AKUR8

Penalized Regression and Credibility Applications

2023

Overview

Penalized Regression is Credibility

- Credibility and GLMs
- ASOP No. 25
- Complements of Credibility
- ASOP No. 56
- Three Stages of Application
- Identify Your Opportunities

Credibility and GLMs

Ground Rules and Goals of the Presentation

But what about this one weird thing …

Goal: Understand the general idea – don't get hung up on the small details (yet)

Learning Objectives:

- Ability to explain how and why ASOP 25: Credibility Procedures applies to penalized regression
- Identify specific complements of credibility applicable to your models
- Categorize applications of penalized regression on varying sizes of data that follow the guidelines of ASOP 56: Modeling

Quick Review

How does credibility fit into modeling again?

Q: What is the credibility assumption of non-penalized GLMs?

A: Non-penalized GLMs assign full credibility to the data.

Q: What is the credibility assumption of penalized GLMs?

A: Not full credibility (Unless the penalty term – Lambda – is zero)

Q: What does this difference mean?

Worksheet: Complements of Credibility

Any application of credibility

For your line(s) of business, what complements of credibility have you seen in practice?

(Example answers after 30 seconds to not bias your answers)

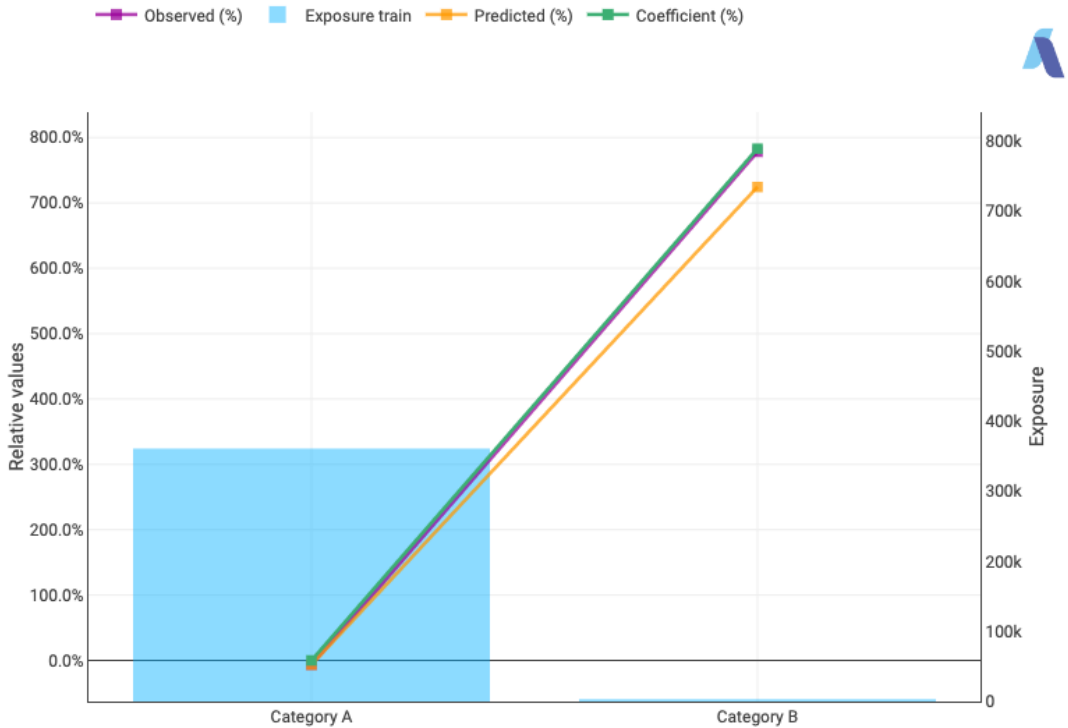
Example answers:

- ISO or other Industry Rates
- Countrywide indication
- When selecting trends for indications: Industry Trends
- When selecting trends for indications: Countrywide Trends
- When selecting loss development factors: Industry LDFs
- When selecting loss development factors: Countrywide LDFs

