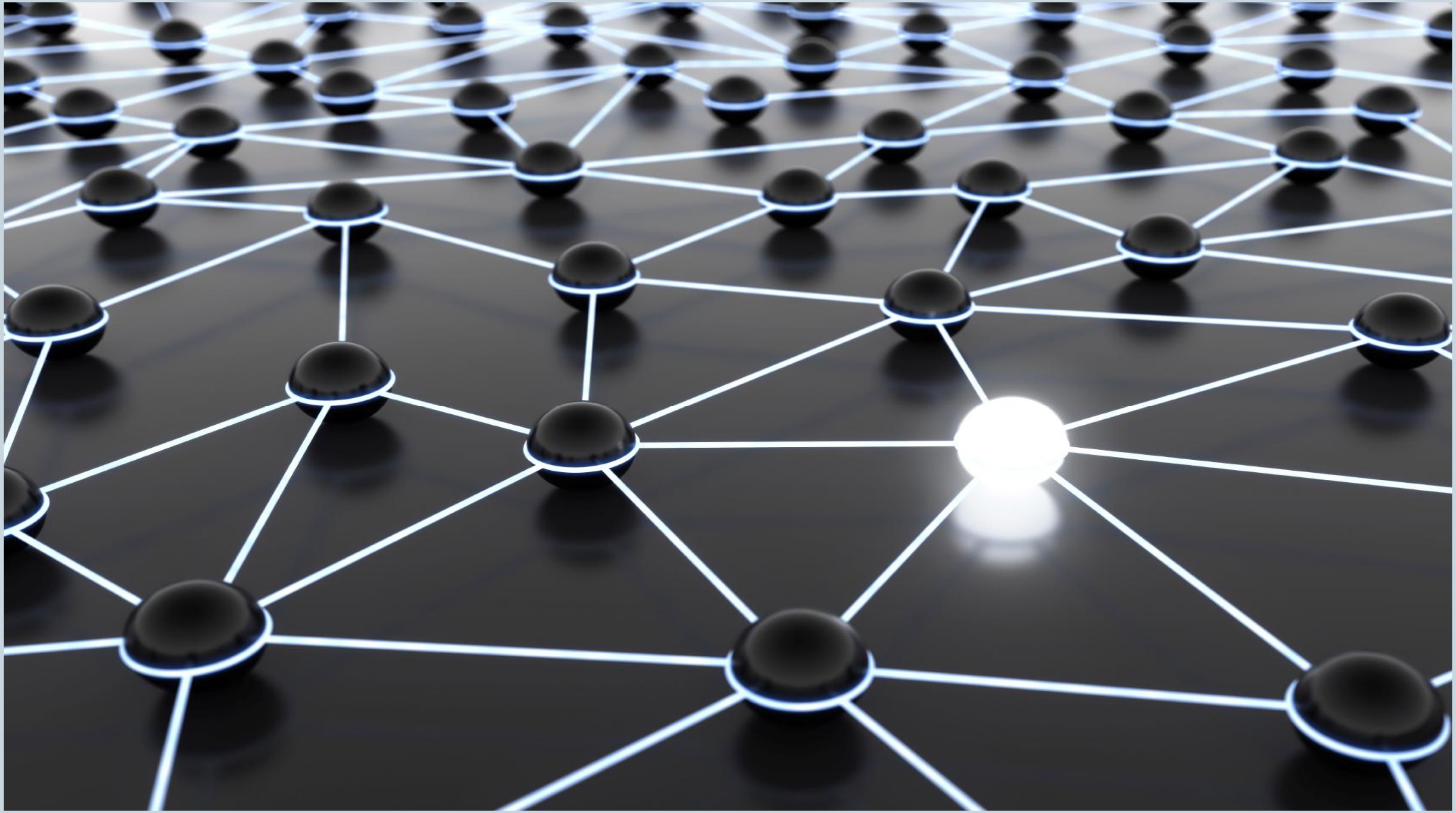

CLRS Meeting — Chicago

September 19-20, 2016

Beyond the Chain-Ladder Framework: Generalized Linear Models for Reserving

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Overview

Today's presentation will cover the following:

Aggregate Generalized Linear Models

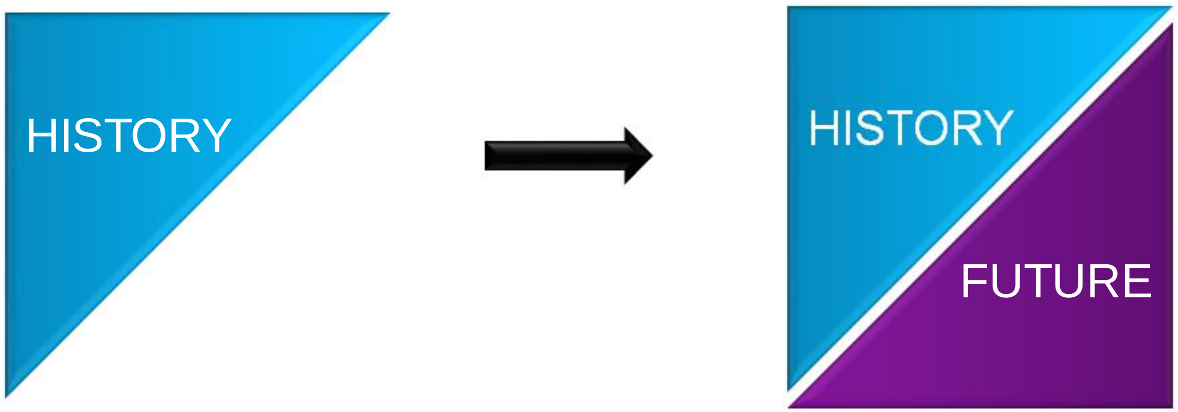
Individual Claim Reserving

Aggregate Generalized Linear Models

I. General Introduction to Method

Actuarial Reserving in a Nutshell

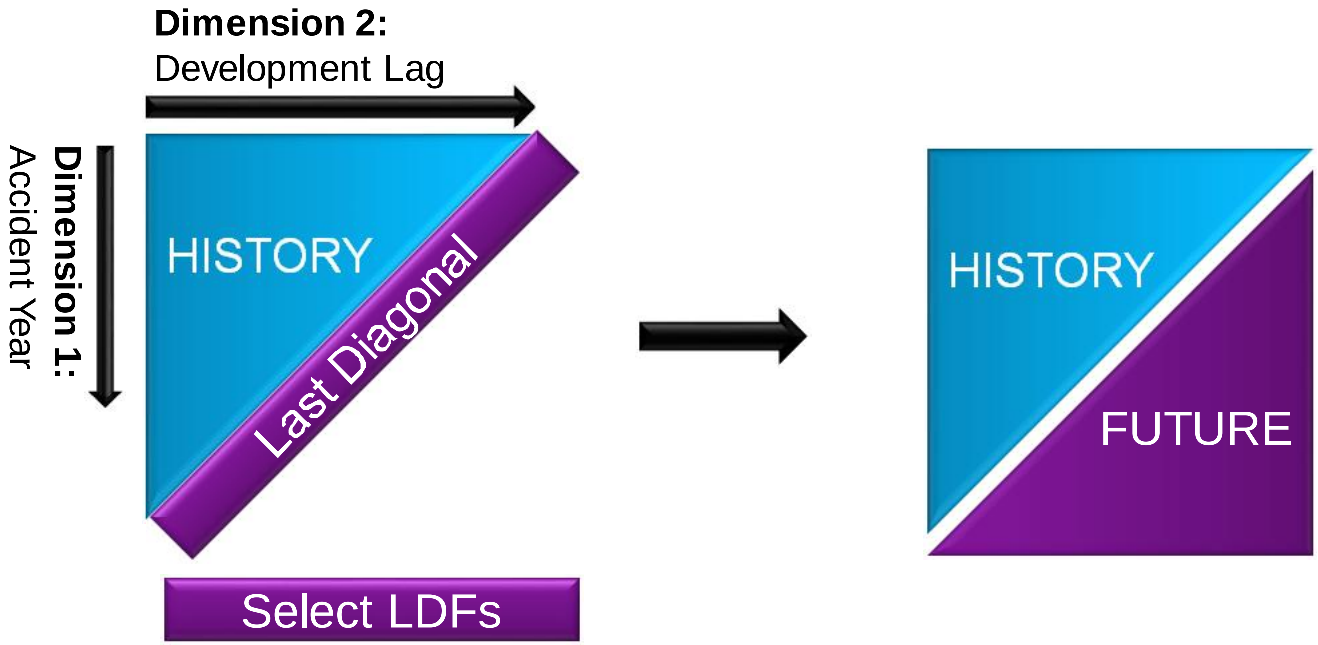
- Traditional actuarial reserving methods has been conceptually described as a process of squaring up a triangle:



- The GLM Reserve method is no different. Estimate future results based on information from historical.

