Basis Risk and Effectiveness of Rainfall Index Insurance for Pasture, Rangeland and Forage

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Rainfall Index Insurance for Pasture, Rangeland and Forage (PRF-RI)

1. In 2007, the Risk Management Agency (RMA) launched a pilot program to provide insurance for pasture, rangeland, or forage acres.
2. RMA developed insurance based on rainfall and vegetation indices which would serve as proxy measures for forage yields (vegetation index program is no longer available) - we focus on "Rainfall Index Insurance"

Research Questions

1. How large is the basis risk for the PRF-RI program?
2. How much of the basis risk can be reduced?

How PRF-RI Works

1. An operator chooses coverage level (70%-90%), which is a share of historical average rainfall for the grid that operator is located, and assigns dollars to several 2-month intervals to be covered by PRF-RI.
2. If the rainfall index falls below the guarantee for some 2-month intervals the operator chose, the operator gets paid proportional to the value he assigned to those intervals.
3. Premium is highly subsidized (ranges from 51 to 59%).
4. In 2016, about 52 million acres enrolled (low participation rate).

Precipitation, Rainfall Index Insurance and Forage Yields

1. Relationship between monthly precipitation and forage yields: Precipitation in April to May (Lee and Boe 2005), April to June (Smart et al. 2005) and May to July (Smoliak 1986) explain forage yields.

2. Rainfall Index Insurance in US
    1. Optimal choice of PRF-RI: Diersen et al. (2015) suggests May-June interval would have highest weights to minimize the variance of producers' returns.
    2. Effectiveness of RI Annual Forage Program (Maples et al. 2016)
    3. Impacts on farmland values (Ifft et al. 2014)

Basis Risk for Index Insurance

1. Basis risk reduces the demand for index insurance (e.g. Clarke 2016; Elabed et al. 2013).
2. Several studies estimate the degree of basis risk for weather derivative or index insurance (e.g. Jensen et al. 2016; Woodard and Garcia 2008). **Estimates on the basis risk for PRF-RI has not documented.**

Basis Risk for PRF-RI

Basis risk for PRF-RI has two sources:

1. Yield variations that are not explained by actual precipitation (Non-precipitation Risk)
2. Measurement error on precipitation, i.e. imperfect correlations between PRF rainfall indices and actual precipitation (Index risk)

How We Measure Basis Risk in PRF-RI

1. Non-precipitation risk: We use errors in predicting yields using actual precipitation.
2. Index risk: We use the difference between the errors in predicting yields using PRF Rainfall Indices and the errors in predicting yields using actual precipitation.

Data

1. We use annual forage yields and monthly precipitation data from two university ranches (Barta Brothers Ranch and Gudmundsen Sandhills Laboratory of University of Nebraska-Lincoln).
   1. Barta Brothers Ranch: Data spans from 1999 to 2015. We have plot-level data from 9 plots.

      (N=93, mean of total forage=1,728lb/acre)

   2. Gudmundsen Sandhills Laboratory: Data spans from 2004 to 2015. We only have ranch-level data.

      (N=12, mean of total forage=1,843lb/acre)

2. PRF indices of each 2-month interval for corresponding years and grids are obtained from RMA.

Estimation Equations

1. Yields and Actual Precipitation

$$Yield_{it} = \beta_0 + \sum_{k=1}^{12} \beta_{lag\ k} Precipitation_{kit-1} + \sum_{k=1}^{12} \beta_k Precipitation_{kit} + \gamma_i + \delta_t + \varepsilon_{it}$$

2. Yields and PRF Indices

$$Yield_{it} = \beta_0 + \sum_{k=1}^{11} \beta_k PRF_{kit} + \gamma_i + \delta_t + \varepsilon_{it}$$

Two Approaches

1. Ordinary Least Squares
2. Regularization Method - Elastic Net Penalty

Elastic Net Penalty (Zou and Hastie 2005)

Let Y and X be the vectors of dependent and independent variable. The vector of coefficients is B and p is the number of regressors. Then, the elastic net estimator is

$$\hat{B} = arg\ min_{\beta}\{|Y - XB|^2\}$$
$$subject\ to\ (1-\alpha)\sum_{j=1}^{p}|\beta_j| + \alpha\sum_{j=1}^{p}{\beta_j}^2 \leq s$$

