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Institut interdisciplinaire du Développement de l'entreprise

Can we infer on behavioral impacts of public policy on accident severity outcomes?

A Swiss case study using historical disaggregate accident reports

21st Swiss Transport Research Conference
12–14 September 2021

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Outline

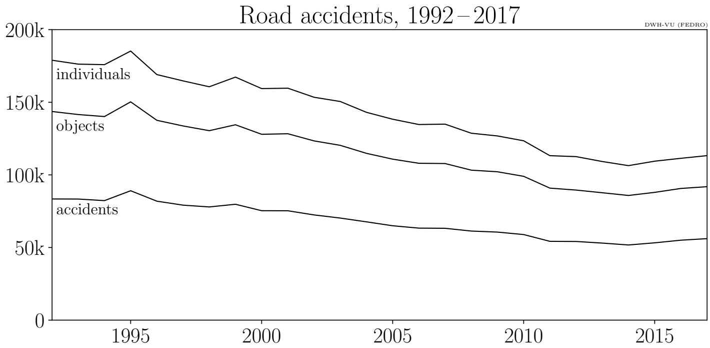
1. Context
2. Modeling Approach
    - Ordered logit
    - Latent variable
3. Dataset
4. Modeling Results
5. Conclusion

Outline

Traffic Accidents in Switzerland

From 1992 to 2017

- Approx. 1.8M reported crashes, 3.7M individuals involved.
- In total, 140k severely injured, **12’802 victims**.
- 230 victims in 2017.



Via Sicura

Action program for road safety

- "Reduce the number of fatalities and serious injuries on our roads."
- 20 legislative measures, both **preventive** and **repressive**.
- Introduced step by step since January 2013.

Preventive measures	
Prohibition for probationary license holders to supervise learners	01.2013
Minimum age for cyclists	01.2013
Minimum age for driving animal-powered vehicles	01.2013
Prohibition for certain groups to drive under the influence of alcohol	01.2014
Mandatory daytime running lights	01.2014
Additional training for offenders	not yet
Repressive measures	
Mandatory fitness-to-drive evaluation in case of serious offenses	01.2013
Longer license suspension and stiffer penalties for extreme offenders	01.2013
Confiscation of motor vehicles in case of "unscrupulous" offenses	01.2013
Declaration of caused losses for public liability insurances	01.2013
Legal recourse from public liability insurers against drunk drivers	01.2013
Use of black box data recorders for speeding drivers	not yet
Alcohol ignition-locking systems for drunk drivers	not yet
Other measures	
Support for cross-border criminal prosecutions	01.2013
Prohibition of traffic control warnings for public or commercial purposes	01.2013
...	

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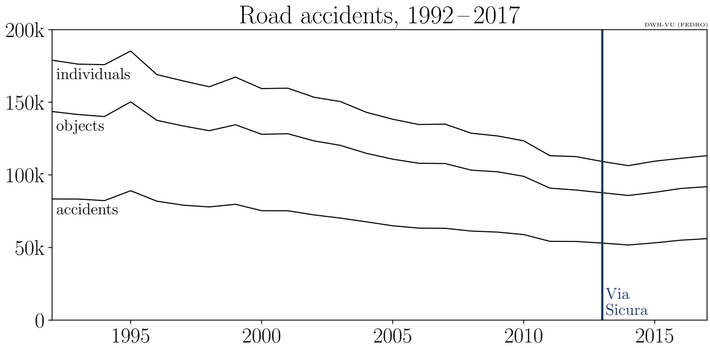

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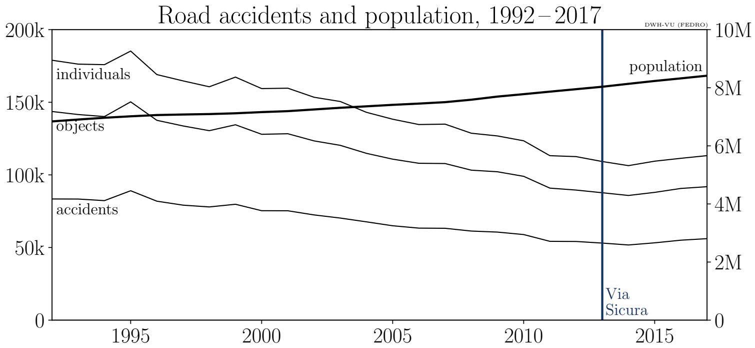