Penalizing a One-Variable Model

Penalization is Credibility

Fully Credible GLM:
Y = Intercept + Bx

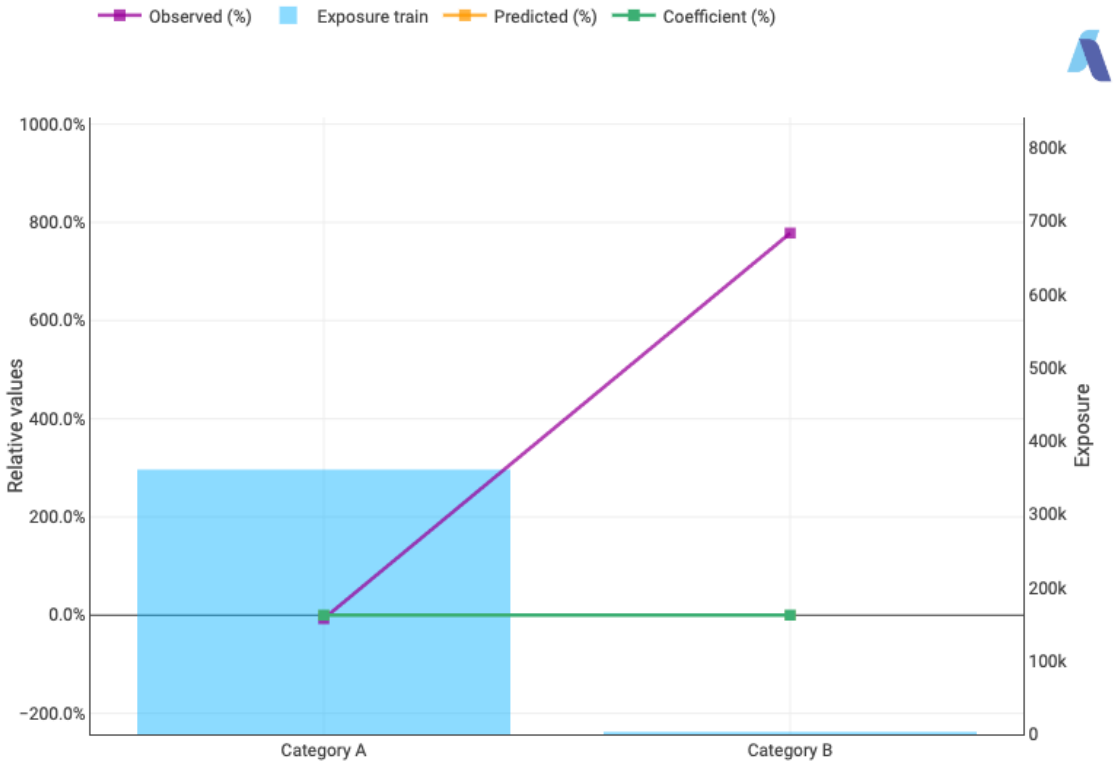


Penalizing a One-Variable Model

Penalization is Credibility

Fully Credible GLM:
Y = Intercept + Bx

Fully Penalized GLM:
Y = Intercept + 0x



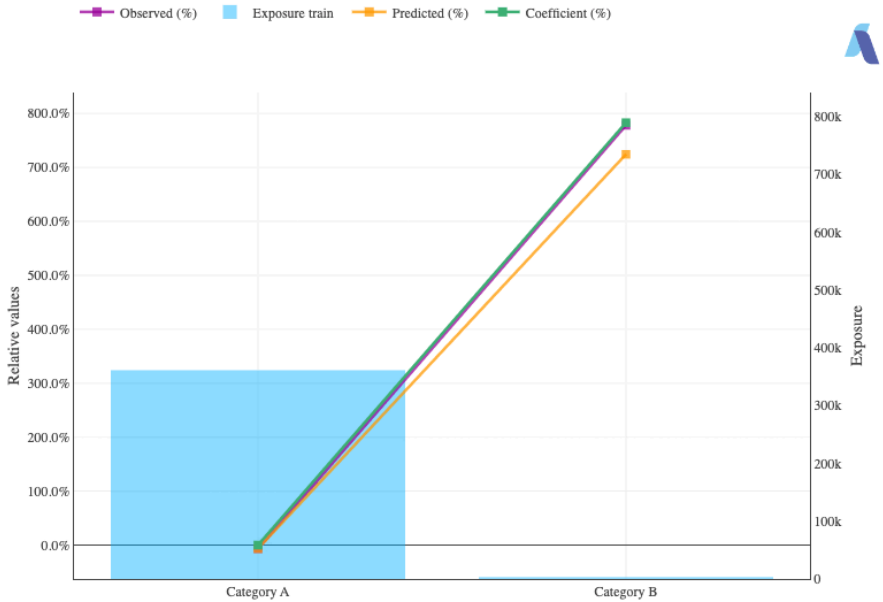
Penalizing a One-Variable Model

Penalization is Credibility

Fully Credible GLM:
Y = Intercept + Bx

Fully Penalized GLM:
Y = Intercept + 0x

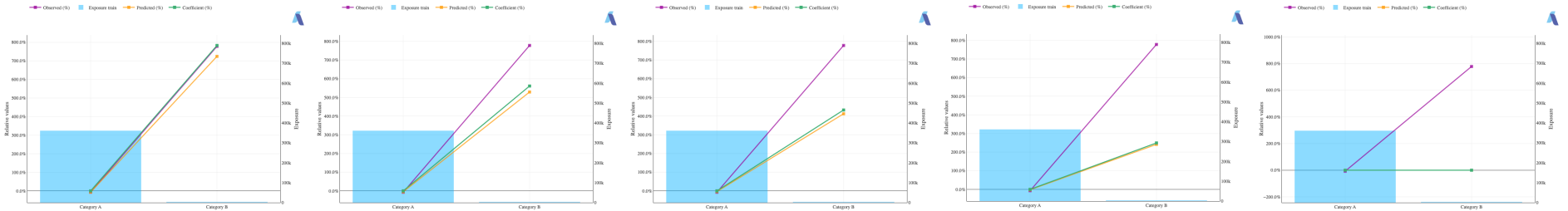
Partially Penalized GLM:
Y = Intercept + B*x
B > B* > 0



When a Modeler Selects a Penalty Parameter, they Apply Credibility

There are tools to assist the selection of a penalty parameter

$$0 \ldots small\ penalty \ldots \lambda \ldots large\ penalty \ldots \infty$$



Estimate = Z * Modeling Data + (1 - Z) * Overall Average

no credibility … … low credibility … … **Overall Average** … … high credibility … … **full credibility**

full credibility … … high credibility … … **Modeling Data** … … low credibility … … **no credibility**

Literature on Penalized Regression and Credibility

Multiple papers exist on this subject – and more will exist soon!

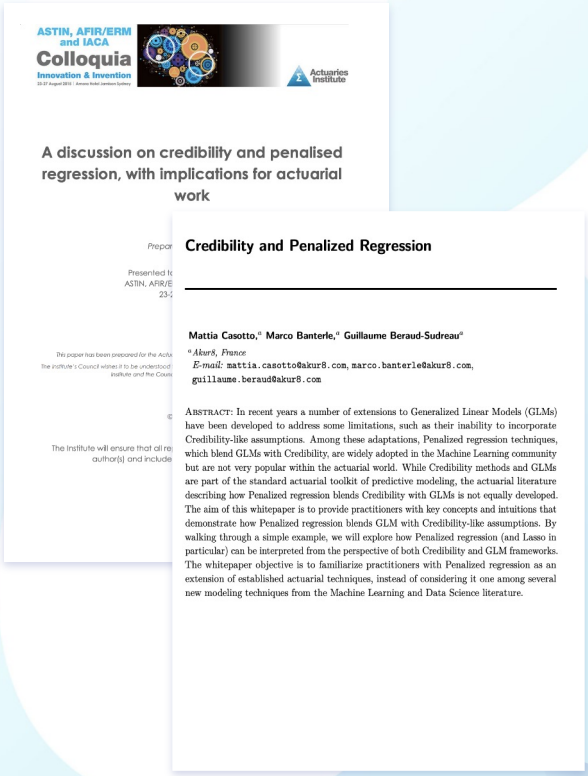
For more information on this topic, please reference the following papers:

- M.Casotto et al. “Credibility and Penalized Regression” (2022)
- Fry, Taylor. “A discussion on credibility and penalized regression, with implications for actuarial work” (2015)
- M. Casotto, T. Holmes, G. Beraud-Sudreau, “Derivative Lasso: Credibility-based signal fitting for GLMs.” (2023 – Draft Available)

Upcoming Call for Reviewers on a CAS Monograph:

- *Contact Brandon Smith if interested: brandon.smith@markel.com*

(Don’t reach out to me – reviewers should be anonymous)



ASOP No. 25
Credibility Procedures

ASOP No. 25 Credibility Procedures

Application to Penalized Regression

1.2 Scope

This Standard applies to actuaries when performing actuarial services involving **credibility procedures** in the following situations:

[…]

c. When the actuary is **blending** or considering blending **subject experience with other experience**; […]

Penalized Regression is **in scope** because the actuary is blending subject experience (modeling data) with other experience (the overall average).

Is penalized regression a credibility procedure?

ASOP No. 25 Credibility Procedures

Application to Penalized Regression

2.2 Credibility Procedure

A process that involves the following:

a. The evaluation of subject experience for potential use in setting assumptions without reference to other data; or
b. The identification of relevant experience and the selection and implementation of a method for blending the relevant experience with the subject experience.

Yes – **Penalized regression is a credibility procedure**. Penalized regression blends the subject experience (modeling segment signal) with relevant experience (the overall average).

ASOP No. 25 Credibility Procedures

Application to Penalized Regression

2.4 Relevant Experience

Sets of data, that include data other than the subject experience, that, in the actuary's judgment, are **predictive of the parameter under study** (including but not limited to loss ratios, claims, mortality, payment patterns, persistency, or expenses). **Relevant experience may include subject experience as a subset.**

As a default, we have selected **1.0 relativities** or 0.0 coefficients as our **relevant experience** when using penalized regression.

We will discuss the appropriateness of this selection in the following slides.