Why GLM ?

- Traditional Chain Ladder method focuses on the development Lag dimension to derive estimates:



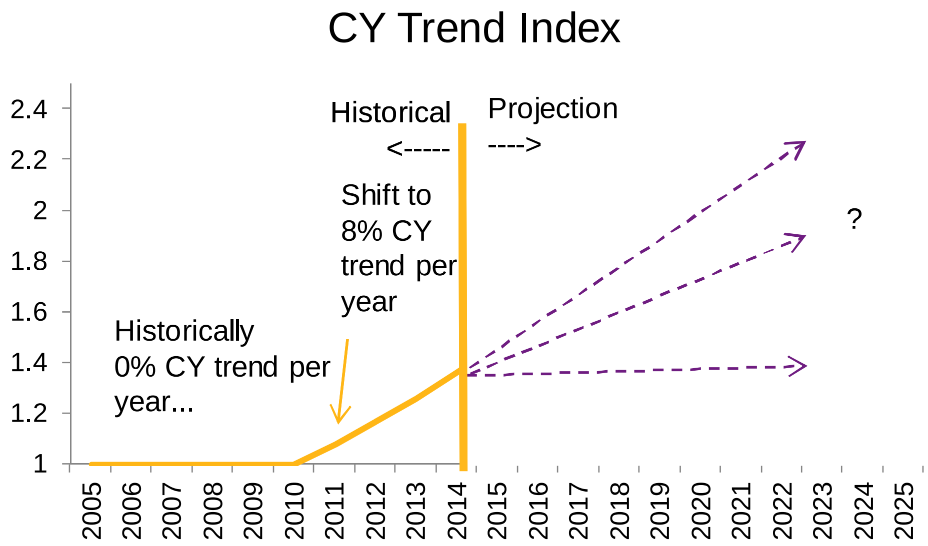
- Each future estimate can be derived based on the selected development factors.

Why GLM ?

- However, one major limitation with chain ladder is that it does not adjust for accident or calendar year effects
- Examples include:
  - New claims handling process
  - Changing settlement pattern
  - Legislative/Regulatory changes
- GLM Reserving allows us to introduce two additional dimensions
  - Dimension 1: Accident Year
  - Dimension 2: Development Lag
  - Dimension 3: Calendar Year

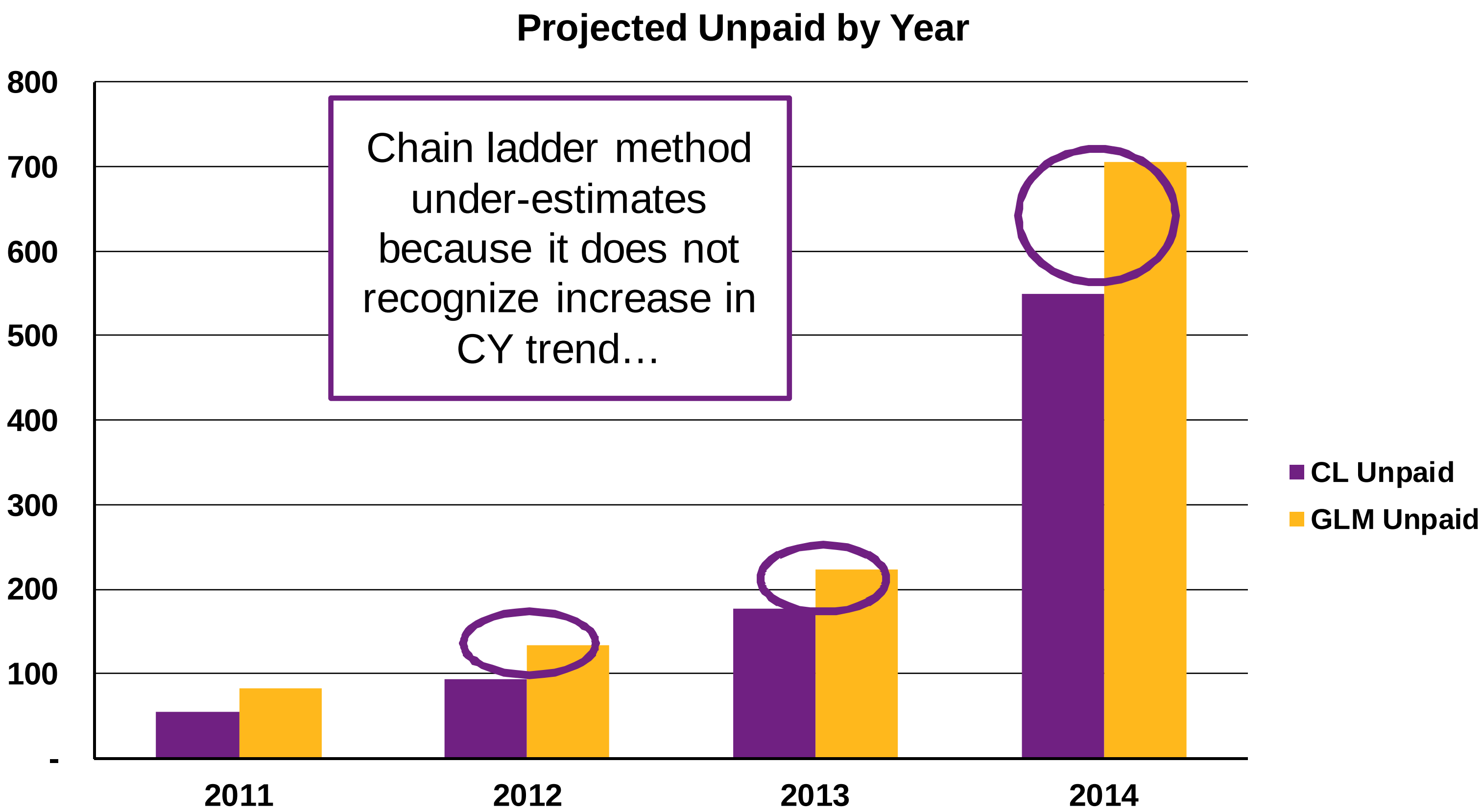
Case Study Example

- Let's quickly go through an illustrative example to demonstrate the impact of calendar year effects using a chain ladder method vs GLM reserving method
- Case Study introduces a calendar year trend in the most recent periods