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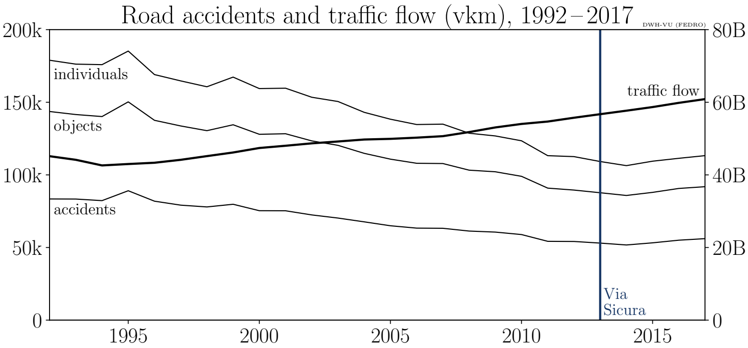


Objective

How do we account for repressive measures in an injury severity model?

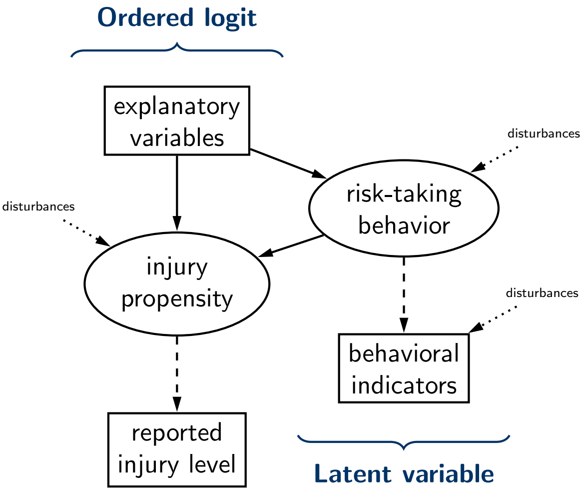
- Dissuasive effect on drivers' behavior.
- In turn, taking less risks reduces crash severity!
- How do we model this?

Leverage the ICLV framework

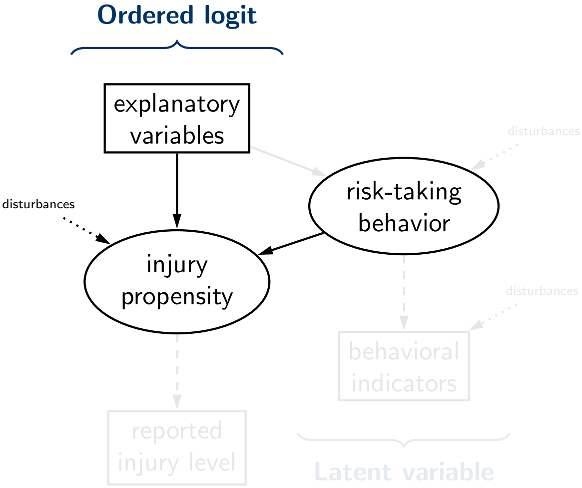
- An ordered logit for individual injury severity is specified;
- We define a latent variable that represents the risky driving behavior;
- The impact of the Via Sicura on that behavior is captured.

Outline

Model structure



Ordered logit: structural equation



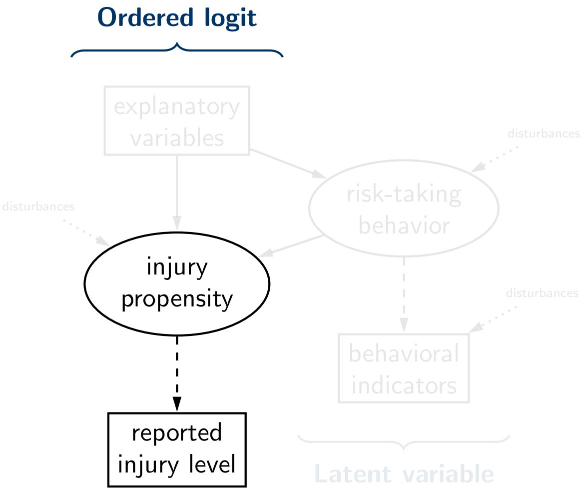
Ordered logit: structural equation

Injury propensity y_n^*

$$y_n^* = \sum_{k=1}^{K} \beta_k x_{nk} + \beta_z z_n^* + \varepsilon_n = u_n + \varepsilon_n$$

- x_{nk} are the explanatory variables;
- β_k are the associated coefficients;
- z_n^* is the latent variable and β_z is its associated coefficient;
- $\varepsilon_n \sim \text{Logistic}\,(0, 1)$.