ASOP No. 25 3.3 Selection of Relevant Experience

Application to Penalized Regression

- The actuary should use care in selecting the relevant experience.
- Such relevant experience should have characteristics similar to the subject experience. Characteristics to consider include items such as demographics, coverages, frequency, severity, or other determinable risk characteristics that the actuary expects to be similar to the subject experience. If the proposed relevant experience does not meet and cannot be adjusted to meet such criteria, it should not be used.
- The actuary should apply credibility procedures that appropriately consider the characteristics of both the subject experience and the relevant experience.
- The actuary should consider the extent to which subject experience is included in relevant experience. If subject experience data is a material part of relevant experience, the use of that relevant experience may not be appropriate. In some instances, no relevant experience is available to the actuary. In this situation, the actuary should exercise professional judgment, considering available subject experience, in setting an estimate of expected values.

ASOP No. 25 3.3 Selection of Relevant Experience

Application to Penalized Regression

Subject Experience: Observed

Relevant Experience: Overall Average

Overall average **includes** the observed. ASOP 25 states that it is appropriate that the subject experience is a subset of the relevant experience.

ASOP No. 25 3.3 Selection of Relevant Experience

Application to Penalized Regression

Such relevant experience should have characteristics similar to the subject experience.

Characteristics to consider include items such as demographics, coverages, frequency, severity, or other determinable risk characteristics that the actuary expects to be similar to the subject experience.

If the proposed relevant experience does not meet and cannot be adjusted to meet such criteria, it should not be used.

If your data is homogeneous enough to model, it should satisfy this requirement.

ASOP No. 25 3.3 Selection of Relevant Experience

Application to Penalized Regression

The actuary should apply credibility procedures that appropriately consider the characteristics of both the subject experience and the relevant experience.

If modeling is appropriate for your analysis, penalized regression is likely also appropriate.

ASOP No. 25 3.3 Selection of Relevant Experience

Application to Penalized Regression

The actuary should consider the extent to which subject experience is included in relevant experience.

If subject experience data is a material part of relevant experience, the use of that relevant experience may not be appropriate. In some instances, no relevant experience is available to the actuary.

In this situation, the actuary should exercise professional judgment, considering available subject experience, in setting an estimate of expected values.

Since the output of this model is a relativity, penalized regression is likely appropriate.

ASOP No. 25 3.3 Selection of Relevant Experience

Application to Penalized Regression

Is there a **better choice** for a complement of credibility?

How would this **complement of credibility** be implemented?

Worksheet: Other Complements of Credibility

Any application of credibility

For your line(s) of business, what complements of credibility have you seen in practice?

Are there parallel complements of credibility that can be used for segmentation?

Note: This is brainstorming, write something down even if you think there are some problems with it.

(Example complements after 30 seconds to not bias your answers)

Original Complement	**Potential Modeling Complement**
ISO or other Industry Rates	ISO Rating Plan
Industry Trends	Industry or Competitor Rating Plan
Countrywide Trends	Current Rates or Current Segmentation
Industry LDFs	*Selection of Relevant Industry/Competitor Factors**
Countrywide LDFs	Current CW Model (For a state model)

The Offset: A Complement of Credibility

One-variable model, lasso penalization

Offsets are adjustments to each risk's base prediction.

Prediction = Intercept * Offsets * Modeled Factors

What happens when we **both offset and model** a variable in penalized regression?

	Without Offsets	With Offsets
Complement of Credibility	~Intercept	~Intercept * Offset
Indicated Factor	Exp(Coefficient)	Exp(Coefficient * Offset)
Prior Assumption	Factor is 1.0	Factor is the Offset

When a variable is both offset and modeled, lasso penalization will reduce its coefficient to 0.0 and remove it from the model if the offset is a best estimate.

Building a Model With a Complement for Implementation

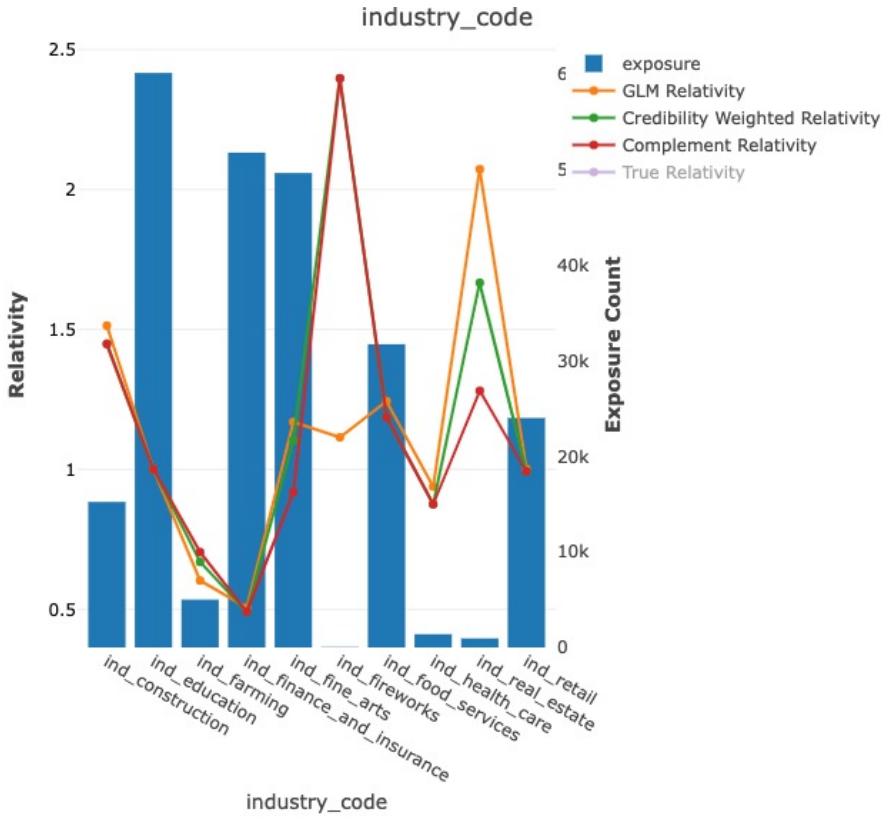
Recommended Starting Practices

1. Apply a complement of credibility as an offset AND include these variables as predictors

2. Use Derivative Lasso, AGLM with Lasso, or GAM using Lasso to eliminate or reduce the need for variable transformations

