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An integrated ordered logit and latent variable model for crash injury severity

A Swiss case study using disaggregate crash reports

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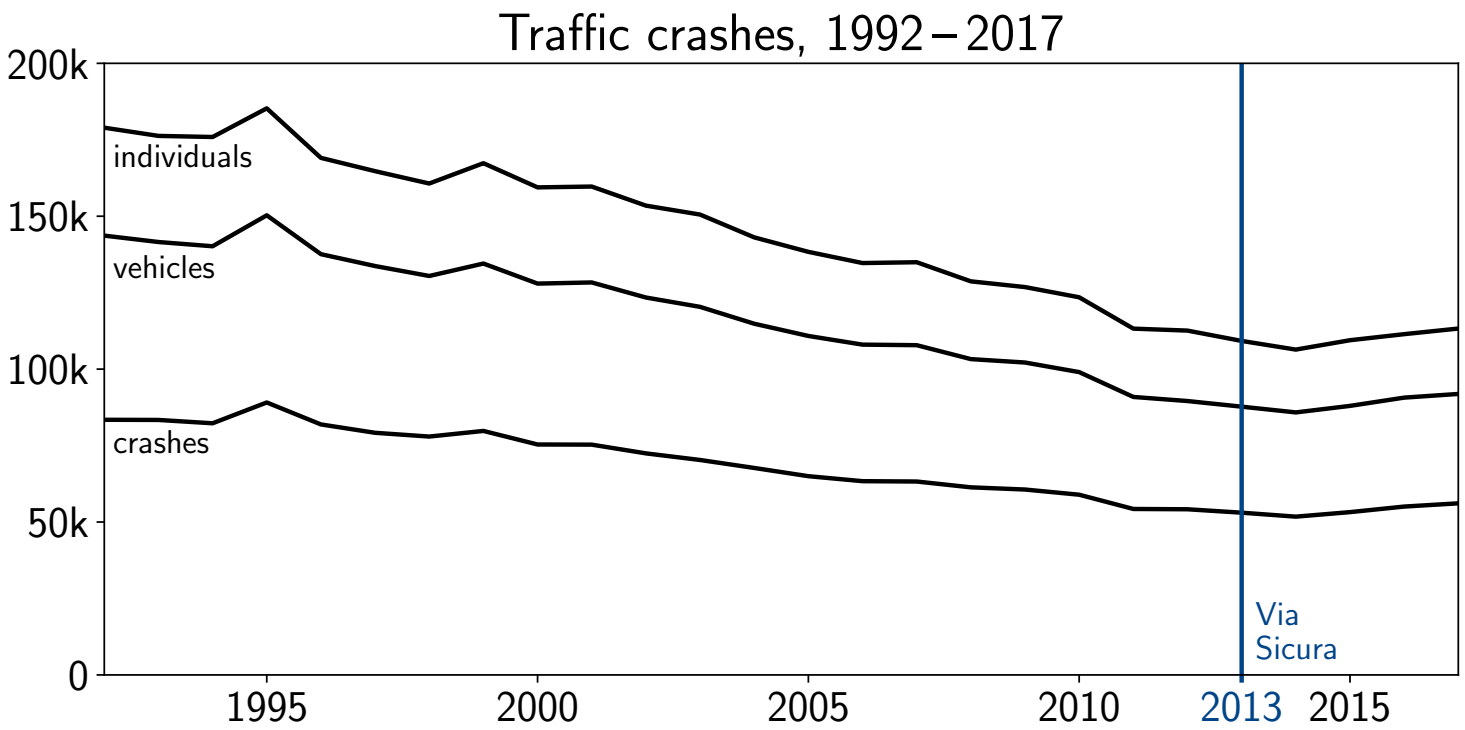
Road safety in Switzerland

Via Sicura (FEDRO, 2005)

- Action program for road safety.
- "Reduce the number of major and fatal injuries on Swiss roads."
- 20 legislative measures, both **preventive** and **repressive**.



Official evaluation

Approach (FEDRO, 2017)

- Regression on yearly totals of major and fatal injuries:
  - Estimate on 2000 – 2012.
  - Predict on 2013 – 2015, **as if Via Sicura did not exist!**
- 4 distinct models, averaged.

	2013	2014	2015
Ridge	4471	4599	4313
Lasso	4495	4546	4504
PLS	4354	4442	4332
Non-linear	4269	4180	4025

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Observed (with Via Sicura!)	4398	4286	4351

