Models for Crop Insurance Indemnities

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Overview

Introduction

- From 2007 to 2016, the federal crop insurance title had the second-largest outlays in the farm bill, after nutrition
- The total net cost of the program for crop years 2007-2016 was about $72 billion (Rosa, Isabel)

Overview

Why is Crop Insurance Important?

- Financially protects farmers from loss of crop and revenue
- All consumers benefit from a secure agriculture industry
- Ratemaking and reserving are important problems in actuarial science
- Dependence models may influence the reserving of insurance companies

Overview

Causes of Loss

- Weather: rain, temperature, length of growing season
- Bacteria, viruses, pests
- Implies that insurance amounts may differ between regions and peril types
- Different causes of losses may influence the dependence of policyholders

Overview

What is an Indemnity?

- A safeguard against loss
- In terms of US crop insurance: a payment made when crop yields under-perform
- USDA RMA authorizes 15 private companies to provide insurance

Overview

The Goal

- To predict indemnity amounts for specific farms based on region, commodity grown, and peril types
- To illustrate that spatial dependence matters, in terms of the aggregate loss, and should influence the operation of an insurance company
- To show that the risk capital that insurance companies should prepare will be influenced by this dependence

Data

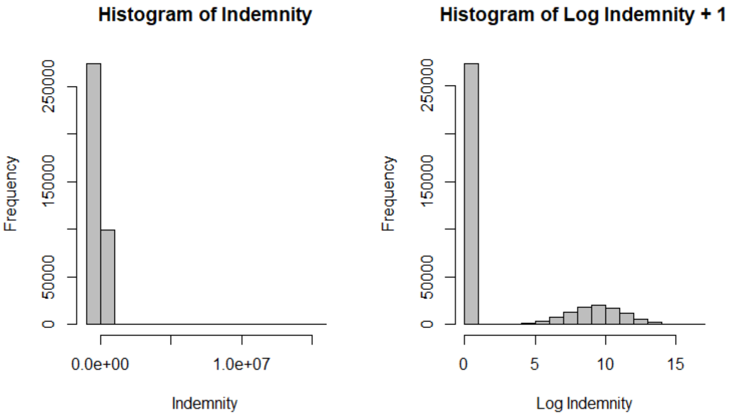
Overview of Data Aggregated by State

State	Farms	Indemnity Amount	Liability Amount	Zeros
MI	8804	90308988	1932773671	6506
OH	8436	56665925	3289548279	6318
FL	5913	347854824	2824855303	3847
CA	10468	303183746	8492481313	8143
NY	3927	24691936	622665816	3063

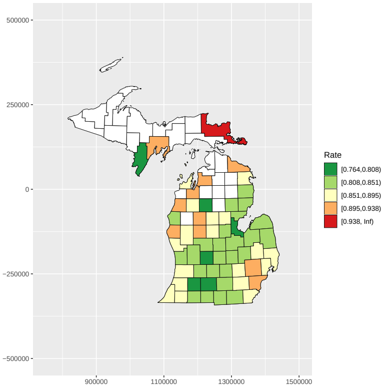
Models for Crop Insurance Indemnities

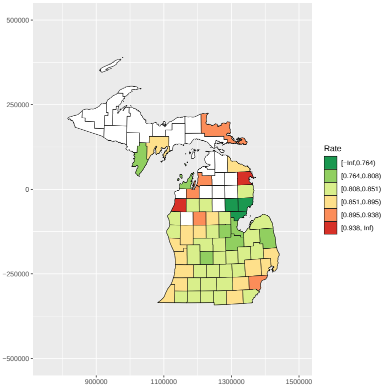
Introduction
Data
Analysis

Histogram of Indemnity Amount



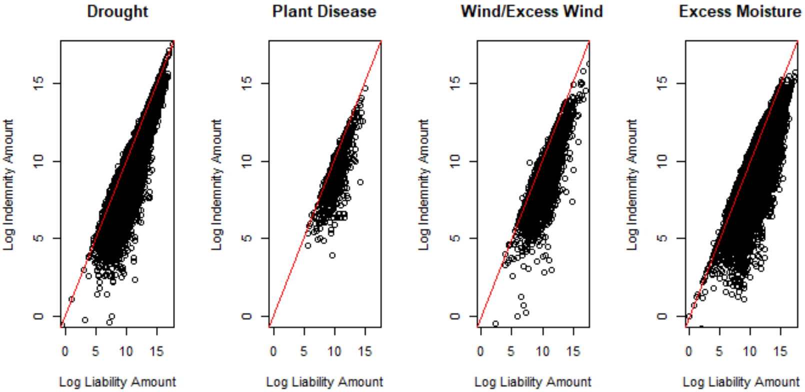
Relativity Map in Michigan (Training and Validation Sample)