3. Tune the Lambda Penalty parameter until the model generalizes appropriately across train/test or CV folds.

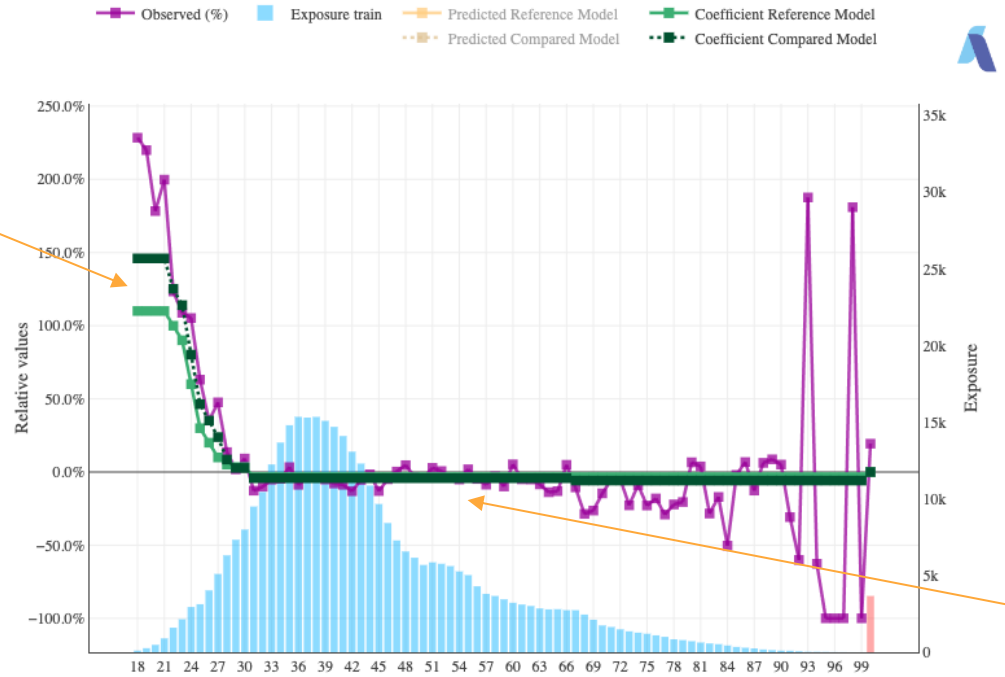
This process is very similar to the traditional model building process



Driver Age Modeled with a Complement of Credibility

Complement = Light Green | Complement + Modeled Coefficient = Dark Green

Significant difference identified by the model



Model is not significantly different – no Change

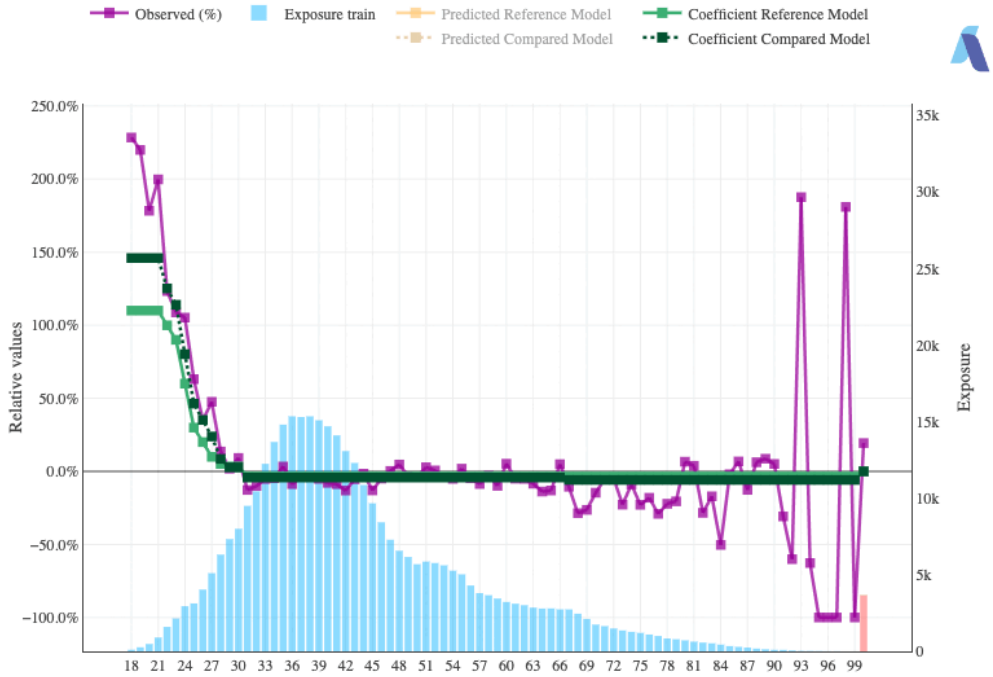
Driver Age Modeled with a Complement of Credibility

Complement = Light Green | Complement + Modeled Coefficient = Dark Green

As the penalty increases, the modeled coefficient moves to zero.

When the modeled coefficient is zero, the complement has full credibility.

What can we do with this model? Well…



ASOP No. 56
Modeling

ASOP No. 56: Modeling

Focus on the Intended Purpose

3.1.1 Designing, Developing, or Modifying the Model

- When the actuary designs, develops, or modifies the model, the actuary should confirm, in the actuary's professional judgment, that the **capability of the model** **is consistent with the** **intended purpose**. Items the actuary should consider, if applicable, include but are not limited to the following:
    a. The level of detail built into a model;
    b. The dependencies recognized; and
    c. The model's ability to identify possible volatility of output, such as volatility around expected values.

3.1.3 Using the Model

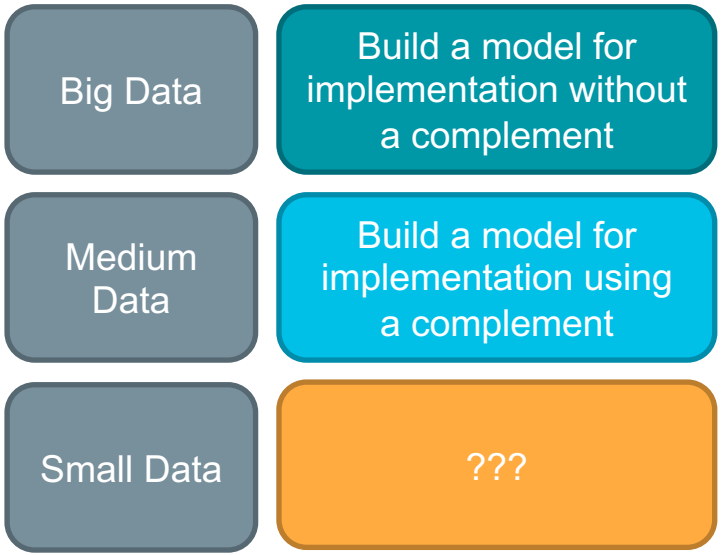
- When using the model, the actuary should make reasonable efforts to confirm that the model structure, data, assumptions, governance and controls, and **model testing and output validation are consistent with the intended purpose**.

3.1.5 Data

- The actuary should use, or confirm use of, **data appropriate for the model's intended purpose** and should refer, as applicable, to ASOP No. 23, Data Quality, when selecting, reviewing, or evaluating data used in the model, either directly or as the basis for deriving, estimating, or testing assumptions used in the model.