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	CV-error	2013	2014	2015
Ridge	108	4471	4599	4313
Lasso	213	4495	4546	4504
PLS	134	4354	4442	4332
Non-linear	141	4269	4180	4025
Average		4397	4442	4294
Observed (with Via Sicura!)		4398	4286	4351
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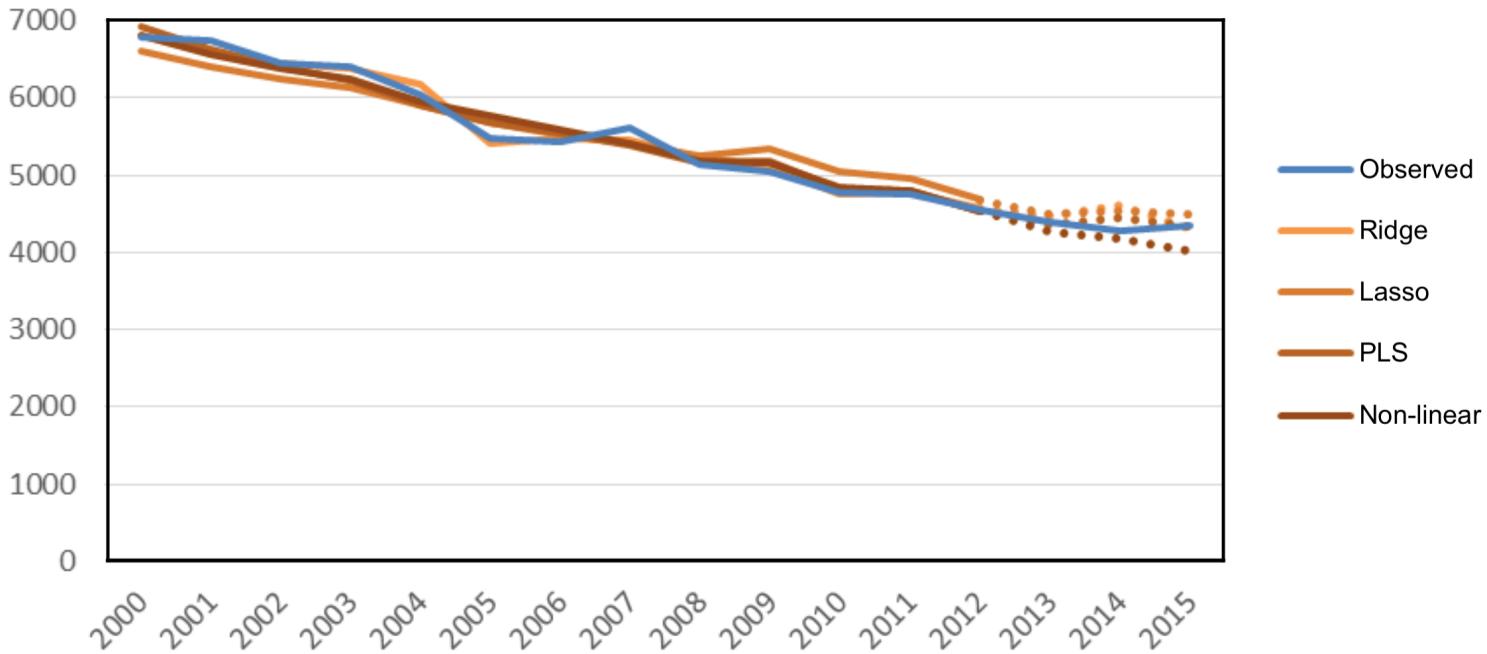
Official evaluation

Outcome (FEDRO, 2017)

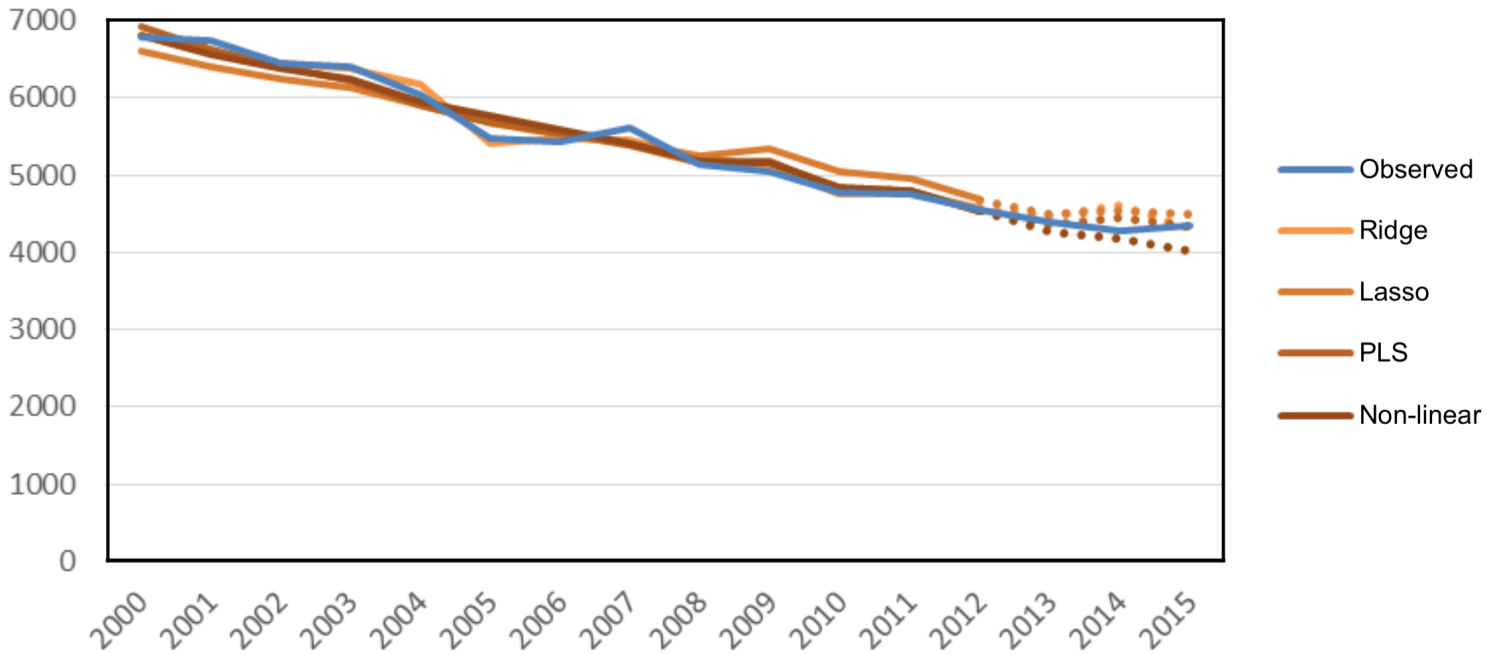
- The effect of Via Sicura is **not significant**...