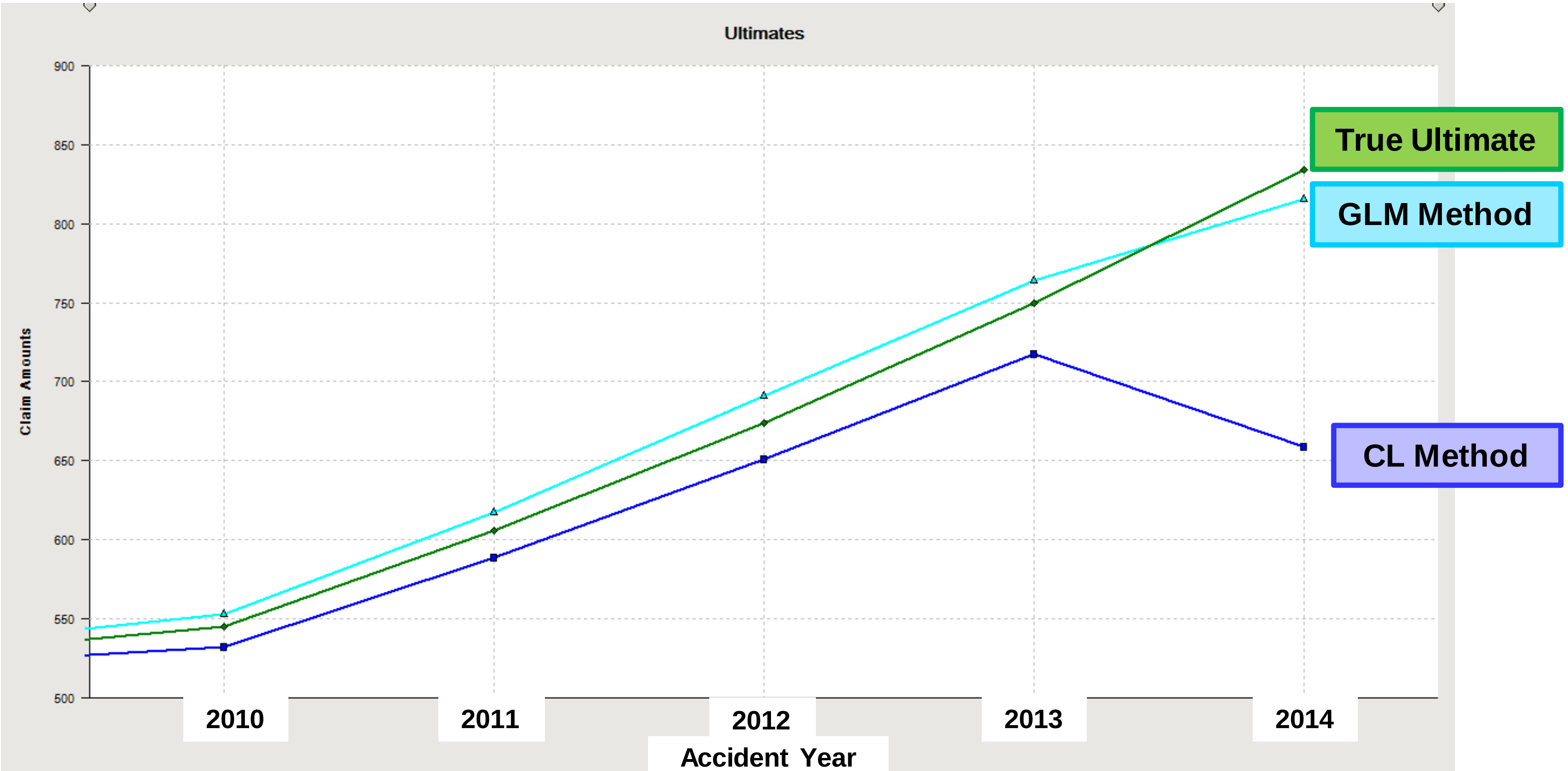
Case Study Example

- Comparing results for GLM Reserving vs. Chain Ladder



Case Study Example

- Impact can be *significant*. In this example, the difference from unpaid is only 4% for GLM Method versus -22% difference for Chain Ladder



- Improved estimates

Aggregate Generalized Linear Models

II. GLM Basics

Section Introduction

- Overview of Predictive Models
- Explaining the GLM Framework
- Basic GLM Example

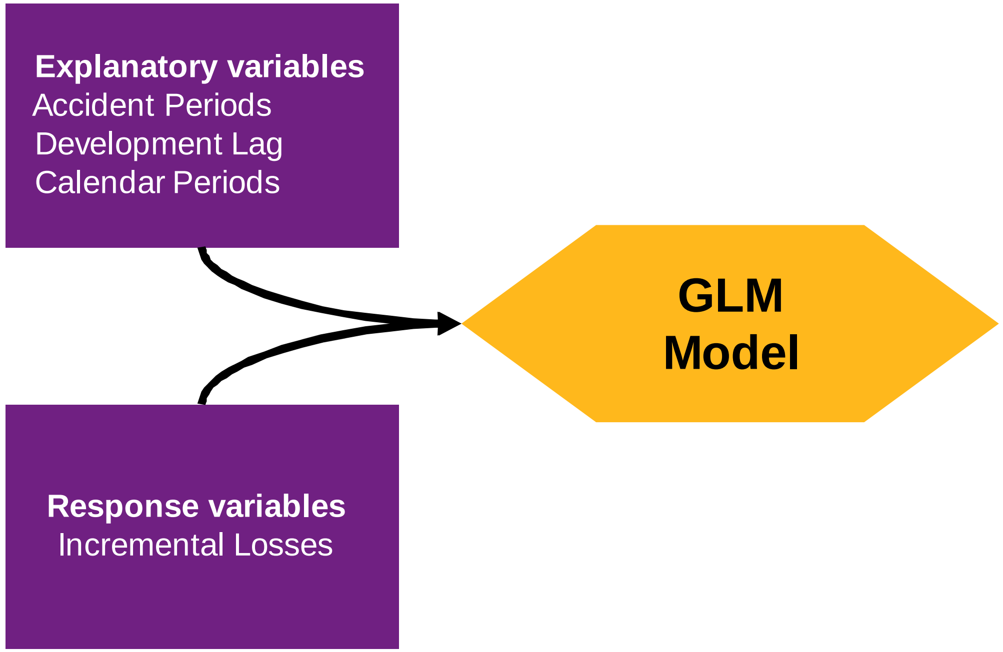
Before going into the GLM Reserve Method, we will cover some basic GLM concepts that will help us down the road…

Predictive Models

- Multivariate statistical model to predict a response variable using a series of explanatory variables

Explanatory variables
- Variables that help **explain** what we are seeing

Response variables
- Variables that **respond** to explanatory variables and we are trying to predict



- We will use the explanatory variables to try and explain the behavior of incremental losses

Practical User Considerations
Selecting a Link Function & Error Structure

Options for Error Structure

Normal or Gamma

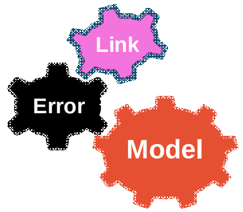
- Normal distribution assumes that all observations have the same fixed variance
- Gamma distribution assumes that the variance increases with the square power of the expected value of each observation

Poisson Scale Free

- A.k.a. "Over-dispersed Poisson" Distribution
- Mean = λ
- Variance = λ x Scale factor
- Allows variance to be lesser/greater than the mean

Poisson – Scale = 1

- Strict definition of Poisson distribution is applied, mean must equal the variance
- It assumes that the variance increases with the expected value of each observation



GLM Building Blocks

y = h(**Linear Combination of Parameters**) + Error

2

Linear Combination of Parameters

Accident Year Parameters

$\beta_{14}, \beta_{13}, \beta_{12}, \ldots, \beta_{05}$

Development Lag Parameters

$\beta_{12m}, \beta_{24m}, \beta_{36m}, \ldots, \beta_{120m}$

Calendar Year Parameters

$\beta_{CY14}, \beta_{CY13}, \beta_{CY12}, \ldots, \beta_{CY05}$

Aggregate Generalized Linear Models

III. GLM Reserving Example

Section Introduction

In this section, we will cover the following:

- Start with 2-dimensional approach
- Show all years volume weighted average vs GLM
- Show how any cell in the historical triangle is linear combination of beta parameters

A simple example

- In order to "demystify" the GLM reserve model, we will walk through a basic example and show how future estimates are calculated:
  - Start with building a 2 dimensional GLM reserve model:
    - Dimension 1 = Accident Year
    - Dimension 2 = Development Lag
  - Show that results are comparable to Chain Ladder Method using all years volume weighted average

A simple example

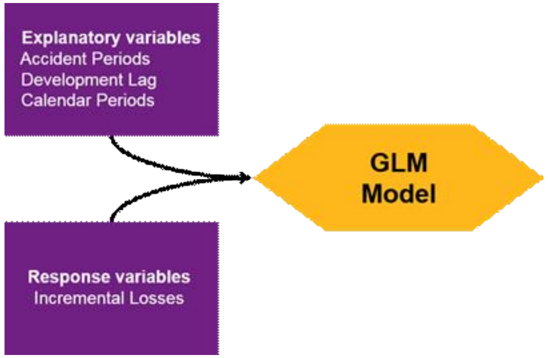
Incremental Paid Loss Triangle

Accident Year	12m	24m	36m	48m	60m	72m	84m	96m	108m	120m
2005	92	265	47	24	14	7	5	5	6	3
2006	95	273	49	25	12	8	6	6	7	
2007	98	281	50	22	14	9	7	7		
2008	100	290	46	24	15	10	8			
2009	103	288	51	27	17	11				
2010	72	321	57	30	19					
2011	80	357	64	33						
2012	89	397	71							
2013	98	441								
2014	110									

- GLM reserve method is based on predicting the response variable, incremental losses.