Cross-validation

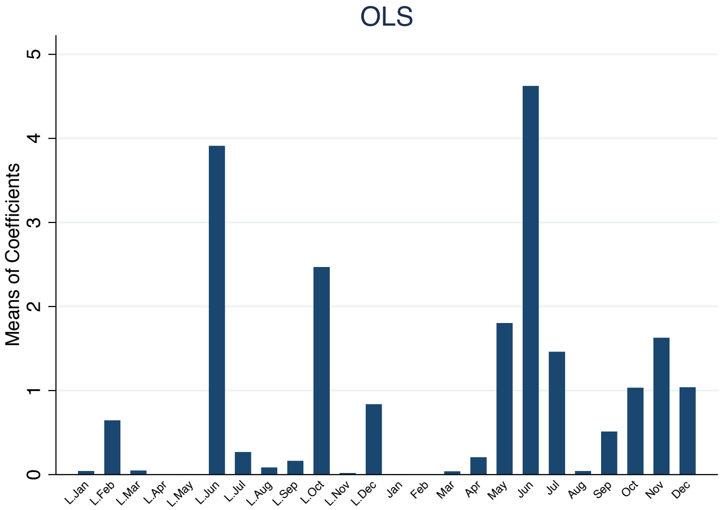
1. Step 1: We partition our data into training and test datasets. We randomly draw $N * 1/10$ from our sample and assign them as the "test" dataset. Remaining is the "training" dataset.

2. Step 2: We fit our models to the "training" dataset.

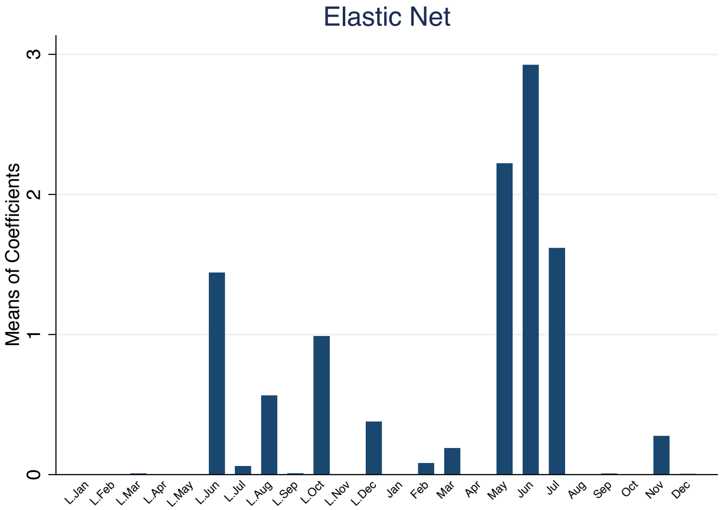
3. Step 3: We compute Root Mean Square Errors (RMSE) using the "test" dataset.