Official evaluation

Outcome (FEDRO, 2017)

- The effect of Via Sicura is **not significant**...
- ... but is the method appropriate?



Can we do better?

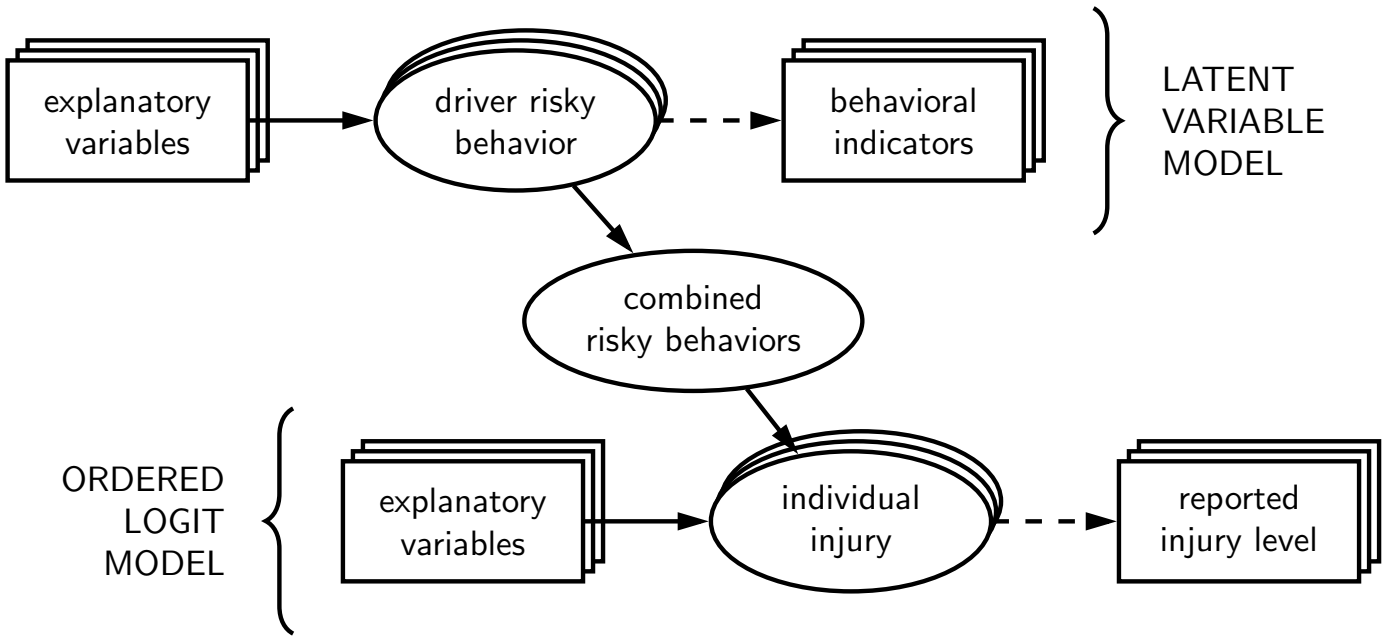
Hybrid model (≈ Lavieri *et al.*, 2016)

- Ordered logit for individual injury severity.
- Risky behavior as a latent variable.
- Capture dissuasive effect of repressive measures.

Available data

- **All traffic crashes** reported in Switzerland between 1992 and 2017:
  - 1.8M crashes.
  - 3.0M vehicles.
  - 3.7M individuals.
- Model validation on 2012 – 2013.

Model structure



Latent variable model

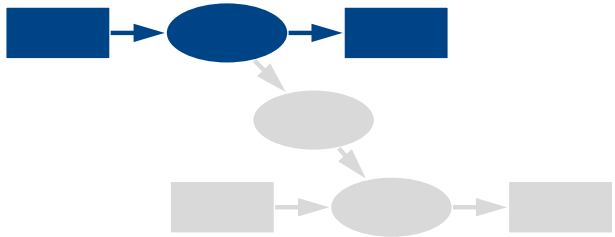
Driver risky behavior

$$x_d^* = \sum_{\ell} \gamma_\ell x_{d\ell} + \omega_d$$

Behavioral indicators

$$I_{id}^* = \alpha_{i,0} + \alpha_{i,1} x_d^* + \nu_{id}$$

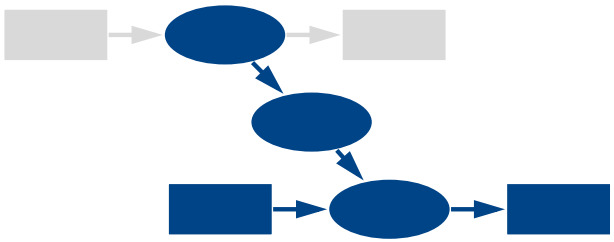
$$\begin{cases} P\left(I_{id} = 0\right) = P\left(I_{id}^* < 0\right) \\ P\left(I_{id} = 1\right) = P\left(I_{id}^* \geq 0\right) \end{cases}$$