Ordered logit: measurement equation

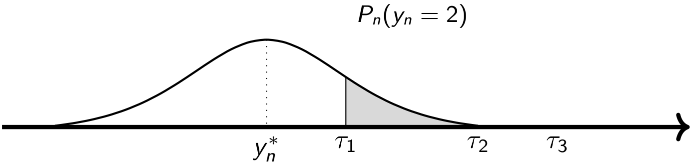


Ordered logit: measurement equation

Reported level of injury y_n

$$
\begin{aligned}
P_n\left(y_n = j\right) &= P\left(\tau_{j-1} < y_n^* < \tau_j\right) \\
&= P\left(\tau_{j-1} < u_n + \varepsilon_n < \tau_j\right) = F\left(\tau_j - u_n\right) - F\left(\tau_{j-1} - u_n\right)
\end{aligned}
$$

- $j \in \{1, 2, 3, 4\}$;
- τ_1, τ_2, τ_3 are thresholds to be estimated.



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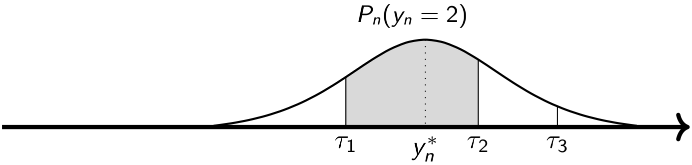
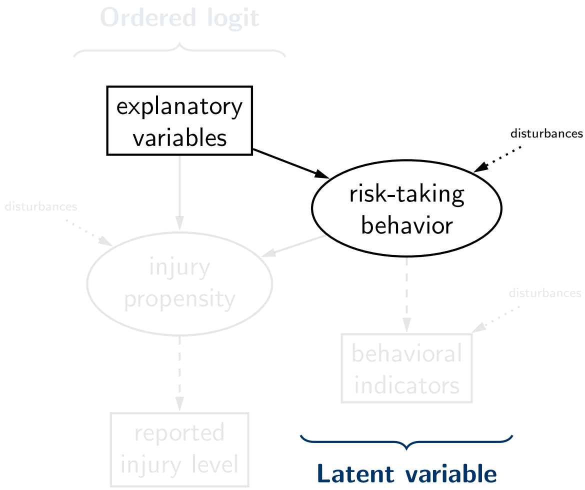


Latent variable: structural equation



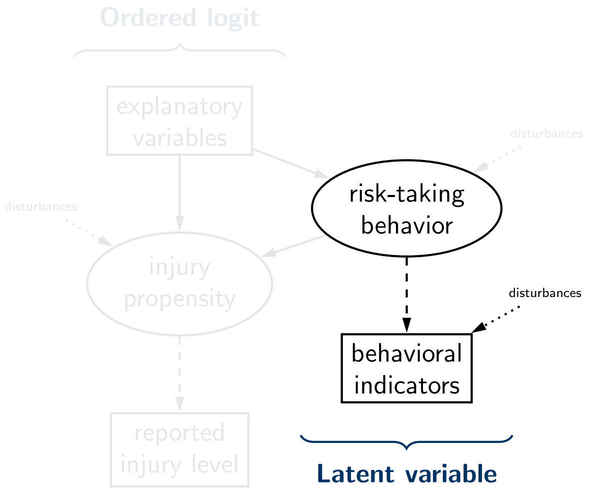
Latent variable: structural equation

Risk-taking behavior z_n^*

$$z_n^* = \gamma_0 + \sum_{\ell=1}^{L} \gamma_\ell x_{n\ell} + \omega_n$$

- γ_0 is an intercept;
- $x_{n\ell}$ are the explanatory variables;
- γ_ℓ are the associated coefficients;
- $\omega_n \sim \mathcal{N}(0, \sigma_\omega)$.