Three Stages of Modeling Application

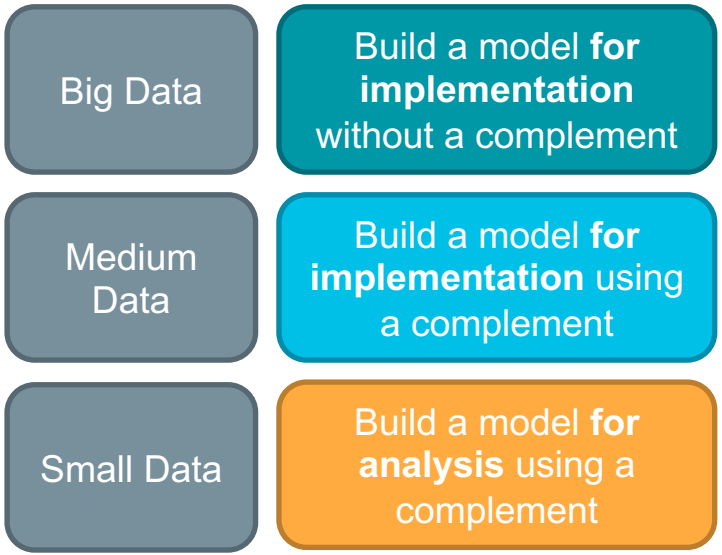
Penalized regression has practical use cases at various levels of credibility



Addition of a Complement of Credibility may satisfy the requirements of ASOP 56 to use penalized regression to create a rating plan for implementation on a medium-sized dataset

Three Stages of Modeling Application

Penalized regression has practical use cases at various levels of credibility



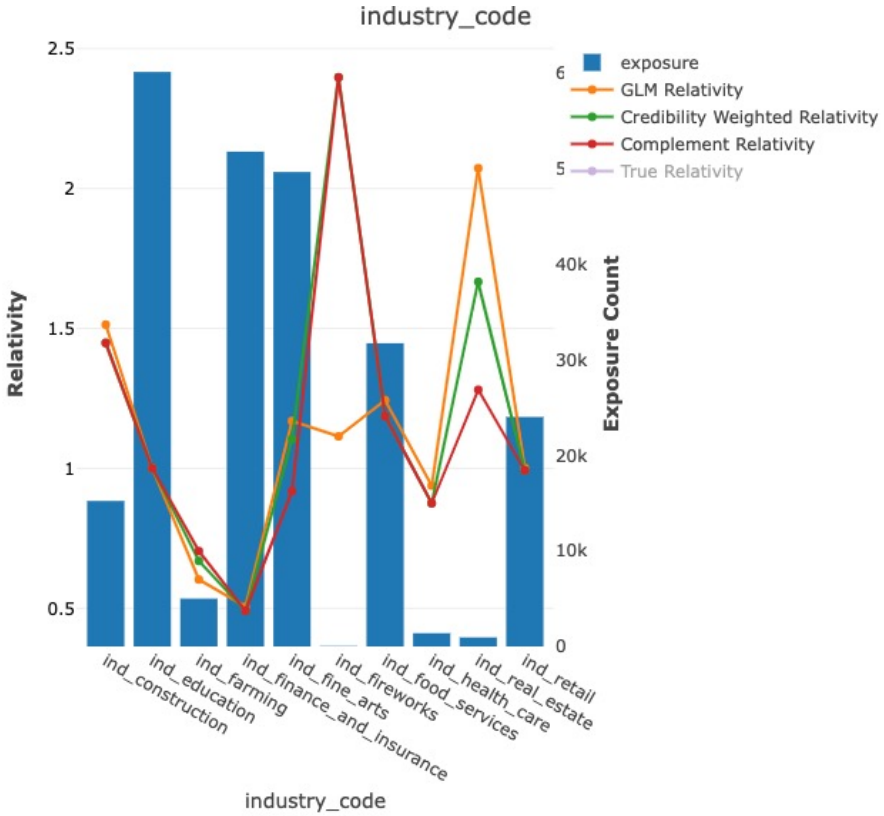
Addition of a Complement of Credibility may satisfy the requirements of ASOP 56 to use penalized regression for the **intended purpose of analysis** on a small dataset.

Building a Model With a Complement for Analysis

Replace Dashboard Analysis and Identify Opportunities

1. Apply a complement of credibility as an offset
2. Use Derivative Lasso, AGLM with Lasso, or GAM using Lasso to eliminate or reduce the need for variable transformations
3. Tune the Lambda Penalty parameter until the model generalizes appropriately across train/test or CV folds.

This process requires significantly less tuning than a model for implementation, as the intended purpose is for identification of opportunities and not justification of changes.



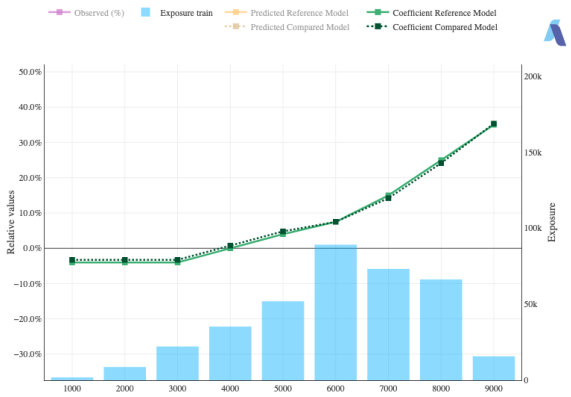
Using Penalized Regression for Analysis – Model Monitoring

Model on the latest year of data only – this data is not fully credible

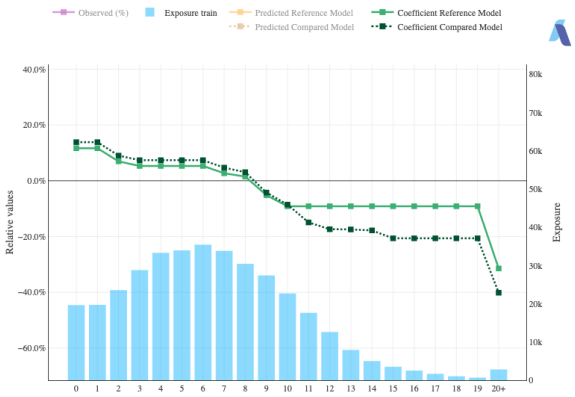
An actuary may judgmentally increase the penalty parameter until only a few variables are significant

- Mileage has collapsed to the original factor; it is **not in scope** for updates
- Accident count has collapsed to the original factor; it is **not in scope** for updates
- Vehicle age has NOT collapsed to the original factor; it is **in scope** for updates*

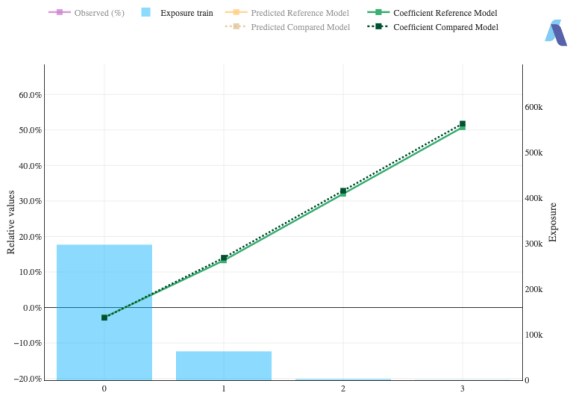
Mileage – Not in scope



Vehicle Age – **In Scope**



Accident Count – Not in scope



*Note the intended purpose is to decide scope for updates, NOT to support updates

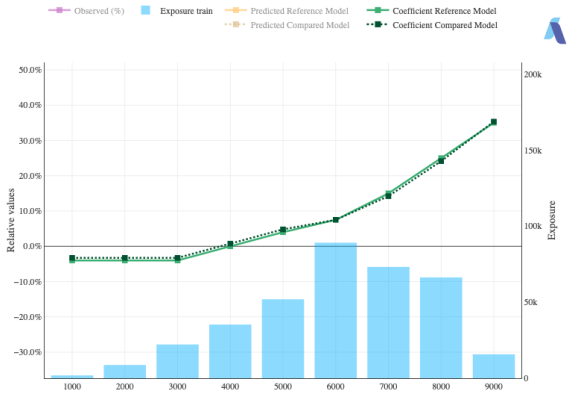
Using Penalized Regression for Analysis – State Analysis