Ordered logit model

Combined risky behaviors

$$x^* = \frac{1}{D} \sum_{d=1}^{D} x_d^*$$

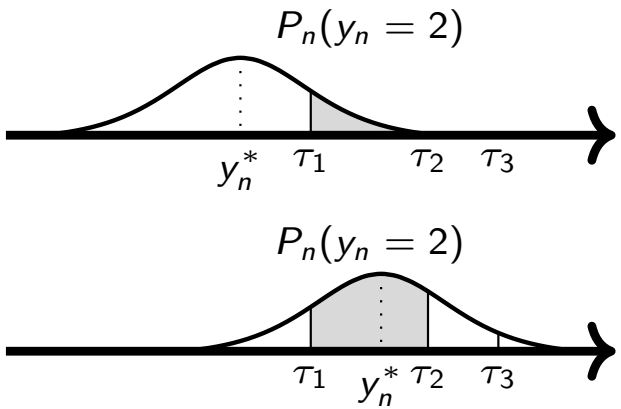


Individual injury

$$y_n^* = \sum_k \beta_k x_{nk} + \beta^* z^* + \varepsilon_n$$

Reported injury level

$$P_n\left(y_n = j\right) = P\left(\tau_{j-1} < y_n^* < \tau_j\right)$$



Estimation report

Sequential estimation.

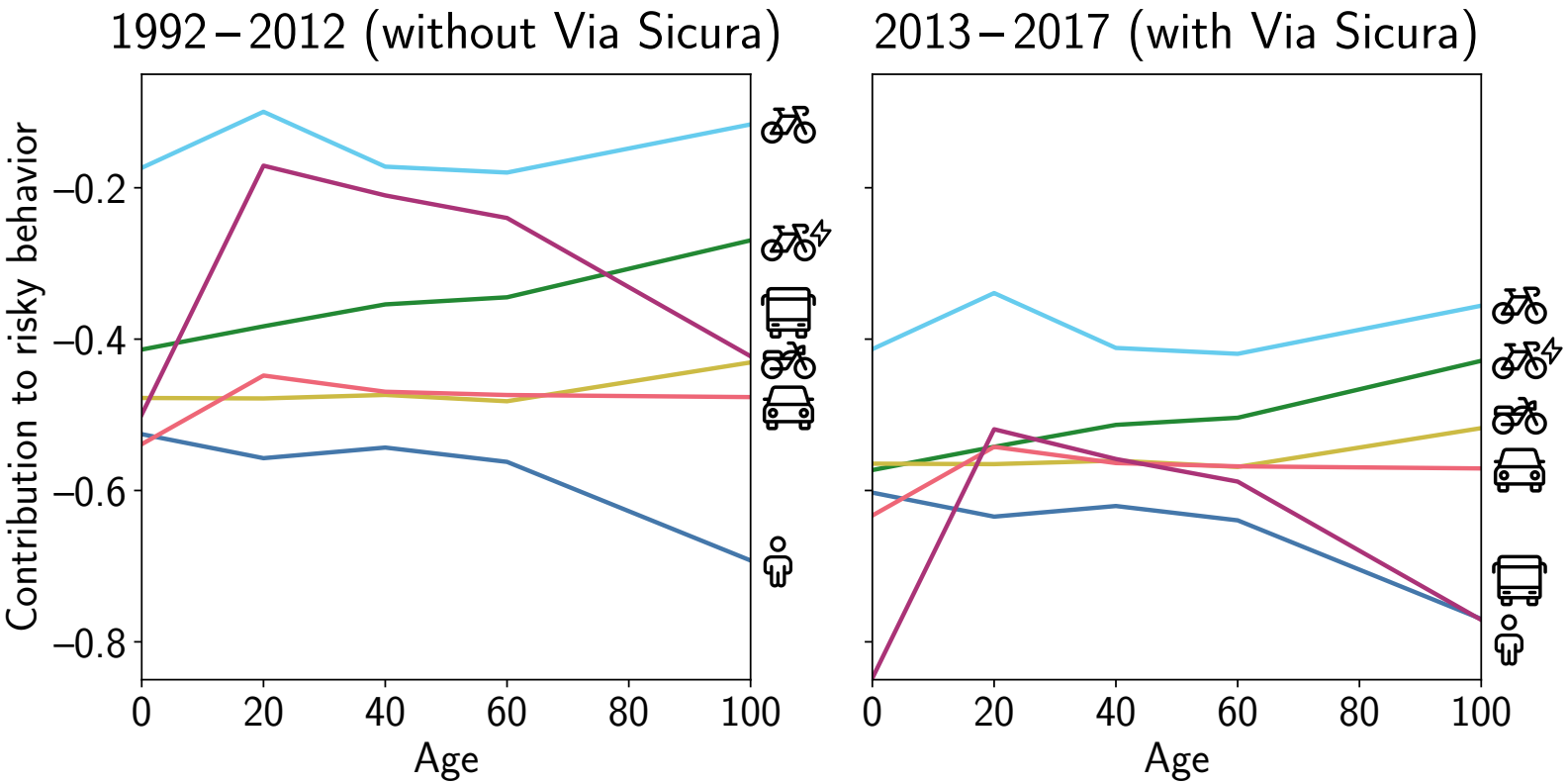
- Using Biogeme (Bierlaire, 2018; 2020).