Latent variable: measurement equation



Latent variable: measurement equation

Continuous indicators I^*_{in}

$$I^*_{in} = \alpha_{i,0} + \alpha_{i,1} z^*_n + \nu_{in}$$

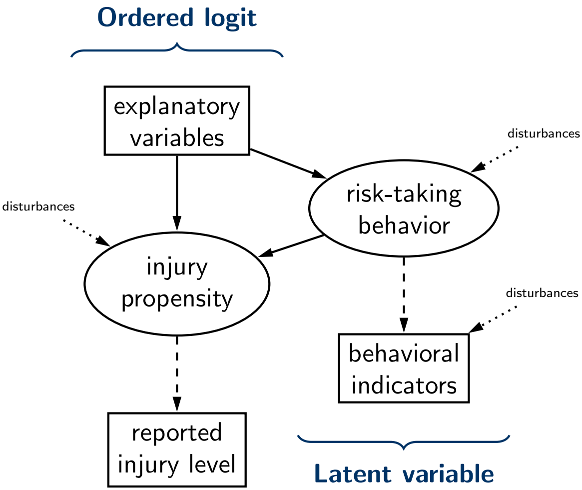
- $\alpha_{i,0}$ is an intercept;
- $\alpha_{i,1}$ measures the effect of the latent variable z^*_n;
- $\nu_{in} \sim \mathcal{N}(0, \sigma_i)$.

Discrete indicators I_{in}

$$\begin{cases} P(I_{in} = 0) = P(I^*_{in} < \mu_i) = P(\alpha_{i,0} + \alpha_{i,1} z^*_n + \nu_{in} < \mu_i) = \Phi\left(\frac{\mu_i - \alpha_{i,0} - \alpha_{i,1} z^*_n}{\sigma_i}\right) \\ P(I_{in} = 1) = 1 - P(I_{in} = 0) = 1 - \Phi\left(\frac{\mu_i - \alpha_{i,0} - \alpha_{i,1} z^*_n}{\sigma_i}\right) \end{cases}$$

- μ_i are thresholds to be estimated.

Model structure



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Dataset

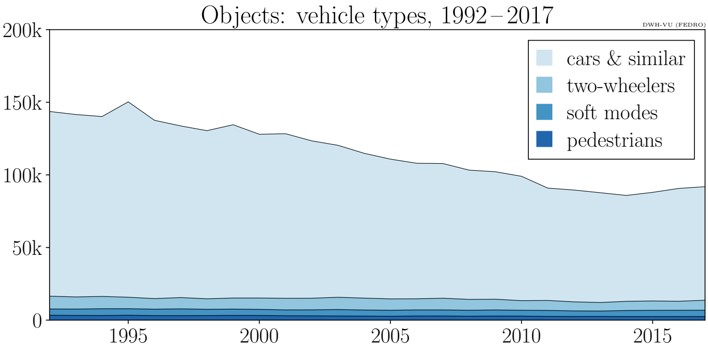
Swiss Traffic Accidents (DWH-VU, FEDRO)

- **All traffic accidents** reported in Switzerland from 1992 to 2017.
- Derived from police reports.
- Variables at the accident, object and individuals levels.
- Injury severity reported on a 4-level scale:
  - 1 – no injury;
  - 2 – minor injury;
  - 3 – major injury;
  - 4 – fatal injury.

Descriptive characteristics

Objects

- Overall, almost 3M objects involved.
- 87.3% are cars and similar: 127k in 1992 down to 78k in 2017.
- The rest includes motorized two-wheelers, soft modes and pedestrians.