Refit on state data using a current or countrywide model as an offset

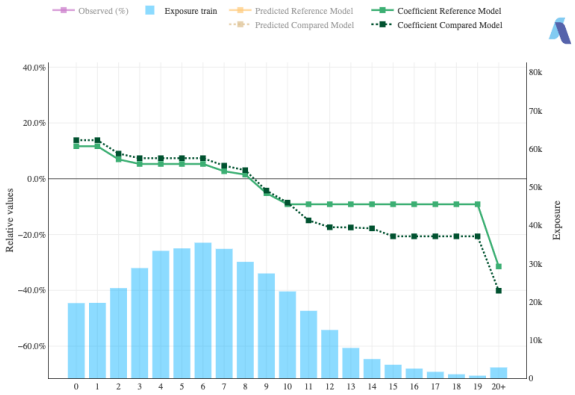
An actuary may judgmentally increase the penalty parameter until only a few variables are significant

- Mileage has collapsed to the original factor; it is **similar to countrywide**
- Accident count has collapsed to the original factor; it is **similar to countrywide**
- Vehicle age has NOT collapsed to the original factor; it is **behaving differently than countrywide** *

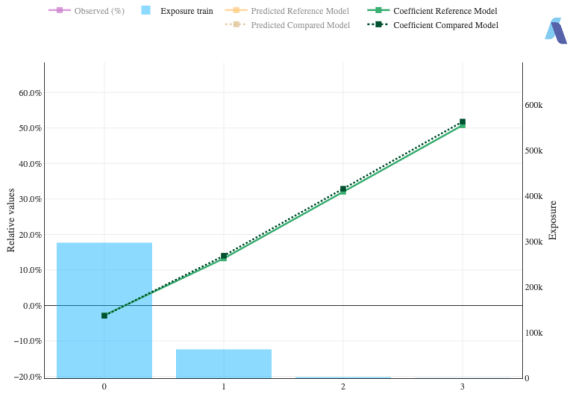
Mileage – Similar to CW



Vehicle Age – **Different than CW**



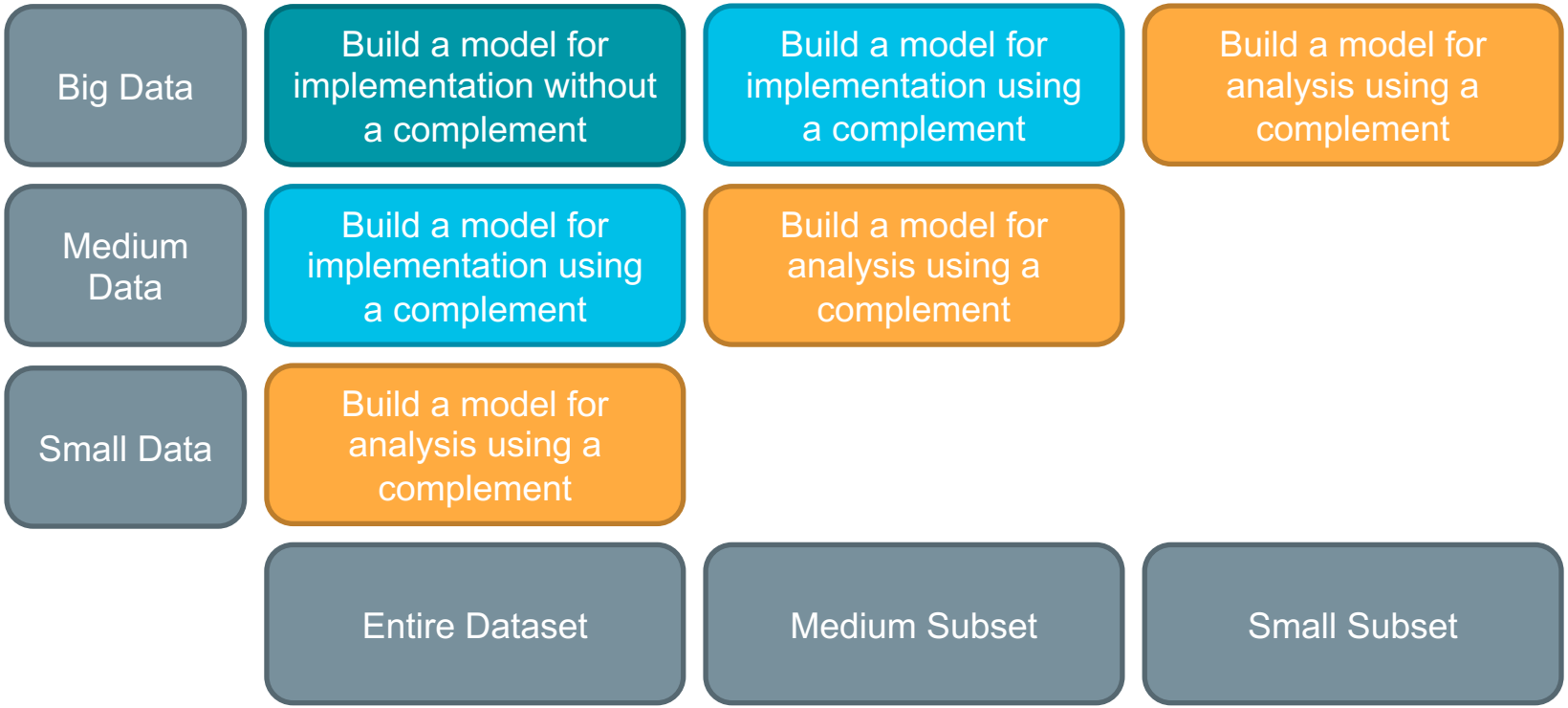
Accident Count – Similar to CW



*Note the intended purpose is to identify opportunities – NOT to support updates

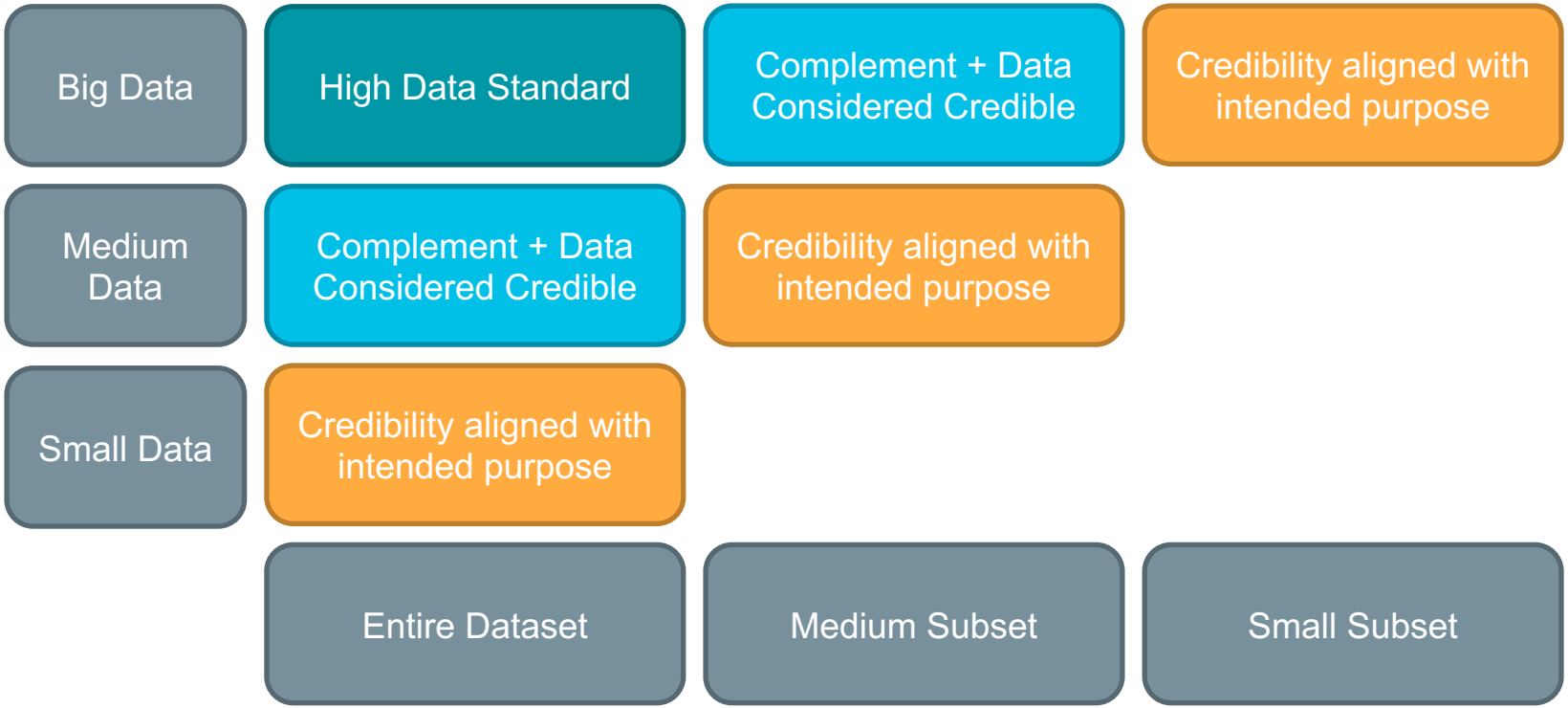
Three Stages of Modeling Application

Penalized regression has practical use cases at various levels of credibility



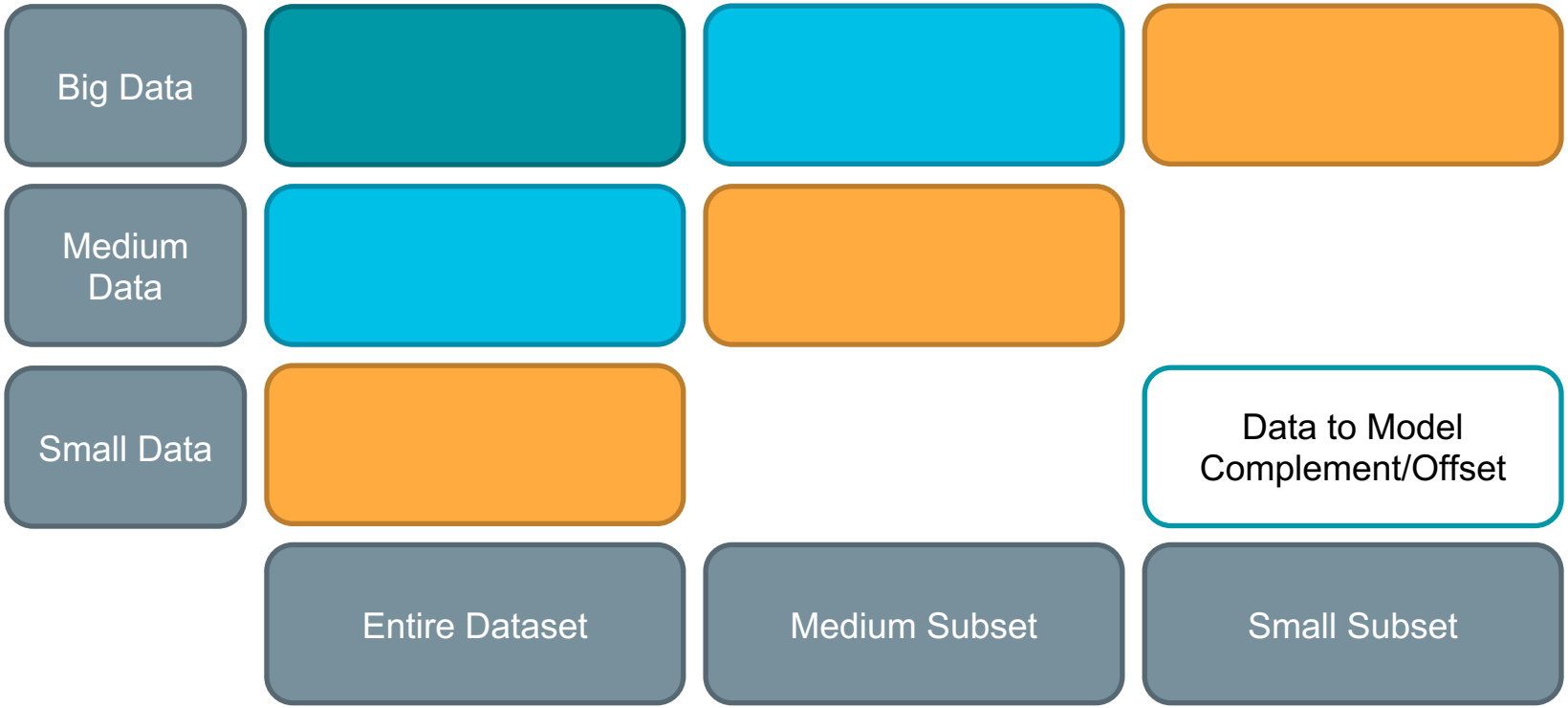
Three Stages of Modeling Application – Data Requirements