	LV model	OL model
Sample size	2.5M	2.1M
Est. parameters	48	20
Norm. init. LL	−0.439	−1.077
Norm. final LL	−0.438	−0.486
Norm. val. LL	−0.420	−0.504
Optimization time	0:59:33	4 : 27 : 12

Latent variable model

	Value	Rob. t-test
γ_female_driver	-0.0298	-49.3
γ_two_phase	-0.0454	-53.8
γ_passenger_aboard	-0.0263	-44.3
γ_child_aboard	-0.0214	-16.5
γ_late_night	0.0991	69.4
γ_bad_visibility	-0.0153	-11.3
γ_bad_road	-0.00451	-7.23
γ_bad_weather	-0.00917	-13.2

Latent variable model



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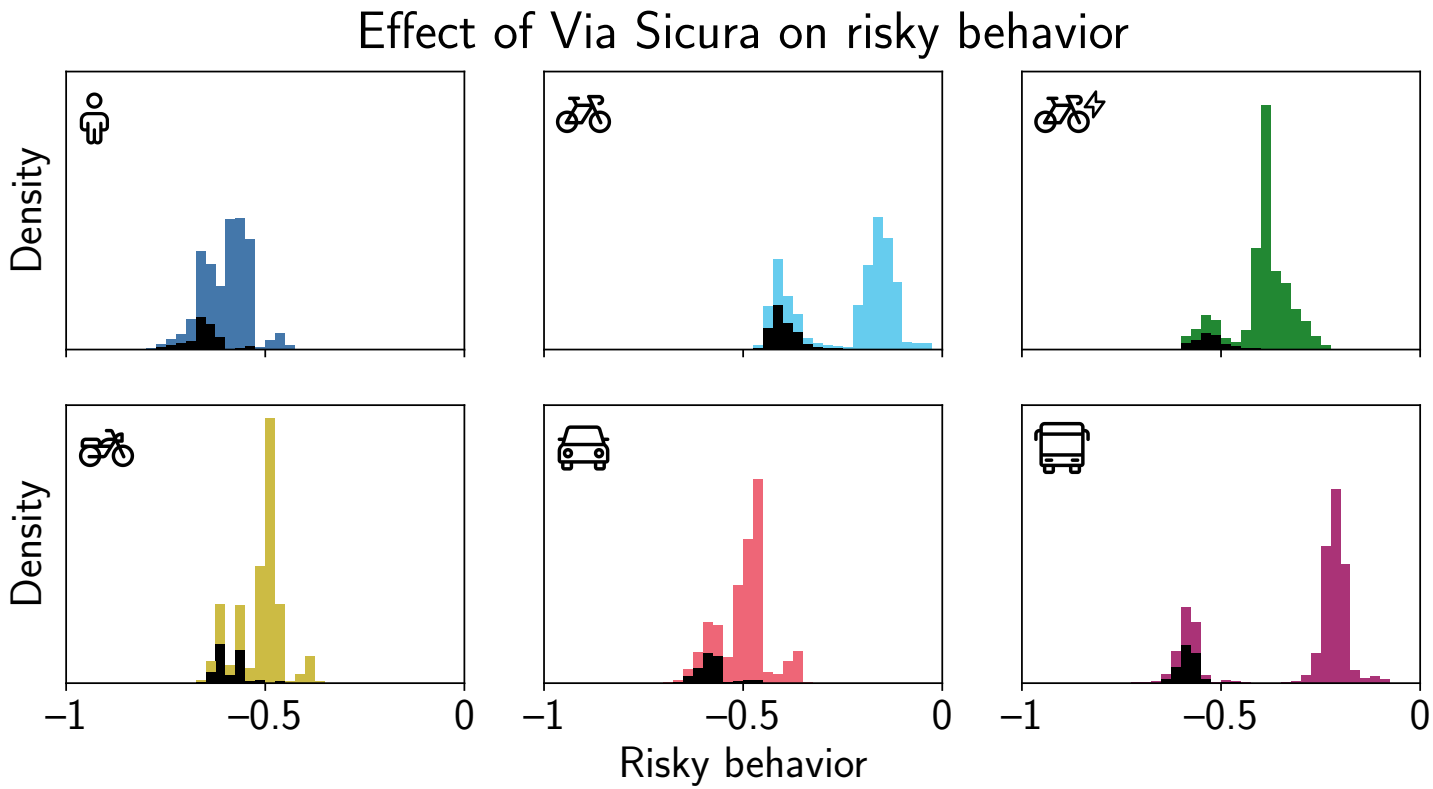