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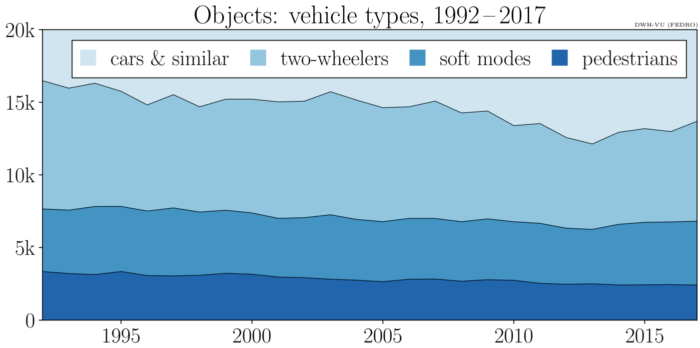
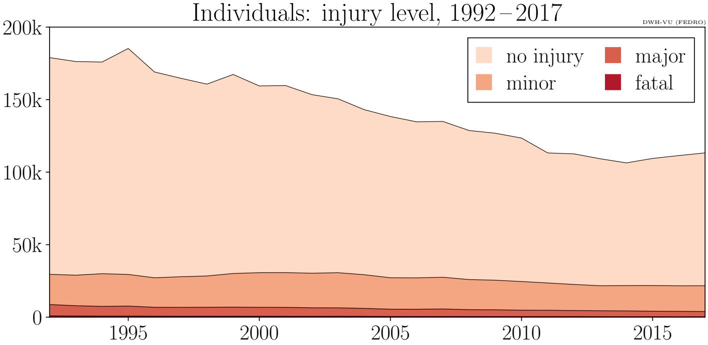


Descriptive characteristics

Individuals

- Overall, 3.7M individuals involved.
- Approx. 81% are unhurt.
- Major and fatal injuries halved over the 26 years.



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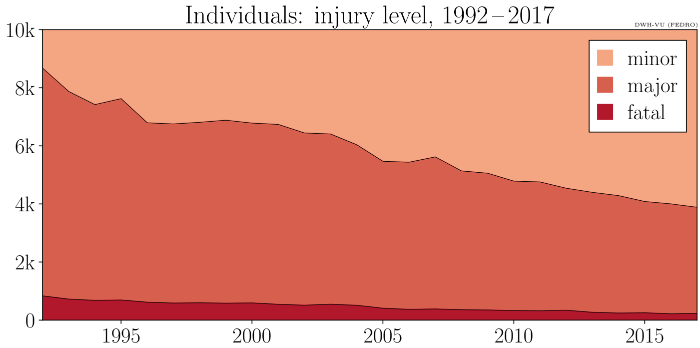
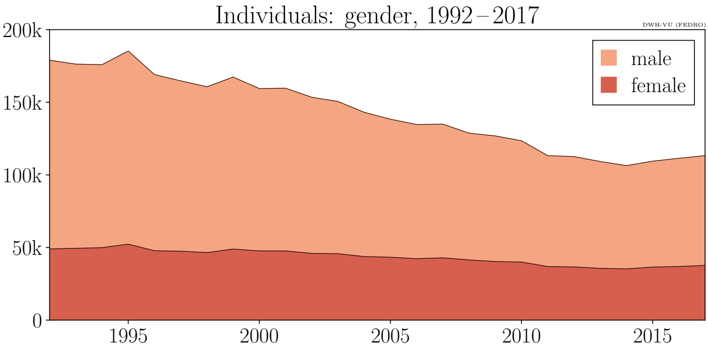


Descriptive characteristics

Individuals

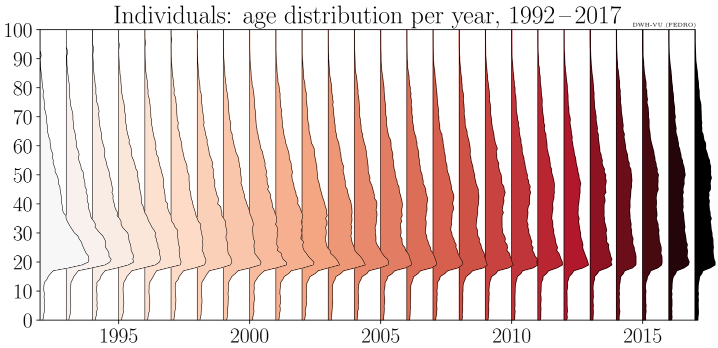
- Overall, 3.7M individuals involved.
- 62.7% are men (49.6% in the Swiss population).
- Women are more prone to suffer minor and major injuries.



Descriptive characteristics

Individuals

- Overall, 3.7M individuals involved.
- Young adults (18 − 35) are largely over-represented in the early years.
- Children and seniors are under-represented.