Standards for data size and credibility differ by intended purpose



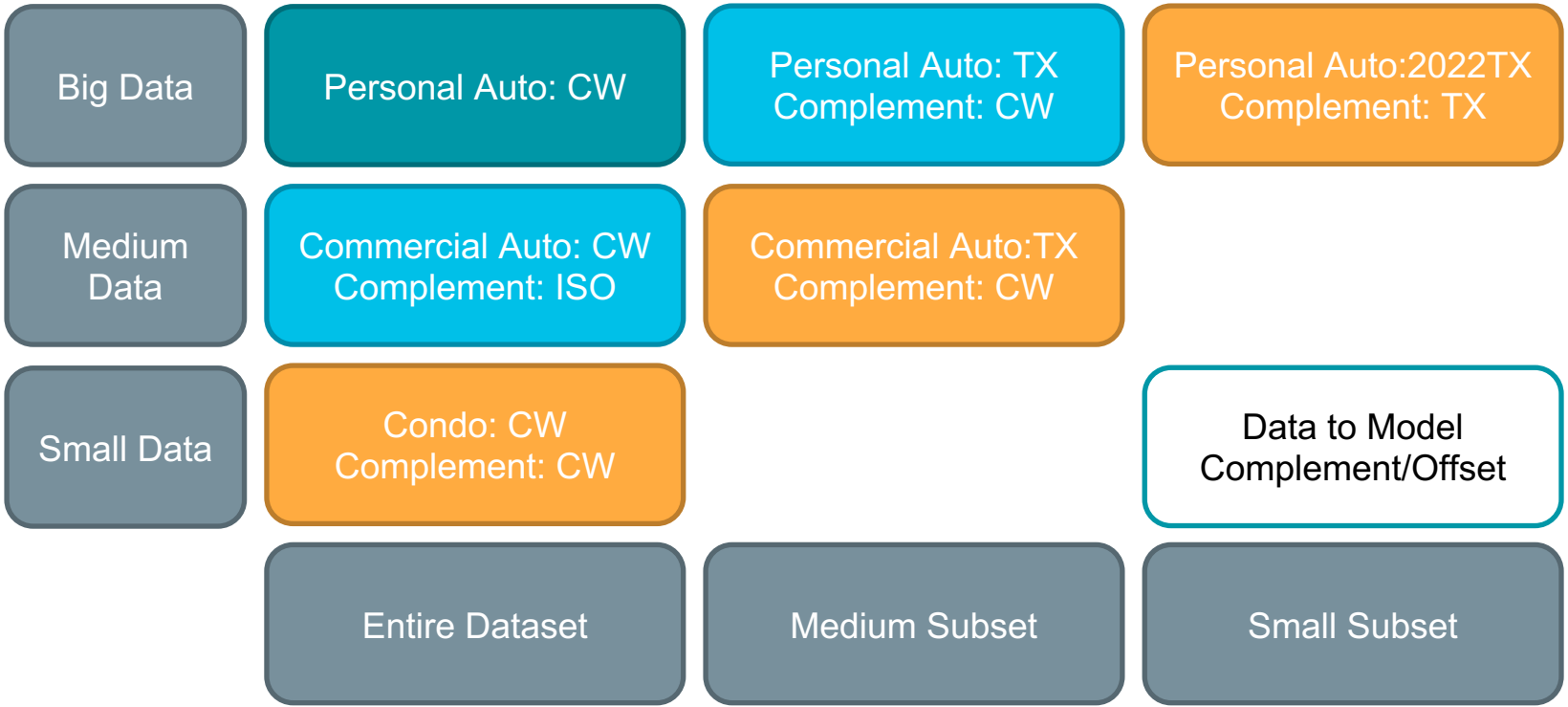
Worksheet: Where are YOUR opportunities?

Penalized regression has practical use cases at various levels of credibility



Worksheet: Where are YOUR opportunities? (Example)

Penalized regression has practical use cases at various levels of credibility



Conclusion

You now understand the general idea – now think about the small details!

Learning Objectives:

- Ability to explain how and why ASOP 25: Credibility Procedures applies to penalized regression
- Identify specific complements of credibility applicable to your models
- Ability to identify applications of penalized regression on varying sizes of data while fulfilling the requirements of ASOP 56: Modeling

Additional Takeaway: A worksheet and framework to apply penalized regression to your business

Modeling is Credibility Additional Guidance

ASOP 56: Modeling: 3.1.4 Model Structure

The actuary should assess whether the structure of the model (including judgments reflected in the model) is **appropriate for the intended purpose**. The actuary should consider the following, as applicable, for a particular model:

a. Which provisions and risks specific to a business segment, contract, or plan, if any, **or interactions more broadly**, are material and appropriate to reflect in the model;
b. Whether the form of the model is appropriate, such as a projection model (deterministic or stochastic), statistical model, or predictive model;
c. Whether the use of the model dictates a particular level of detail, for example, whether grouping inputs will produce reasonable output, or whether a certain level of detail in the output is needed to meet the intended purpose;
d. Whether there is a material risk of the model overfitting the data; and
e. Whether the model appropriately represents options, if any, that could be reasonably expected to have a material effect on the output of the model. Examples include call options on fixed income assets, policyholder surrender options, and early retirement options.

Take care in choosing your complement of credibility.

Take care in choosing the intended purpose of your model.

ASOP 56: Modeling: 3.6 Evaluation and Mitigation of Model Risk

The actuary should evaluate model risk and, if appropriate, take reasonable steps to mitigate model risk. The type and degree of model risk mitigation that is reasonable and appropriate may depend on the following:

a. The model's **intended purpose**
b. The nature and complexity of the model;
c. The **operating environment** and governance and controls related to the model;
d. Whether there have been changes to the model or its operating environment; and
e. **The balance between the cost of mitigation efforts and the reduction in potential model risk.**

Model risk mitigation efforts should be commensurate with model risk. When a model is used **for the intended purpose of data analysis**, model risk is quite low.

Example: If you are using the output of your model as if it were a dashboard, the input data and model should be as rigorously reviewed as the data that is input into a dashboard.

Example: If you are using the model to fully justify changes, the model should be more rigorously reviewed commensurate with this implementation risk.

ASOP No. 25 3.4 Professional Judgment

The actuary should exercise professional judgment when using a credibility procedure. The use of credibility procedures is not always a precise mathematical process. For example, in some situations, an acceptable procedure for blending the subject experience with the relevant experience may be based on the actuary assigning full, partial, or zero credibility to the subject experience without using a rigorous mathematical model.

Application for Penalized Regression:

- Judgmentally selecting a larger penalty term may be appropriate to avoid overfitting. In terms of credibility, overfitting is assigning too much credibility to the subject experience.
- It is *not* generally recommended to select a smaller penalty term than test statistics indicate as this is textbook overfitting and not the proper application of a credibility procedure.
- Selecting between the total indicated factor and the complement may be appropriate.
- Actuaries should take care to evaluate the effect of penalization on all segments for appropriateness. Penalized regression does not remove actuarial judgment entirely.

ASOP No. 25 3.4 Homogeneity of Data

In carrying out credibility procedures, the actuary should consider the homogeneity of both the subject experience and the relevant experience. Within each set of experience, there may be segments that are not representative of the experience set as a whole. The predictive value can sometimes be enhanced by separate treatment of these segments.

Application for Penalized Regression:

- If using industry segmentation as a complement, the actuary should consider how different their own mix of business is from the data used to calculate industry segmentation.
- It may be appropriate to use only some factors of an industry rating plan as a complement of credibility and not others. For example, an insurer may trust external vehicle age factors, but not certain business classifications due to the insurer's unique underwriting practices.
- (Always consider correlations when selecting your complements of credibility)

ASOP No. 25 4.1 Disclosure

Whenever appropriate in the actuary's professional judgment, the actuary should disclose the credibility procedures used and any material changes from prior credibility procedures.

Application in Penalized Regression:

- Penalized Regression is a credibility procedure under the scope of ASOP No. 25 and an actuary should consider required disclosures from this ASOP.
- For example, if your selected complement of credibility has changed from a prior analysis or filing, it is likely appropriate to disclose this as it is a material change from prior credibility procedures.

Application in Non-Penalized Regression:

- Is it necessary to disclose that when using a GLM, the actuary has judgmentally or otherwise assigned full credibility to the data?

Modeling is Credibility