$Y_{AY,DL}$ = Incremental loss
AY = Accident Year AY,
DL = Development Lag, DL

Example:
$Y_{2011,12m} = 80$



A simple example

Incremental Paid Loss Triangle

Accident Year	12m	24m	36m	48m	60m	72m	84m	96m	108m	120m
2005	92	265	47	24	14	7	5	5	6	3
2006	95	273	49	25	12	8	6	6	7	
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2010	72	321	57	30	19					
2011	80	357	64	33						
2012	89	397	71							
2013	98	441								
2014	110									

- Any cell in the historical triangle is linear combination of “beta” parameters
- Incremental losses are related to explanatory variables multiplicatively
- Resulting model gives exactly the same forecast as the chain ladder model

$$Y_{AY,DL} = EXP\ (\beta_0 + \beta_{AY} + \beta_{DL}) + \varepsilon$$

Log link function

Linear combination of explanatory variables predicts incremental losses, based on AY and DL

A simple example

		β_{12}	β_{24}	β_{36}	β_{48}	β_{60}	β_{72}	β_{84}	β_{96}	β_{108}	β_{120}
	Accident Year	**12m**	**24m**	**36m**	**48m**	**60m**	**72m**	**84m**	**96m**	**108m**	**120m**
β_{05}	2005	92	265	47	24	14	7	5	5	6	3
β_{06}	2006	95	273	49	25	12	8	6	6	7	
	2007	98	281	50	22	14	9	7	7		
	2008	100	290	46	24	15	10	8			
β_{09}	2009	103	288	51	27	17	11				
β_{10}	2010	72	321	57	30	19					
β_{11}	2011	80	357	64	33						
	2012	89	397	71							
β_{13}	2013	98	441								
β_{14}	2014	110									

Begin with a Base Parameter, β_0

We will choose Accident Year 2005, Development Lag 12 months as the base parameter

Why use a Base Parameter?

Needed to allow for model convergence

Setting a base parameter reduces the number of variables by 1

A simple example

	Accident Year	12m	24m	36m	48m	60m	72m	84m	96m	108m	120m
	2005	92	265	47	24	14	7	5	5	6	3
β_{06}	2006	95	273	49	25	12	8	6	6	7	
	2007	98	281	50	22	14	9	7	7		
	2008	100	290	46	24	15	10	8			
β_{09}	2009	103	288	51	27	17	11				
β_{10}	2010	72	321	57	30	19					
β_{11}	2011	80	357	64	33						
	2012	89	397	71							
β_{13}	2013	98	441								
β_{14}	2014	110									

Explanatory Variables

Dimension 1 = Accident Year

β_{11} = Multiplicative parameter that describes accident year 2011

$Y_{11,DL} = EXP(\beta_0 + \beta_{11} + \beta_{DL}) + \varepsilon$

A simple example

		β_{24}	β_{36}	β_{48}	β_{60}	β_{72}	β_{84}	β_{96}	β_{108}	β_{120}
Accident Year	**12m**	**24m**	**36m**	**48m**	**60m**	**72m**	**84m**	**96m**	**108m**	**120m**
2005	92	265	47	24	14	7	5	5	6	3
2006	95	273	49	25	12	8	6	6	7	
2007	98	281	50	22	14	9	7	7		
2008	100	290	46	24	15	10	8			
2009	103	288	51	27	17	11				
2010	72	321	57	30	19					
2011	80	357	64	33						
2012	89	397	71							
2013	98	441								
2014	110									

Explanatory Variables

Dimension 2 = Development Lag

β_{48m} = Multiplicative parameter that describes development lag 48 months

$Y_{AY,48m} = EXP(\beta_0 + \beta_{AY} + \beta_{48m}) + \varepsilon$

A simple example

	Accident Year	12m	24m	36m	48m	60m	72m	84m	96m	108m	120m
	2005	β_0 92	265	47	24	14	7	5	5	6	3
β_{06}	2006	95	273	49	25	12	8	6	6	7	
	2007	98	281	50	22	14	9	7	7		
	2008	100	290	46	24	15	10	8			
β_{09}	2009	103	288	51	27	17	11				
β_{10}	2010	72	321	57	30	19					
β_{11}	2011	80	357	64	33						
	2012	89	397	71	??						
β_{13}	2013	98	441								
β_{14}	2014	110									

Here's another example.

Example 1. $Y_{12,36m} = EXP(\beta_0 + \beta_{12} + \beta_{36m}) + \varepsilon$

Example 2. $Y_{12,48m} = EXP(\beta_0 + \beta_{12} + \beta_{48m}) + \varepsilon$

A simple example

Accident Year Parameter	Value
β_{2005}	n/a
β_{2006}	0.029
β_{2007}	0.056
β_{2008}	0.082
β_{2009}	0.105
β_{2010}	0.124
β_{2011}	0.225
β_{2012}	0.325
β_{2013}	0.424
β_{2014}	0.338

Development Lag Parameter	Value
β_{12m}	n/a
β_{24m}	1.260
β_{36m}	(0.485)
β_{48m}	(1.177)
β_{60m}	(1.704)
β_{72m}	(2.244)
β_{84m}	(2.533)
β_{96m}	(2.612)
β_{108m}	(2.470)
β_{120m}	(3.143)

Base Parameter	Value
β_0	4.358

Example 1:

$Y_{12,36m} = EXP(\beta_0 + \beta_{12} + \beta_{36m})$

$= EXP\ (4.358 + 0.325 - 0.485)$

$= 67$ (vs actual 71)

Example 2:

$Y_{12,48m} = EXP(\beta_0 + \beta_{12} + \beta_{48m})$

$= EXP\ (4.358 + 0.325 – 1.177)$

$= 33$

A simple example

Accident Year	2-D GLM Unpaid	Chain Ladder Unpaid	Difference
Prior	470	470	0
2008	484	484	0
2009	497	497	0
2010	510	510	0
2011	522	522	0
2012	532	532	0
2013	589	589	0
2014	651	651	0
Total	**5,632**	**5,632**	**0**

- When excluding the calendar year dimension, as we did in this example, the results are the same as chain ladder method using all year volume weighted average

Incorporating the Calendar year effect

$$\log(\mu_{ij}) = \eta_{ij}$$

Log "link" function

$$\eta_{ij} = c + \sum_i a_i + \sum_j b_j + r\tau$$

Linear predictor

$$\tau = i + j - 2$$

Calendar time

Problem:

The model is now over-parameterised – there is a relationship between origin, development and calendar time, one dimension is a linear combination of the other two. A unique solution is not identifiable.