4. Step 4: We repeat Steps 1 through 3 hundred times. We report the means of coefficients and the means of RMSE.

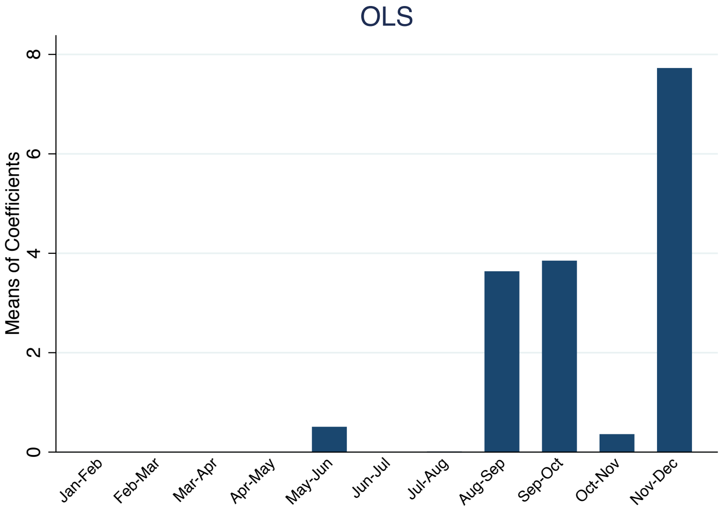
Yields and Actual Precipitation: OLS



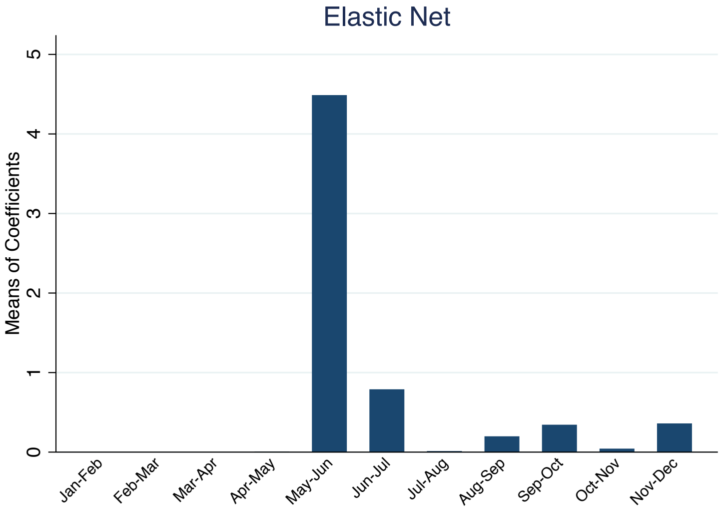
Yields and Actual Precipitation: Elastic Net



Yields and PRF Indices: OLS



Yields and PRF Indices: Elastic Net



Root Mean Square Errors and the Magnitude of Basis Risk

Table: Root Mean Square Errors

	Models	
Explanatory Vars.	OLS	Elastic Net
Precipitation	275.35	260.08
PRF without Lags	303.45	318.32

Discussion

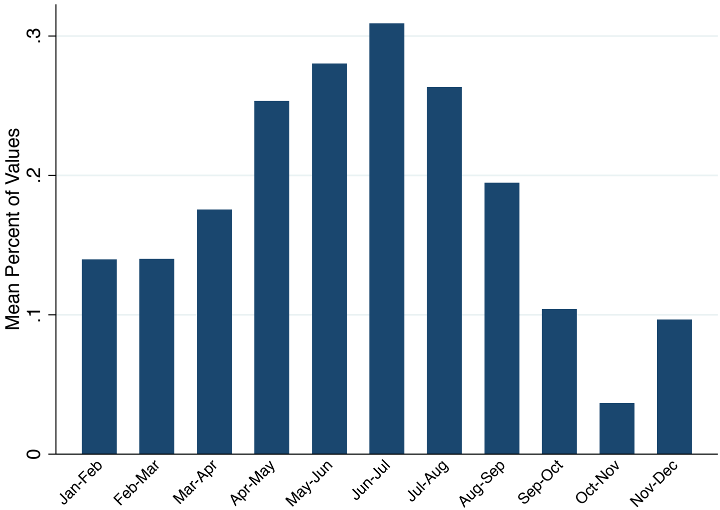
1. Which months' precipitation matter most?

   Elastic net selects precipitation in May, June and July.

2. Can the basis risk for PRF-RI be reduced?

   Index risk is about 12% of overall basis risk. How much of these can be eliminated?

Ranchers' Actual Choices: 2013-2017



Preliminary Conclusions

1. Precipitation in May - July matters most. The PRF program has a room to improve.
2. Ranchers' choices are different from so-called "optimal" interval choices: This indicates that the actual basis risk is higher.
3. Can we/should we modify the PRF program in a way to reduce the basis risk?: Possible options are restricting the two-month intervals to the growing season, including the previous year's precipitation, and improving precipitation measures.

Future Researches

1. Explore ranchers' choices on a) the participation and b) the choices on the two-month intervals.
2. Improve the forage yield - precipitation model: consider nonlinear precipitation impacts or separate responses across warm-season and cool-season forage.
3. More data: Another ranch in Hays, Kansas

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