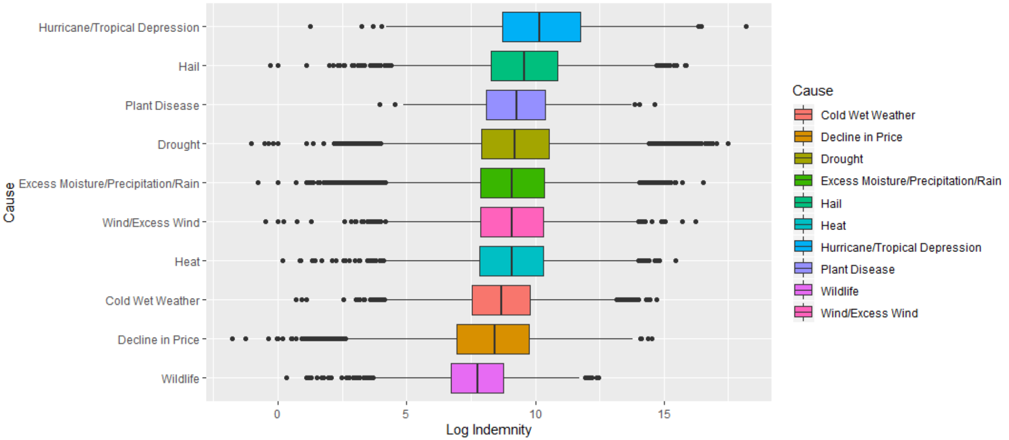


Data

Indemnities and Liabilities by Peril Type



Log Indemnities by Peril Type



Model

Important Note

- Most of the farms will run in the right way
- Only a few of them will suffer a loss

What is the Appropriate Distribution?

- The answer is Tweedie Distribution
- It is a distribution that has 0 mass and using a compound model allows us to obtain the residuals more easily

Model

Introduction to Tweedie distribution

A random variable Y follows Tweedie if Y follows exponential dispersion models with mean and variance:

$$E(Y) = \mu \quad Var(Y) = \sigma^2 \mu^p$$

where p is called the Tweedie power parameter

If $1 \leq p \leq 2$, it will become a compound Poisson/Gamma distribution

Model

Expression of Y

$$T \sim Poisson(\lambda)$$

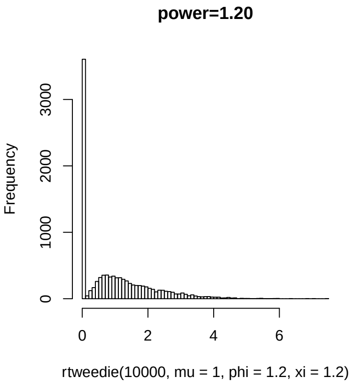
$$X_i \sim Gamma(\alpha, \beta)$$

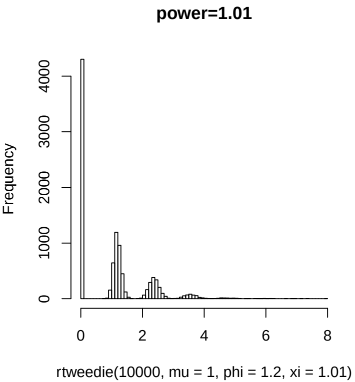
$$Y = \sum_{i=1}^{T} X_i$$

Connection

The frequency of indemnity $\sim Poisson(\lambda)$
The severity of indemnity $\sim Gamma(\alpha, \beta)$

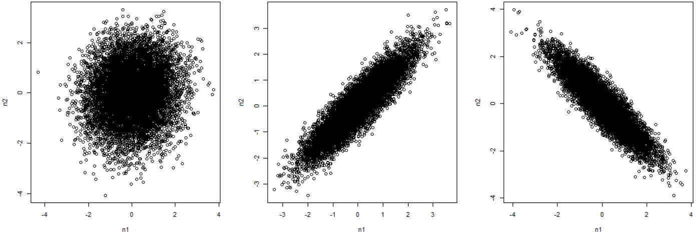
Shape of Tweedie Distribution





Copula Function Demonstration

We use the Copula function to construct three groups of data. Within each group of data, there are two normally distributed variables. The covariances in each group are 0.1, 0.9, and -0.9 respectively.



$$Var(X+Y) = Var(X) + Var(Y) + 2Cov(X,Y)$$

Analysis

Some Common Peril Types

(1) Drought

(2) Plant Disease

(3) Wind/Excess Wind

(4) Excess Moisture/Precipitation/Rain

(5) Hurricane/Tropical Depression

Analysis

Process

(1) Aggregate the information we need to generate a table

(2) Use the **tweedie.profile() function** to generate the **MLE** of the Tweedie index power parameter

(3) Construct the exact PDF of Tweedie distribution

(4) Obtain the Cox-Snell residuals

(5) Obtain the covariance

Results

Covariance of Specific Peril Types

2 policyholders in the same state have correlations of:

Drought	Plant Disease	Wind	Precipitation	Hurricane
0.4581	0.3214	0.3116	0.3406	0.0472

- Covariances indicate dependence for those policyholders within the same state

Conclusion

Implications

- Different peril types have different dependence structure
- The risk capital held by an insurance company should be different depending on the peril types being covered
- Underwriting strategies and loss reserving practices may be influenced by this

Thank you!