The Optimal Model

- Use stepwise procedures to reduce the number of parameters and find the optimal model
- Several optimisation schemes could be proposed
  - Optimise backward – iteratively tests each parameter and removes the ones that are not statistically significant
  - Optimise forward – Iteratively tests each parameter and adds in the ones that are statistically significant
  - Optimise backward/forward – Optimise backward first and Optimise forward second

Aggregate Generalized Linear Models

IV. Conclusion

Conclusions

- Model Limitations
  - Still working with limited set of data points; i.e. a 10 x 10 triangle only has 55 data points
    - Run the risk of "Overfitting" if too many parameters included – Model explains historical experience but poor future predictive value
- Origin, development and calendar period effects are interlinked, so it can be very difficult to interpret the parameters
- When calendar period effects are included, it is always necessary to extrapolate in the calendar period direction
  - The results will be sensitive to the assumptions regarding extrapolation
  - A model that fits the observed data well may not be good for forecasting!

Individual Claim Reserving

Agenda

- Predictive Modeling Overview
  - Applications
    - Reserving
    - Claims Triage
- Traditional Reserving Development Methods
  - Key Points
  - Challenges
- Reserving with Predictive Modeling
  - Advantages
- Aggregate Reserving Methods
  - Aggregate Incremental Paid Method
  - Calendar Year Method
- Individual Claim Reserving Methods
  - Incremental Paid Method
  - Claim Closure Rate Method
  - Open Claim Method
  - Frequency/Severity Method

Individual Claim Reserving

V. Predictive Modeling Overview

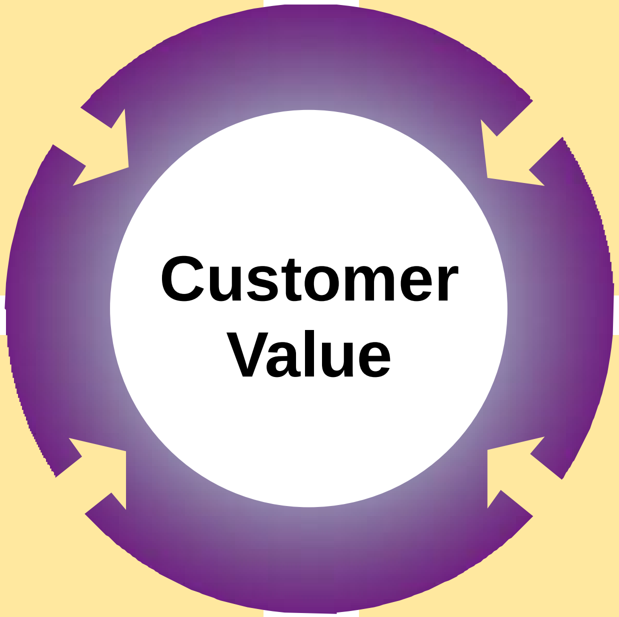
Predictive Models

Application

Predictive modeling can help integrate all aspects of insurance operations and help identify the value of all customers

Underwriting
Determine UW rules
Perform credit analysis
Evaluate agents/regions
Target inspections

Pricing
Set base rates
Identify predictors
Quantify relationships



Marketing
Predict response rates
Perform conversion analysis
Determine retention

Claims
Set reserves
Triage claims
Predict fraud

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Individual Claim Reserving

VI. Traditional Reserving Development Methods

Traditional Development Methods

Traditional methods **aggregate** all claims in each cell within the historical triangle on a **cumulative** basis

Accident Year 2002

Claim	12	24	36	48
000001	0	1,000	1,000	5,000
000021	50	50	50	50
000060	0	0	0	250
000124	300	500	500	750
000328	125	400	400	400
000443	0	0	100	2,000
2002 Total	**475**	**1,950**	**2,050**	**8,450**

Individual Claim Reserving

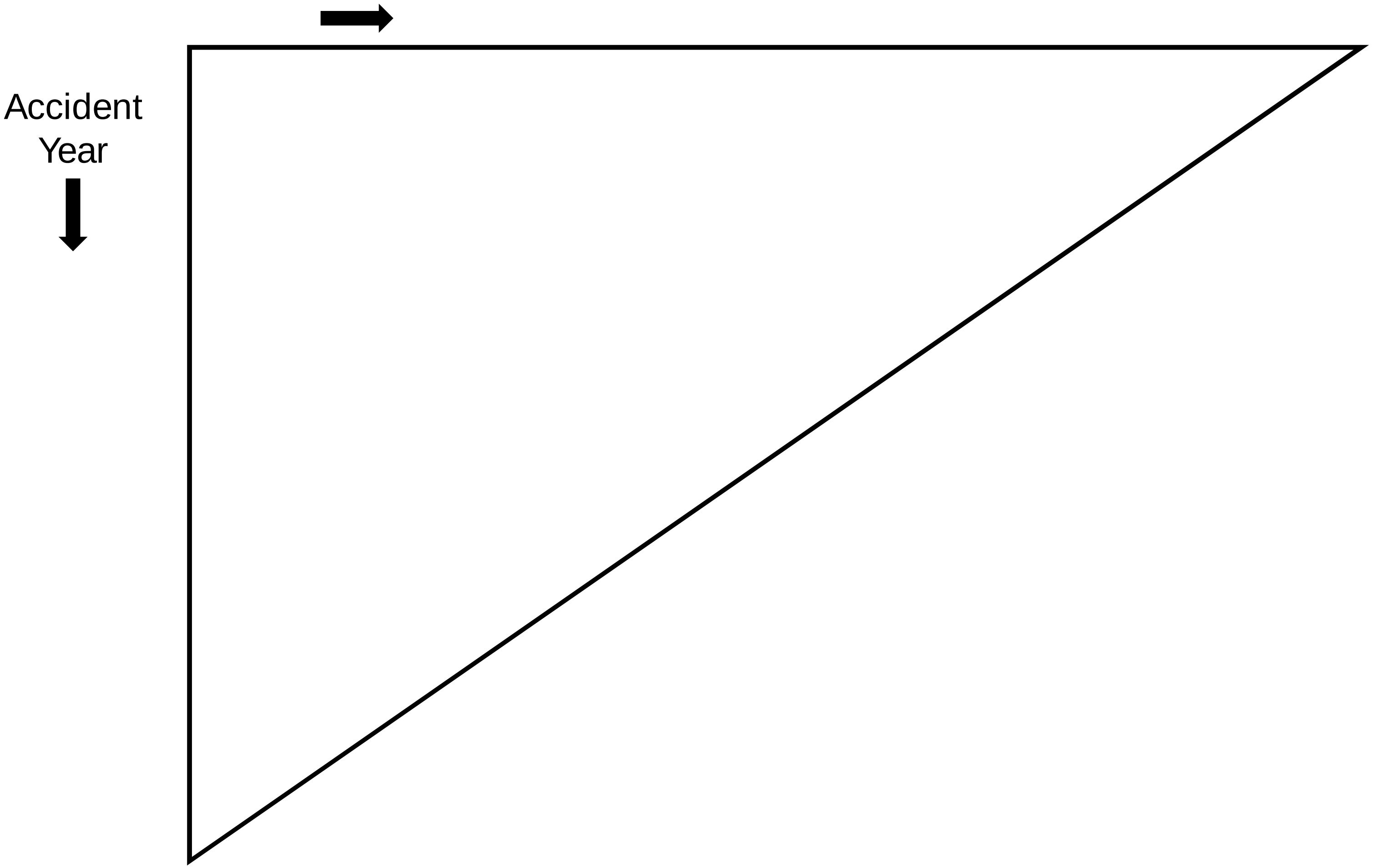
VII. Reserving with Predictive Modeling

Predictive Modeling Reserving Methods

- Multiple methodologies exist under a predictive modeling framework
  - Aggregate Data
  - Individual Claim Data
- Advantage: The incorporation of additional variables beyond the traditional two-dimensional model using “year” and “lag” enable us to identify patterns and trends that otherwise would be masked in the data:
  - Can address the inconsistency weakness in traditional methods
  - Provides insights into the drivers of claim cost
    - How much does age affect the cost of WC claims?
    - What is the impact of opioid usage on the cost of claims?
    - How much did reform measures impact claim costs?
  - Enables us to establish consistent and more accurate case reserves