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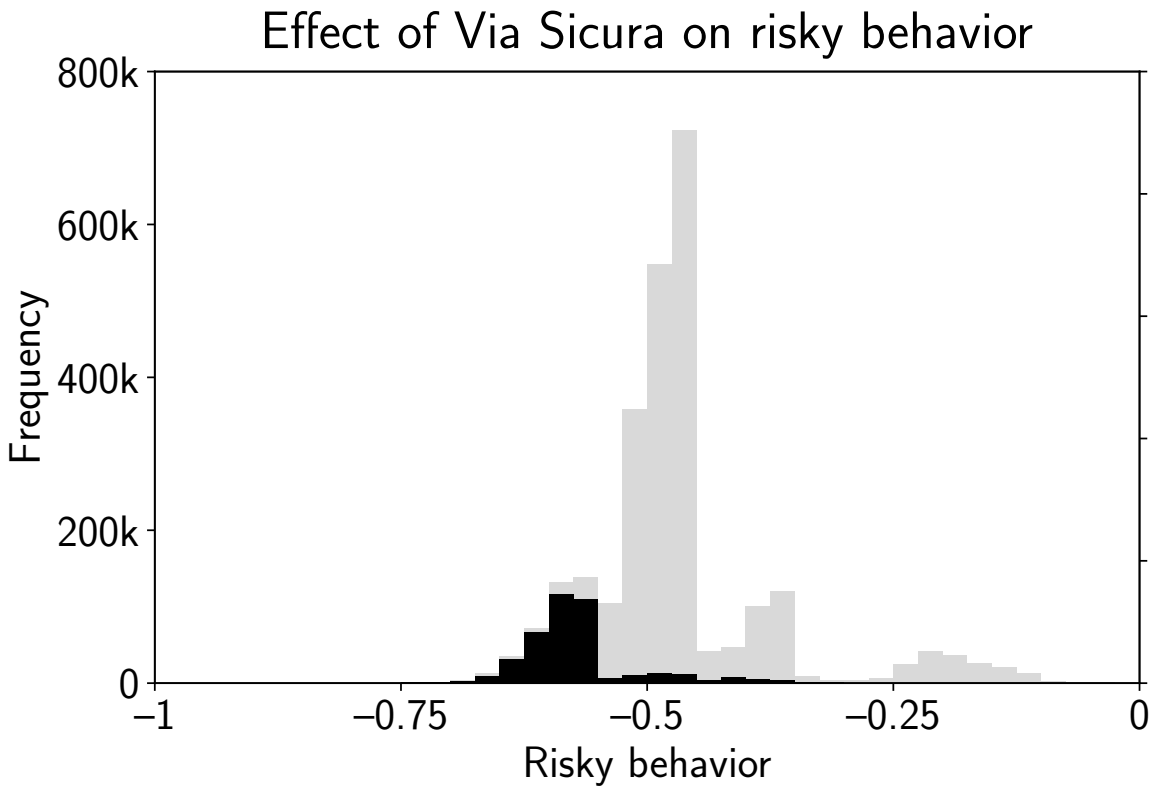

