\frac{1}{\gamma}}}$$

Kahneman & Tversky (1979)

$$\pi(p) = \exp\left(-\left(-\ln p\right)^{\alpha}\right)$$

Prelec (1998)

$$\pi(p) = \frac{\delta p^{\gamma}}{\delta p^{\gamma} + (1-p)^{\gamma}}$$

Goldstein & Einhorn (1987)

## Crop Insurance and CPT

Key question: what is a loss?

Broad Framing: farmers recognize value of a hedge.

$$x - r'' = Y - E[Y] + I - p$$

Narrow framing: insurance is a standalone gamble.

$$x - r'' = I - p$$

### The Value Function

- Insurance guarantee, G (e.g., G = 0.75 E[Y])
- Indemnity,  $I = (G Y)^+$
- Premium, p(G)
- Narrow framing, so insurance is **not** a hedge.

$$V(G) = w(1 - F(G)) \cdot v^{-}(-p(G))$$
  
+ 
$$\int_{y=G-p(G)}^{G} \frac{\partial w}{\partial F}(1 - F(y))f(y) \cdot v^{-}(G - p(G) - y)dy$$
  
+ 
$$\int_{y=0}^{G-p(G)} \frac{\partial w}{\partial F}(F(y))f(y) \cdot v^{+}(G - p(G) - y)dy$$

#### The Value Function, Detail

$$w(1-F(G))\cdot v^{-}(-p(G))$$

- Atomic point representing discrete probability of losing the full premium.
- Small, but the most extreme loss w/ narrow framing.
- Always underweighted, so long as  $Pr(I = 0) > e^{-1}$ .

#### The Value Function, Detail II

$$\int_{y=G-p(G)}^{G} \frac{\partial w}{\partial F} \left(1 - F(y)\right) f(y) \cdot v^{-} \left(G - p(G) - y\right) dy$$

- Range of small losses where 0 < I < p(G).
- Can be over/under-weighted depending on slope of *w*.
  - e.g., likely over-weighted if Pr(I = 0) > 0.75, since w' > 1 in that region.
- Risk-lovingness in loss domain (convexity of *v*<sup>-</sup>) means this value lies above (less negative than):

$$v^{-}\left(G - p(G) - E_{w}\left[y \middle| 0 < I < p(G)\right]\right)$$

#### The Value Function, Detail III

$$\int_{y=0}^{G-p(G)} \frac{\partial W}{\partial F} (F(y)) f(y) \cdot v^{+} (G - p(G) - y) dy$$

- Range of gains from indemnity payoff, I > p(G)
- Over-weighted in the tails relative to higher probability, but smaller gains
- Induces bias towards lower coverage, e.g., F(G) < 0.20.
- Risk-aversion in gainsdomain (concavity of  $v^+$ ) means this value lies below (less positive than):

$$v^{+}\left(G-p(G)-E_{w}\left[y|I>p(G)\right]\right)$$

# Simulating Weights

Babcock (2015) introduces a simulation method similar to expected utility simulation, except cumulative weights accumulate separately, and from the extremes, for both losses and gains.

Babcock's Method:

- Simulate the ECDF, yielding *N* = *m* losses and *n* gains.
- For losses, i = 1, ..., m:

$$f(x_i) = w(Pr(x \le x_i)) - w(Pr(x < x_i))$$
$$= w(i/N) - w(i/N - 1/N)$$

- For gains, 
$$j = m + 1, ..., m + n$$
:  

$$f(x_j) = w(Pr(x \ge x_j)) - w(Pr(x > x_j))$$

$$= w((N + 1 - j)/N) - w((N - j)/N)$$

# Simulating Weights, II



# A Simple Example

- Revenues ~ N(4, 1)
- Coverage = 75% (i.e., *G* = 3)
- Fair Premium
- Prelec weighting function, a = 0.7
- Narrow framing

# Example ECDF



75% Coverage Level

## Example ECDF



100% Coverage Level

## Simulation Parameters

#### **Table 1. Parameterizations and Premium Rates for Representative Farms**

	Corn York Co, NE	Wheat Sumner Co, KS	Cotton Lubbock Co, TX
Type of Insurance	Revenue	Revenue	Yield
Expected Yield	190 bu/ac	33 bu/ac	650 lb/ac
Expected Price	\$4.40/bu	\$8.77/bu	\$0.55/lb
Price Volatility	37%	33%	25%
Price-Yield Correlation	0	-0.3	0
Premium Rate			
$\alpha = 0.50$	0.010	0.098	0.089
$\alpha = 0.55$	0.016	0.115	0.102
$\alpha = 0.60$	0.024	0.134	0.114
$\alpha = 0.65$	0.035	0.154	0.128
$\alpha = 0.70$	0.048	0.174	0.141
$\alpha = 0.75$	0.064	0.195	0.155
$\alpha = 0.80$	0.083	0.217	0.169
$\alpha = 0.85$	0.104	0.239	0.183
Yield Parameters			
Maximum	250	80	1338
Minimum	0	0	0
Shape1	9.340	1.938	1.363
Shape2	2.949	2.760	1.444

Note: Yields are assumed to follow a beta distribution and prices follow a log-normal distribution.