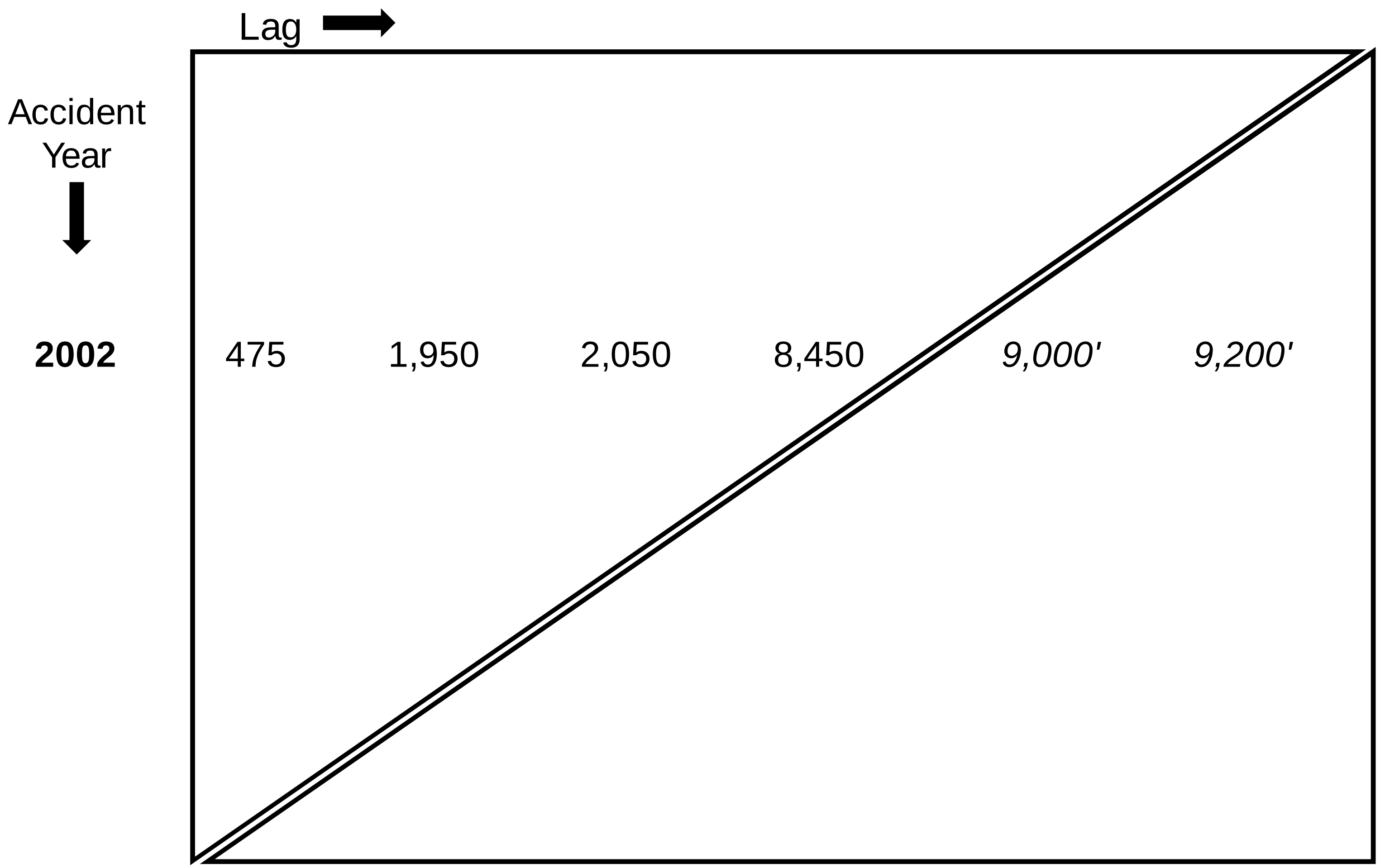
Traditional Loss Development Methods

Repeat the process for each year until entire triangle is populated



Traditional Loss Development Methods

Goal is to square up the triangle using link ratios



Traditional Development Methods

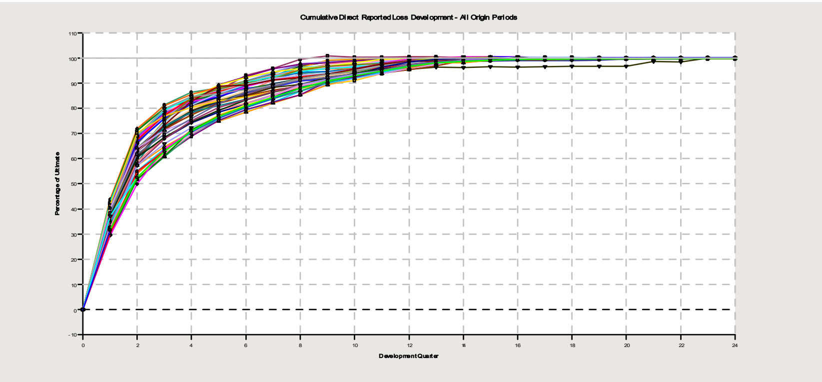
Key Points

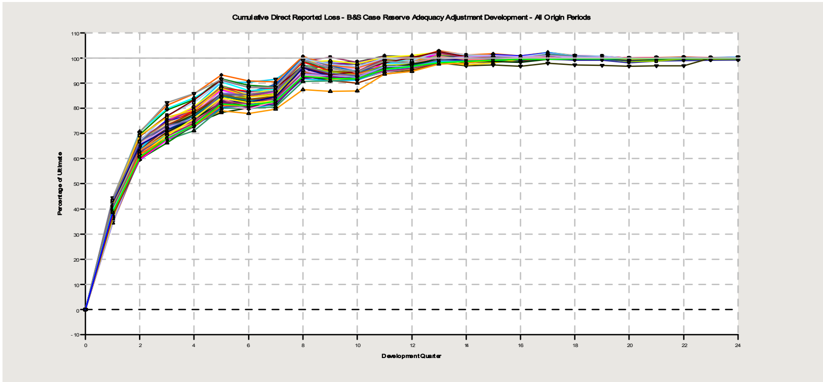
- Aggregated Data
  - Forfeit almost all information unique to each claim
  - Paid, case, reported, open, closed
- Evaluates across only two dimensions: Year and Lag
- Estimates IBNER and pure IBNR together
- Accuracy hinges on consistency
  - Claim closure rate
  - Case reserve adequacy
  - Inflation
  - Reinsurance
- Traditional development methods work quite well when the historical data is consistent, reasonably credible and contains sufficient history

Traditional Development Methods

Challenges

- Challenge is dealing with inconsistency
  - Can consistency/inconsistency be measured?
    - Few cells within triangle make it challenging to measure
    - Small changes are oftentimes masked by random volatility but can impact indications significantly
    - Especially difficult with low frequency/high severity business
  - When measurable, can historical data be adjusted to be consistent?
    - Traditional adjustment approaches tend to produce patterns that are difficult to interpret





Individual Claim Reserving

VIII. Aggregate Reserving Methods

Aggregate Incremental Paid Method

A traditional aggregate loss development method can be replicated in a GLM framework