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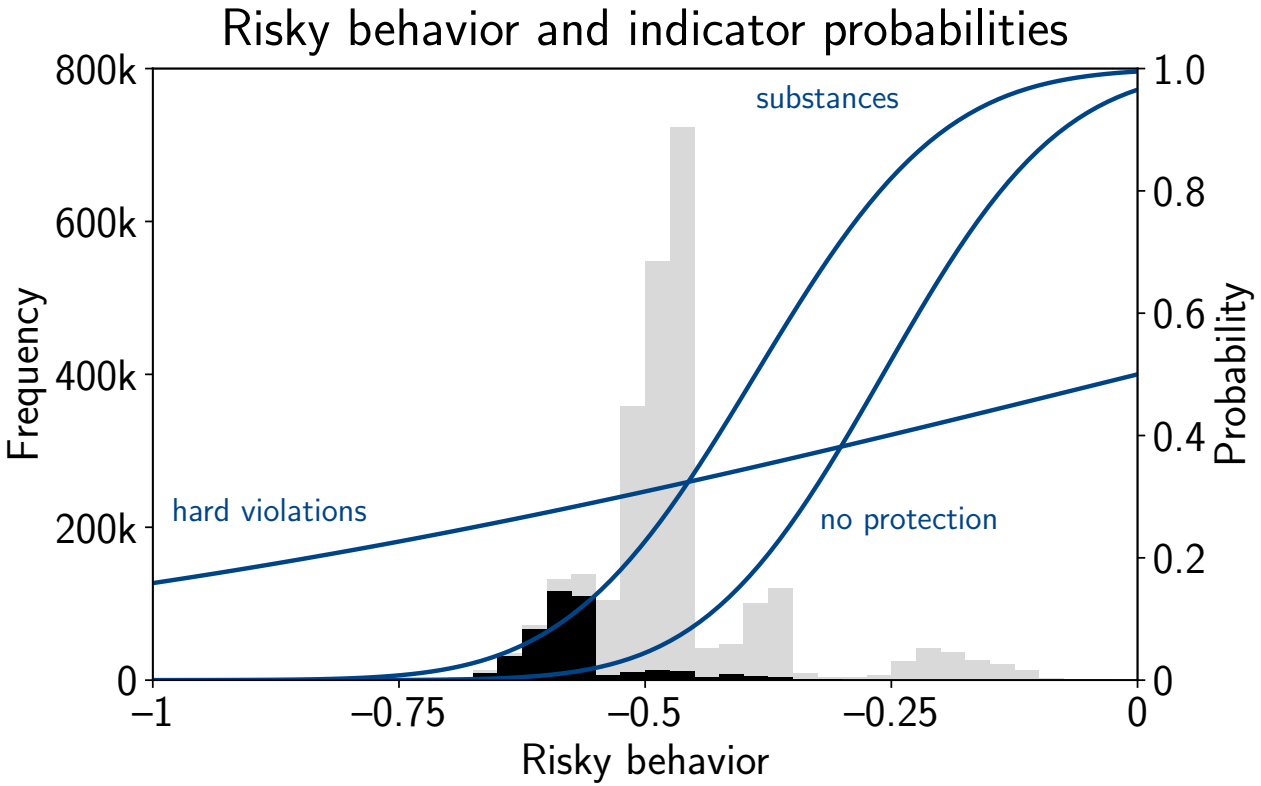
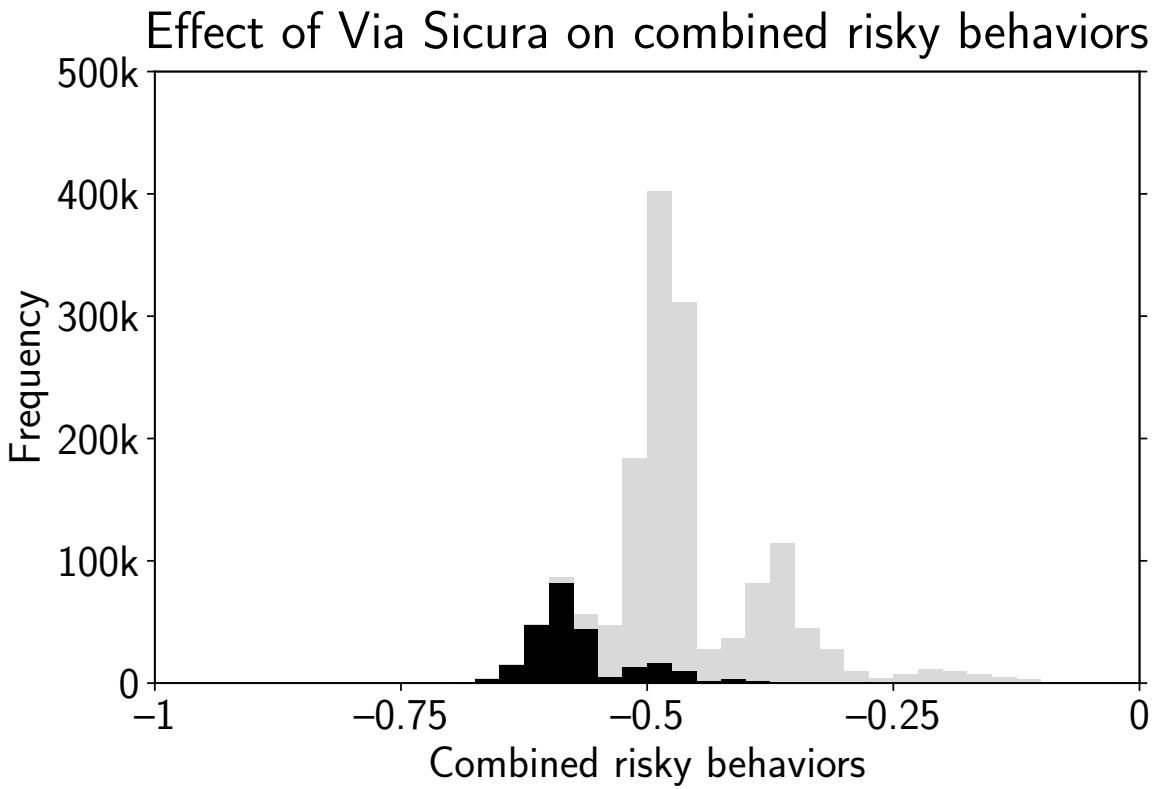
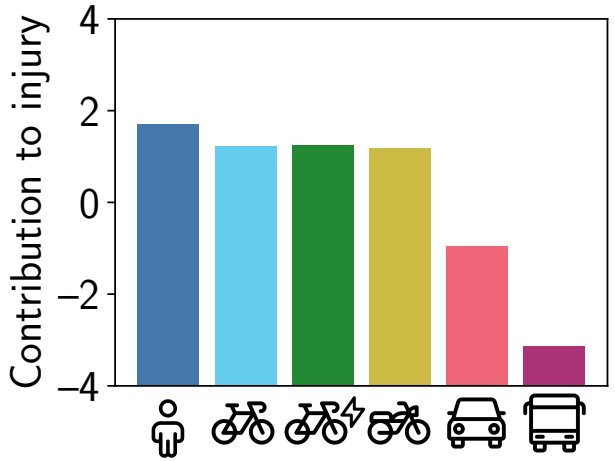


