Premium Rate Adequacy of Rainfall Index Insurance: A Case of Cyclic Weather Pattern and Current Rating Methodology

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Selected Poster prepared for presentation at the 2023 Agricultural & Applied Economics Association Annual Meeting, Washington DC: July 23- 25, 2023

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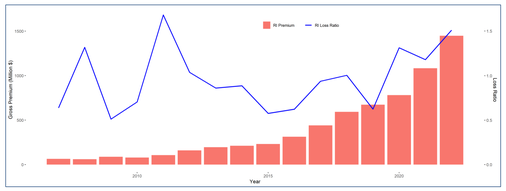
Abstract

- Rainfall index has grown to become one of the most popular insurance products offered by the U.S. crop insurance program
- As a result of poor loss performance and observed rating inefficiencies of this insurance, we conducted research to evaluate the statistical properties of rainfall index
- We also assessed the premium rate with current methodology and investigated an alternative rating method
- We found a very strong trend in the rainfall index from 1990 onward and also a significant serial correlation
- Premium rates are found to be inadequate in most of the rainfall grids where exposure is aggregating and should be as much as 20% higher from current premium rate

Introduction

- Rainfall Index (RI) insurance is the only parametric coverage plan offered by Risk Management Agency (RMA) for Pasture, Rangeland, and Forage (PRF), Annual Forage, and Apiculture
- RI premium rate is based on the percent of rainfall deviation from average from the year 1948 for rainfall grid for a set of 2 months interval. Each grid covers an area equal to .25 degrees in latitude by .25 degrees longitude.
- With 16 years of RI experience, this program grew significantly from $63 million to 1.4 billion premium.

Fig 1: Rainfall Index Historical Experience



- A study commissioned by Risk Management Agency (RMA) found that frequency of indemnification is very large with 70 to 90 percent of policies having a claim (Coble et. al 2020).
- Time Series data of weather variables are likely to have trend, serial correlation and cyclical pattern (Kaylen and Koroma, 1991) which increases the amplitude of swings in precipitation index causing over and under insurance
- Past research suggested existence of serial correlation (Sun, Rodrick, and Farquhar, 2017) and trend in weather data that has potential to generate biased premium rate (Adhikari, Knight, Belasco, 2011)
- This study is intended to uncover the rating inefficiencies in precipitation index used for RI rating that may be exploited and threaten the long-term adequacy and sustainability of the program

Methodology

- This research uses the case of Rainfall index insurance offered by RMA for PRF and uses the grided rainfall index data for the year 2022
- We hypothesize that premium rate is not actuarially fair since there is evidence of exposure aggregation and the rainfall index time series suffered from issues of serial correlation, trend, cyclic weather patterns, and inconsistent rain gauge density.
- We used area plan indemnity function to calculate the expected indemnity and premium rate: E (I_{ilt})/ G

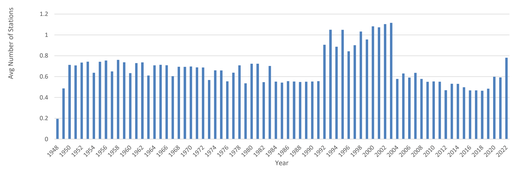
  $I_{iit} = Max(0, G - PI_{it})/G$

  where, I as indemnity, G is guaranteed index which is equivalent to coverage level, and PI is actual precipitation index, subscripts i stands for i^{th} grid and t^{th} year.
- Assuming linear trend $PI_{it} = \alpha + \beta t_i + \varepsilon_{it}$ and with serial correlation $\varepsilon_{it} = \delta + \gamma\varepsilon_{it-1}$. Therefore, indemnity and rate are biased
- We conducted this study for the entire rainfall grid and index interval. However, for the ease of presenting result we aggregate to county and state level
- Results are presented in table, charts, and map at the state and county level

Results

- Precipitation data's rain gauge networks varied over time. The averaged weather stations varied in number by year and location (Fig 2). Therefore, average precipitation from weather stations for any grid from year to year can be influenced by the quantity of gauges, the physical location, and elevation of gauges.

Fig 2: Average Number of Rain-Gauge Density by Year



- Historical precipitation is known to have serial correlation ((Sun, Rodrick, and Farquhar, 2017) and so does the precipitation index
- We aggregate the precipitation index at the state level weighted by county level 2022 RI premium and estimated the serial correlation for five major states
- We found a very strong positive and negative serial correlation exists

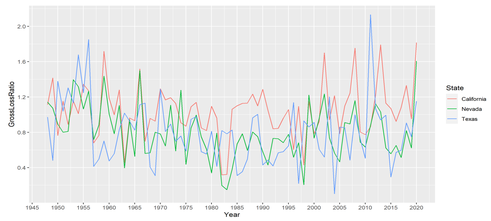
Table 1: Serial Correlation in Precipitation Index

State	Serial Correlation Order 1	Order 2	Order 3
Arizona	-0.38	-0.20	0.36
Nevada	-0.66	0.77	-0.94
New Mexico	-0.17	0.53	0.14
Oregon	-0.93	0.85	0.09
Texas	0.82	0.30	0.15