Difference is that GLM triangle is set to an incremental basis

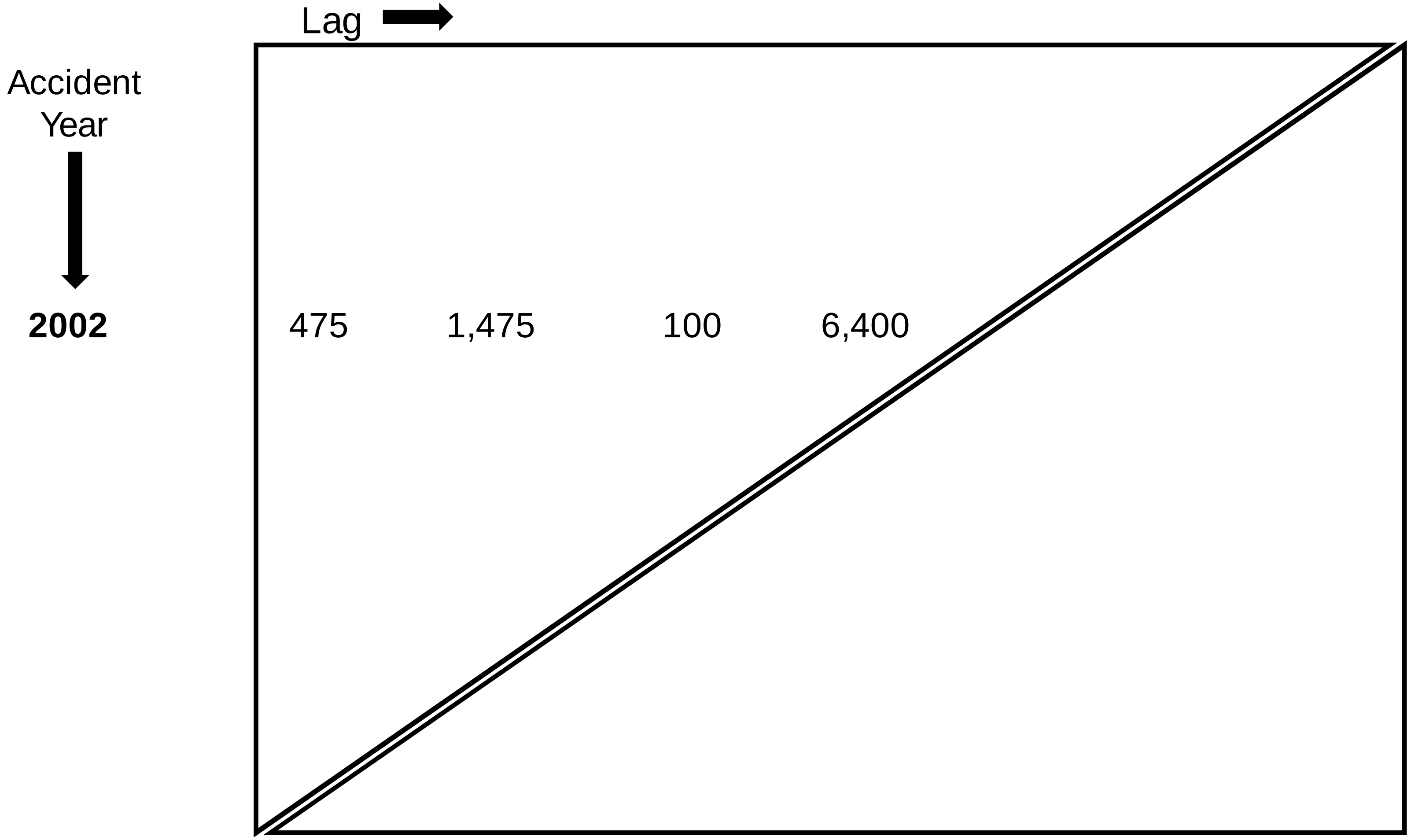
Accident Year 2002

Claim	12	24	36	48
000001	0	1,000	1,000	5,000
000021	50	50	50	50
000060	0	0	0	250
000124	300	500	500	750
000328	125	400	400	400
000443	0	0	100	2,000
2002 Total	**475**	**1,950**	**2,050**	**8,450**

2002 Incr	475	1,475	100	6,400

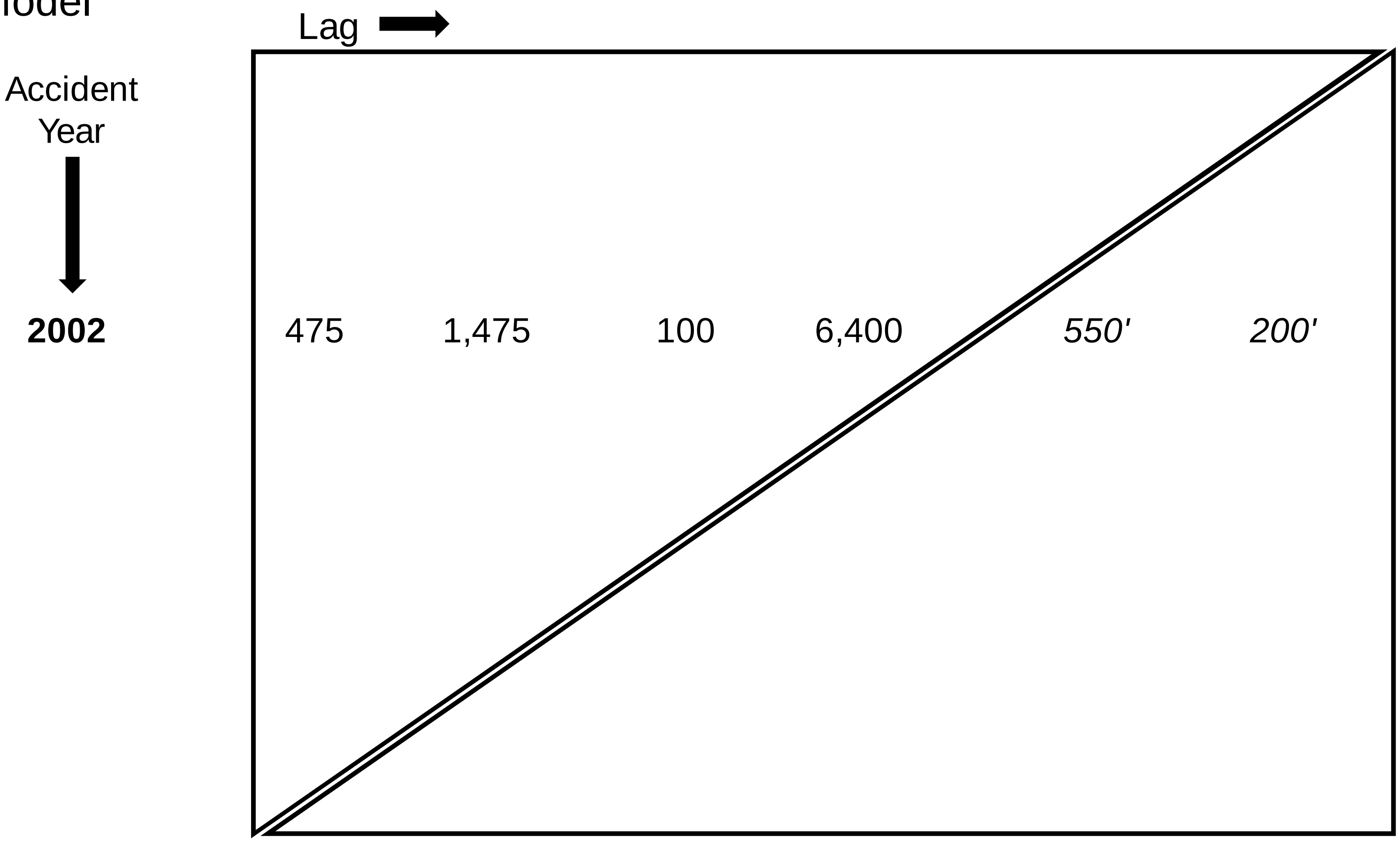
Aggregate Incremental Paid Method

Goal in GLM is the same: square up the triangle using parameters from the model



Aggregate Incremental Paid Method

Goal in GLM is the same: square up the triangle using parameters from the model



Aggregate Incremental Paid Method — GLM Structure

Response Variable = **Systematic Component** + **Random Component**

y = h (Linear Combination of Rating Factors) + Error

Incremental Paid Loss = **Log Link Function** **(Accident Year + Lag)** + **Poisson Error**

Aggregate Incremental Paid Method

Key Points

- Aggregated Data
  - Forfeit almost all information unique to each claim
  - Paid, case, reported, open, closed
- Evaluates across only two dimensions: Year and Lag
- Estimates IBNER and pure IBNR together
- Accuracy hinges on consistency
  - Claim closure rate
  - Case reserve adequacy
  - Inflation
  - Reinsurance
- Replicates a traditional paid loss development method using volume weighted average link ratios