Ordered logit model



Ordered logit model

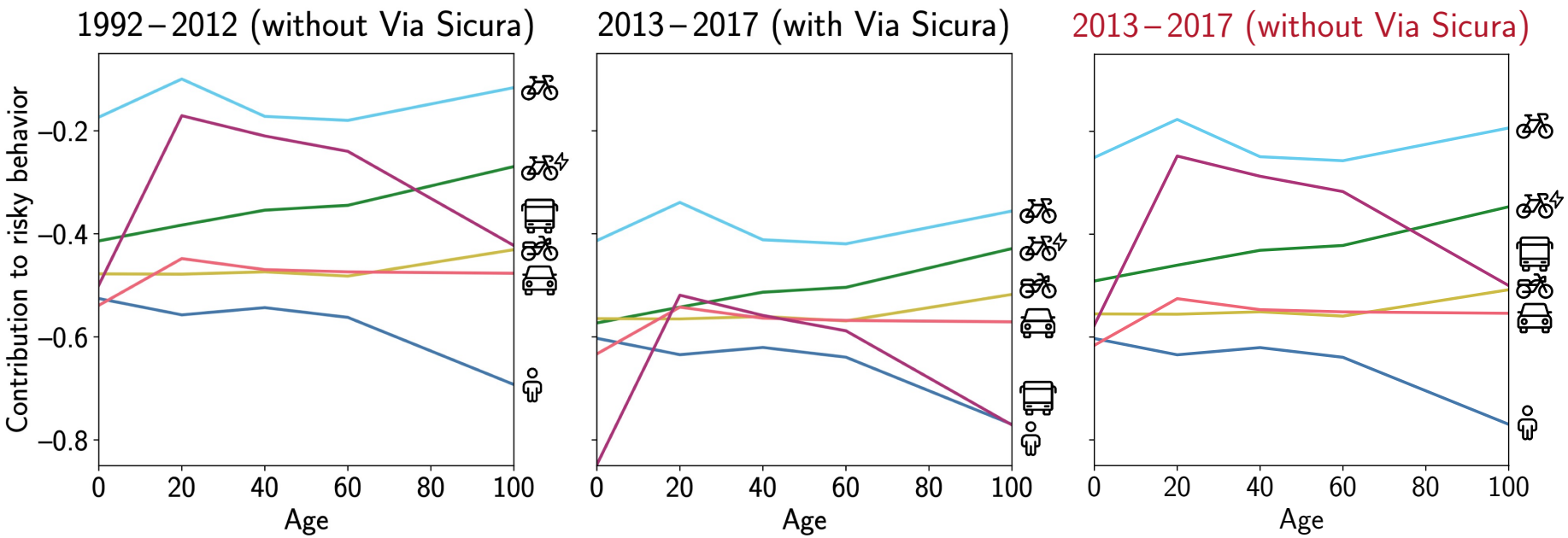
	Value	Rob. t-test
β_RISKY	0.630	22.2
β_BELT	-1.310	-168.0
β_HELMET	-0.292	-11.3
β_MAX_SPEED_TRAFFIC_HIGH	0.797	87.6
β_MAX_SPEED_TRAFFIC_NORMAL	0.998	173.0



So... is Via Sicura effective?

Counterfactual

- Our model misses out plenty of effects on risky behavior.
- The Via Sicura variable mistakenly captures some of them.
- What if Via Sicura was abandoned today?



So... is Via Sicura effective?

Counterfactual

- A world without the Via Sicura measures...
- ... but with the effects its coefficient mistakenly captured.

	Simulated levels of injury, 2013–2017		
	with Via Sicura	without Via Sicura	counterfactual
No injury	255'015 (78.7%)	252'517 (77.9%)	254'244 (78.5%)
Minor	52'549 (16.2%)	53'994 (16.7%)	52'904 (16.3%)
Major	15'231 (4.7%)	16'183 (5.0%)	15'607 (4.8%)
Fatal	1'184 (0.4%)	1'285 (0.4%)	1'225 (0.4%)

	Elast. wrt. change in risky behavior	
	without Via Sicura	counterfactual
No injury	−0.050	−0.049
Minor	0.156	0.154
Major	0.266	0.263
Fatal	0.351	0.343

Conclusion

Summary

- Ordered logit and latent variable model.
- Via Sicura has a dissuasive effect on drivers' risky behavior.
- In turn, crash severity is also influenced.

Future work

- Simultaneous estimation.
- Generalized ordered logit model.
- Data from other countries for a proper counterfactual.
- Model crash occurrences.

References

Data

- Verkehrsunfall Jahresdatensatz (DWH-VU), Federal Roads Office FEDRO.

Via Sicura

- Federal Roads Office FEDRO (2005). Via Sicura, Programme d'action de la Confédération visant à renforcer la sécurité routière.
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Methodology

- Lavieri, P. S., Bhat, C. R., Pendyala, R. M. and Garikapati, V. M. (2016). Introducing latent psychological constructs in injury severity modeling: multivehicle and multioccupant approach, *Transportation research record*.
- Ortelli, N., Bierlaire, M. and de Lapparent, M. (2021). Can we infer on behavioral impacts of public policy on accident severity outcomes? Proceedings of the 21st Swiss Transportation Research Conference.

Model estimation

- Bierlaire, M. (2018). Pandasbiogeme: a short introduction, Technical report, TRANSP-OR 181219. Transport & Mobility Laboratory, ENAC, EPFL.
- Bierlaire, M. (2020). A short introduction to pandasbiogeme, Technical report, TRANSP-OR 200605. Transport & Mobility Laboratory, ENAC, EPFL.

Miscellaneous

- Paul Tol's notes. Colour schemes and templates. URL: `https://personal.sron.nl/~pault/`
- Tamzid Hasan @ thenounproject.com. URL: `https://thenounproject.com/th_studio/`

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