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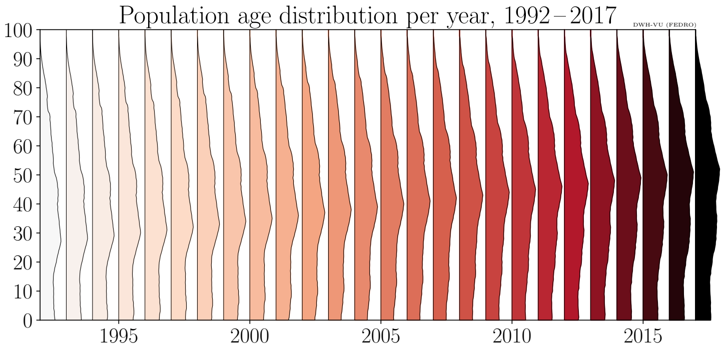

Dataset

Main limitations

- Under-reporting of accidents without injuries.
- Precision and completeness of the data depend on accident severity.
- Precision and completeness of the data depend on the year.
- Only 831k complete observations!

Outline

Model specification

Risk-taking behavior

- Explanatory variables:
  - Via Sicura;
  - Time of the accident (night);
  - Visibility conditions;
  - Road conditions;
  - Passengers' age (child aboard);
  - Drivers' gender.
- Indicators:
  - Driver's substance consumption;
  - Driver's protection;
  - Driver's license.

Injury propensity

- Explanatory variables:
  - Accident type;
  - Speed limit;
  - Vehicle type;
  - Year of entry into service;
  - Seat belt use;
  - Gender and age, interacted.

Estimation results: latent variable

Parameter	Value	Rob. t-test
γ_0	54.4	68.5
γ_via_sicura	−71.0	−67.5
γ_late_night	96.0	68.2
γ_bad_visibility	−14.0	−40.9
γ_bad_road	−9.01	−58.2
γ_child_aboard	−30.5	−58.5
γ_female_driver	−28.4	−68.9
σ_ω	−67.7	−68.8

Estimation results: latent variable

Parameter	Value	Rob. t-test
$\alpha_{\text{substances},0}$	0	—
$\alpha_{\text{no\_license},0}$	−2.20	−568
$\alpha_{\text{no\_protec},0}$	−1.41	−1100
$\alpha_{\text{substances},1}$	1	—
$\alpha_{\text{no\_license},1}$	0.00296	36.9
$\alpha_{\text{no\_protec},1}$	0.00326	58.6
$\sigma_{\text{substances}}$	1	—
$\sigma_{\text{no\_license}}$	1	—
$\sigma_{\text{no\_protec}}$	1	—
$\mu_{\text{substances}}$	95.9	68.1
$\mu_{\text{no\_license}}$	0.590	153
$\mu_{\text{no\_protec}}$	0.143	111

Estimation results: ordered logit

Parameter	Value	Rob. t-test
β_RISKY	0.00293	42.5
β_FRONTAL_COLLISION	0.466	35.5
β_WHILE_PARKING	−1.81	−75.7
β_PEDESTRIAN_INVOLVED	−0.948	−45.4
β_MAX_SPEED_TRAFFIC_NORM	0.600	59.5
β_MAX_SPEED_TRAFFIC_HIGH	0.416	38.8
β_MAX_SPEED_TRAFFIC_UNK	1.07	56.1
β_TWO_WHEELER	1.82	117
β_SOFT_MODE	1.96	67.0
β_PEDESTRIAN	3.03	82.6
β_YEAR_ENTRY	−0.0692	−5.58
β_BELT	−1.45	−115
β_FEMALE	0.503	35.3
β_AGE_FEMALE	0.00455	18.6
β_AGE_MALE	0.000899	4.26
β_AGE_SQ_MALE	0.000108	11.0
τ_1	0.956	32.0
τ_2	3.38	377
τ_3	6.26	157

Outline

Conclusion

Summary

- Inclusion of a behavioral construct in an injury-severity model.
- Appropriate way of capturing the dissuasive effect of repressive measures;
- The model is realistic and in line with the existing literature.

Future work

- Correlation at the vehicle and accident level.
- Additional behaviors: aggressive, distracted, or defensive driving.
- Increase sample size.

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