Calendar Year Method

- As the name implies, this method incorporates a third dimension into the modeling process, calendar year
  - Can be applied to aggregate or individual claim data
- Advantage
  - To be able to incorporate changes in inflation/claim cost into the reserve estimation process
- Challenge
  - Squaring up the triangle requires extrapolation of calendar year into the future

Calendar Year Method — GLM Structure

Response Variable = Systematic Component + Random Component

y = h (Linear Combination of Rating Factors) + Error

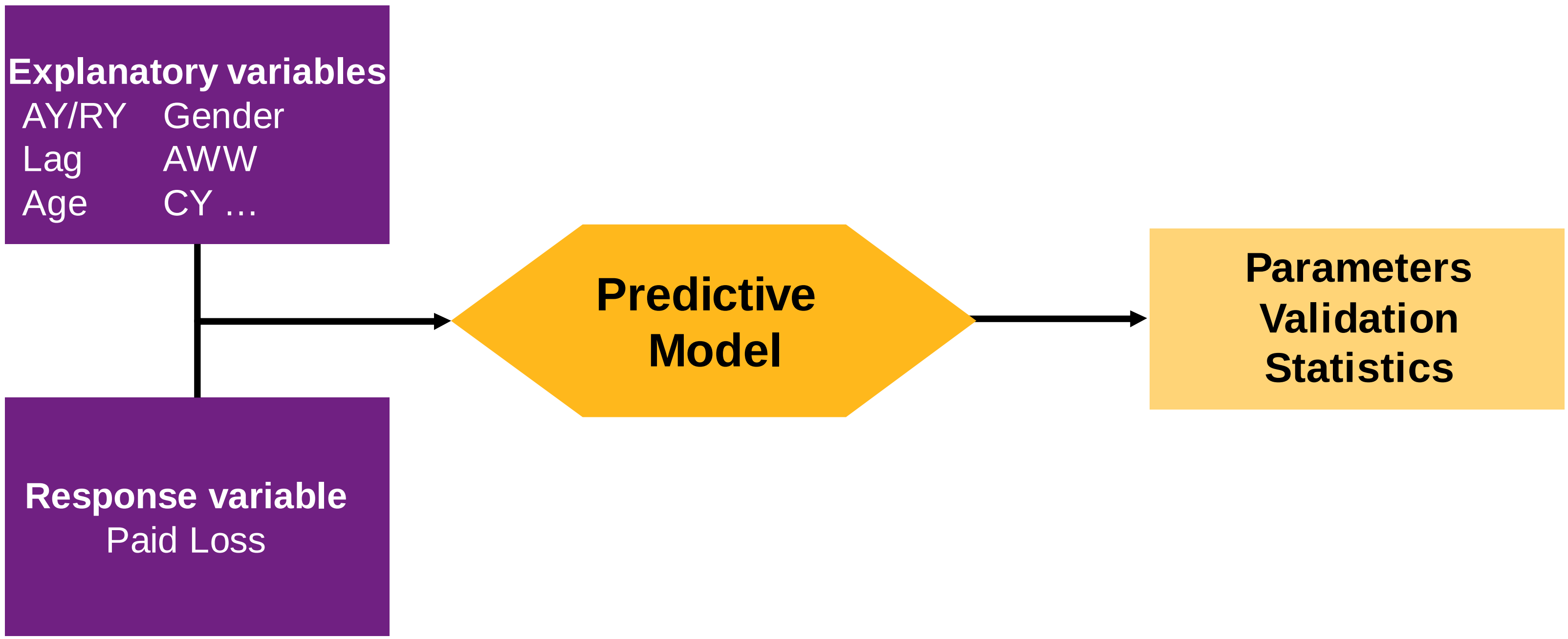
Incremental Paid Loss = Log Link Function (Accident Year + Lag + Calendar Year) + Poisson Error

Individual Claim Reserving

IX. Individual Claim Reserving Methods

Individual Claim Reserving Methods

- Now that the data is configured by claim instead of in aggregate, we can introduce additional explanatory variables that are unique to each claim:



Individual Claim Reserving Methods

WC Data Utilized

- **Insured Characteristics**
  - Policy start/ end date
  - Months with company
  - Number of employees
  - Limits/ Deductible
  - Class code
  - Hazard group
  - Prior Experience
- **Claimant Characteristics**
  - Age
  - Number of dependents
  - Previous disability
  - Marital status
  - Years employed
  - Job level
  - Performance evaluations
- **Billing**
  - Payment history
  - Payment plan
  - Times delinquent
- **Loss Characteristics**
  - Cause of injury
  - Body part injured
  - Day of week
  - Month
  - State
  - Report lag
  - Loss date
- **Service Providers**
  - Medical service provider
  - Pharmaceuticals
- **Geography**
  - Urban/Rural
  - Distance to work

Incremental Paid Method

While previous examples used aggregated data, GLM's also work with individual claim data

Incremental 2002 Claims

Claim	12	24	36	48
000001	0	1,000	0	4,000
000021	50	0	0	0
000060	0	0	0	250
000124	300	200	0	250
000328	125	275	0	0
000443	0	0	100	1,900
2002 Total	**475**	**1,475**	**100**	**6,400**

Incremental Paid Method

Goal: square up the triangle with respect to each individual claim

Lag →

Report Year ↓	Claim ↓				
2002	000001	0	1,000	0	4,000
2002	000021	50	0	0	0
2002	000060	0	0	0	250
2002	000124	300	200	0	250
2002	000328	125	275	0	0
2002	000443	0	0	100	1,900

Results can still replicate a traditional aggregate development method

Incremental Paid Method — GLM Structure

Response Variable = **Systematic Component** + **Random Component**

y = h (Linear Combination of Rating Factors) + Error

Incremental Paid Loss = **Log Link Function** **(Report Year + Lag + Many More)** + **Poisson Error**

Incremental Paid Method

Key Points

- Aggregate incremental paid method blends the estimation of IBNER and pure IBNR into one single estimate
- Individual Incremental Paid method models individual claim data and as a result focuses solely on forecasting IBNER
  - Pure IBNR must be estimated separately
    - Model to predict the frequency of IBNR claims
    - Model to predict the severity of IBNR claims
- Individual claim characteristics used as explanatory variables must be static or known throughout the forecasted periods
  - Med-only/Lost-time
  - Open/Closed

Claim Closure Rate Method

- Models closed claim data and expands on the Calendar Year method by adding a fourth dimension:
  - Year
  - Lag
  - Calendar Year
  - *Claim Closure Rate*
- Discussed in a paper by Greg Taylor and Grianne McGuire
- Advantages
  - Ideal for high frequency / low severity business where minor changes in claim closure rate affect aggregate methods
  - Estimates total IBNR
- Challenge
  - Method for forecasting future closed claims restricts ability to incorporate unique claim characteristics

Open Claim Method

- Open Claim method builds a series of models that takes advantage of all information known about the claims, including:
  - Calendar year – builds upon previous method
  - Latest paid/incurred to date
  - Individual claim characteristics
- Models reserves for each open claim
- Advantage
  - Claim information is not limited to being static or known
- Challenge
  - Multiple models need to be built
  - Credibility concerns can occur in the tail

Open Claim Method

- Advantages
  - Useful for lines of business with robust claim information

Personal Lines

- Policy
  - Age
  - Gender
  - Marital Status
  - Territory
  - Accident history
  - Credit
  - Vehicle
  - Miles driven
  - Etc…
- Claim
  - Amount
  - Status: Open/Closed

Commercial Lines

- Policy
  - Class code
  - Ex-mod
- Claim
  - Age
  - Gender
  - AWW
  - Injury type
  - Nature of injury
  - Attorney involved?
  - Geography
  - Medical treatments
  - Etc…

Frequency / Severity Method

- Aggregate ultimate severity by year estimated through traditional approaches
- Robust severity model is built using all available claim information and latest known information
  - Development is normalized across data
- Ultimate Severity x Severity Model applied to known and IBNR claims individually to produce ultimate
- Advantages
  - Ideal for low frequency / high severity business where aggregate loss development methods are volatile

Questions and Discussion