Embedded predictive analysis of misrepresentation risk in insurance ratemaking

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Motivation

- **Misrepresentation** (see, e.g., Winsor [1995]) is a type of insurance fraud when the applicant choose to give a false statement on a trait (e.g., smoking status and age in health insurance) that may affect the insurance premium.

- In practice, insurance companies usually do not verify information provided by the applicant.

- Due to the financial incentive, misrepresentation happens frequently.

Misrepresentation is **unidirectional** and usually **unobserved**.
Misrepresentation on smoking status

(a) Report smoking

(b) Report nonsmoking

**Figure:** Here, we usually do **not observe** the true status, hence **cannot directly learn** the percentage of misrepresentation.
Ratemaking and misrepresentation

- In insurance ratemaking, actuaries determine health insurance rates based on regression models between historical losses and risk factors such as age, location and smoking status.
- In a traditional ratemaking model, misrepresentation will result in an underestimation of the risk/association.
- Misrepresentation is usually unobserved, with a typical selection bias for the confirmed cases. Hence, standard models may be nonidentifiable (e.g., for misrepresentation percentage and risk effect).
Figure: Loss experience by reported smoking status under ratemaking models, when comparing individuals with same other risk characteristics.
For health insurance, we specify a regression structure that characterizes the relationship between medical losses and true risk profiles such as age, location and smoking status.

We assume there is a latent mechanism on the misrepresentation of smoking status, and we know the direction of error.

In addition, we can specify an embedded predictive model that associate the chance of misrepresentation to the age variable.

In more complicated cases, the risk factors can be selected or tested, like in the case of regular regression analysis.
Smoking effect on loss frequency

(a) Low association

(b) High association

Figure: Posterior distributions for smoking effect $\alpha_1$ on Poisson losses ($n = 1000$).
Age effect on loss frequency

(a) Low association

(b) High association

Figure: Posterior distributions for age effect $\alpha_2$ on Poisson losses ($n = 1000$).
Age effect on misrepresentation risk

(a) Low association  
(b) High association

Figure: Posterior distributions for age effect $\beta_1$ on chance of misrepresentation ($n = 1000$).
Healthcare expense risk factors

Figure: Credible intervals for the effect of smoking and age, for the office-based visits and total medical charges.
Figure: Credible intervals for age effect on odds of misrepresentation, and the estimated misrepresentation probability $p$ for individuals at the average age.
Application in fraud modeling

Fraud is **unidirectional** and usually **unobserved**.

- The methods may be constructed based on a regression model between published **revenues/expenses** and corporate fraudulent activities (e.g., accounting misconduct studied by Hahn et. al. [2016]), after adjusting for other corporate characteristics.

- Using **predictive models on misrepresentation risk**, we may be able to identify **risk factors** that are associated with corporate frauds, and hence have a **scoring system**.

More generally, even for fraud activities that are confirmed, there is a **selection bias**, since the characteristics of the unidentified frauds may be different. So there is a need for statistical models that adjust for the bias.