Results

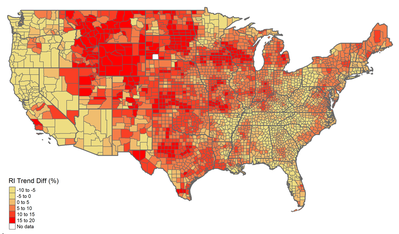
- Loss ratio was computed from 1948 to 2022 based on grided rainfall index as if it was an insurance year for 85% coverage level
- Aggregated loss ratio at the state level showed a clear pattern of weather cycle (1940 – 1970, 1970- 1990, and 1990- 2022) with distinctly different loss ratio pattern
- From 1990 onward there is strong positive trend in loss ratio in three major states suggesting likelihood of higher loss ratio in the years to come

Fig 3: Loss Ratio from As If Analysis



- We attempted to evaluate the trend in rainfall by estimating linear trend prior to and after1990.
- There are very strong trends in grids and intervals where PRF and annual forage exposure are aggregating (Fig 4)
- Ignoring trends observed in the data leads to rating inefficiencies that can lead to an increase in loss ratio and cost of the program

Fig 4: Trend Difference before and after 1990



- In order to segregate the impact of trend in precipitation index, we estimated the premium rate from the entire time series and also by dividing time series prior to 1990 and 1991 onwards
- For ten major states, the premium rate from entire time series is very closely similar to the rate from time series prior to 1990
- The premium rate calculated from 1991 to 2022 rainfall index is significantly different than premium rate from other two time series (Table 2)

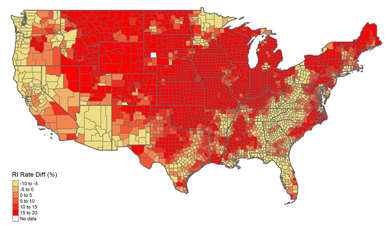
Table 2: Premium Rate Differences

State	Premium Rate 1948 - 2022	Premium Rate 1948 - 1990 (R1)	Premium Rate 1991 - 2022 (R2)	Rate Difference (R1 - R2)/R1
Texas	19.0%	19.6%	18.1%	-7.4%
Nevada	23.8%	23.5%	24.4%	4.0%
Arizona	26.2%	24.6%	28.4%	15.4%
Oregon	16.1%	15.9%	16.5%	4.3%
New Mexico	21.6%	21.7%	21.6%	-0.6%
Florida	12.0%	11.5%	12.7%	10.2%
California	32.5%	32.1%	33.2%	3.4%
Colorado	15.8%	17.6%	13.3%	-24.4%
Idaho	15.8%	16.9%	14.2%	-16.0%
Utah	18.3%	19.1%	17.3%	-9.6%

Results

- The map (Fig 5) highlights rating inefficiencies in general and reveals that premium rate in most of the locations are not adequate and it should be as much as 20% higher from the current premium rate
- Biases in the premium might be contributing to exposure aggregation where rating inefficiencies are most prominent leading to higher effective coverage levels, increased claim frequency and overall inadequate performance of Rainfall Index insurance
- Biases in the premium might be contributing to the larger frequency of claim and overall performance of Rainfall Index insurance

Fig 5: Premium Rate Differences with and without trend



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Conclusion

- RMA commissioned an expert review of the program which does not address the rating inefficiencies and inconsistencies and rain-gauge density
- Studies in statistical properties of weather variables suggested existence of serial correlation, trend, and cyclic weather pattern
- Based on finding of this research, our recommendation is to review the rating procedure and make adjustment to the rainfall index
- Addressing Data Inconsistencies in rain gauge density by incorporating trend, cycles, or alternative lengths in the time-series
- Rate inadequacies can be address though either proper weighting or providing some sort of load in the premium rate
- All the inferences are made from RMA's rainfall index 2022 data for this research and may not be generalized for any other purpose.
- Further research could be explored to see if the intervals insured are related to rangeland grazing or if there is a bias toward subsidy maximization

References

Adhikari S., Knight, T. O. and E, J, Belasco. 2011. The Impact of Weather Cycles and Crop Yield Autocorrelation on Crop Insurance Yield Guarantees. Selected Paper prepared for presentation at the Agricultural & Applied Economics Association's 2011 AAEA & NAREA Joint Annual Meeting, Pittsburgh, Pennsylvania, July 24-26, 2011

Coble K., B. Goodwin, M.F. Miller, R. Rejesus, A. Harri, and D. Linton. 2020. Review of the Pasture, Rangeland, Forage Rainfall Index Crop Insurance Program Indexing and Rating Methodology Final Report, Risk Management Agency of USDA

Kaylen, M. S. and S. S. Koroma. "Trend, Weather Variables and the Distribution of U.S. Corn Yields". Rev. of Agric. Econ. 13/2(1991) 249-258.

Suna, F., M. L., Rodrick and G. D. Farquhar. 2017. "Rainfall statistics, stationarity, and climate change" PNAS, Vol: 15, No. 10: 2305-2310