Experience rating in automobile insurance and point-record driving licenses

Workshop IVASS « Experience ratings in insurance markets: Theory, and Evidence »

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Outline of the presentation

1. Road accidents and traffic violations: two different futures.
2. The dynamics of individual data: the revelation and modification effects.
3. The future of point-record licenses.
4. The role of bonus-malus scales.
5. The memory in non-life insurance data

Road accidents and traffic violations

- The frequency of recorded traffic violations has increased with time (deployment of radars), and would increase dramatically for cars with a real-time connection to the traffic authorities.
- Meanwhile, the frequency of road accidents and the number of fatalities has decreased.
- Traffic violations: short memory, potential high frequency, and the incentive effects are paramount.
- Road accidents: long memory, low frequency, the revelation interpretation of individual histories ranks first.

The dynamics of individual data (I): revelation effects

- The history of a policyholder reveals hidden features of risk distributions (unobserved heterogeneity).
- Revelation effects are not intrinsic (residual interpretation with respect to observable information).
- « Big data » issue: the more you have information, the less can be revealed by the history.
- Revelation effects: the frequency risk level increases with the events (accidents, traffic violations) and decreases with time.

The dynamics of individual data (II): modification effects

- The individual history modifies the risk distributions: either psychological effects (availability bias, gambler's fallacy), or incentive effects.
- Gambler's fallacy: individuals feel protected from a risk after the occurrence of a related event. Supplements the revelation effect.
- Availability bias: the subjective estimation of the frequency of an event is based on how easily a related outcome can be brought to mind. Counteracts the revelation effect.
- Incentive effects: a smart *homo œconomicus,* supposed to master the Hamilton-Jacobi-Bellman equations in academic papers.

Incentive effects of point-record driving licenses

- The incentives to careful driving created by the threat of driving license deprivation increase with the accumulated demerit points of a point-record driving license.
- Empirically: accident risk increases first, then decreases (as a function of demerit points).
- Interpretation: the revelation effect first dominates the incentive effect, then things are reversed.
- Results are less clear-cut for the incentive effects of experience rating.

The future of point-record driving licenses in a « big brother » environment

- Suppose that information asymmetry between the driver and traffic authorities collapses, due to a real-time connection between the car and the driving authorities.
- The control of driving behaviour will gain prominence in a stochastic control framework. Drivers will really manage a capital of demerit points.
- Redemption clauses should be based on the seniority of violations (and not on a violation-free period, as is the case in France with a threshold that depends on the severity).
- The seniority that triggers redemption should be reduced (one year rather than two or three years).

Integrating risk exposure in point-record driving licenses

- Today, point-record driving licenses are very detrimental to drivers with an intensive use of their car for two reasons.
- On the one hand, the elasticity of the license removal risk with respect to traffic violation risk is much greater than one.
- Hence, the license removal risk per kilometer increases with risk exposure.
- On the other hand, the private value of a license removal is much higher for drivers with an intensive use of their car (e.g., with daily commuting).
- Integrating risk exposure in point-record driving licenses could be an upside of a « big brother » environment.

Incentive effects of experience rating and of Bonus-Malus scales

- The incentives increase after a claim if the financial penalties triggered by future claims increase.
- This is related to a convexity property of the rating structure.
- Bonus-Malus scales do not enforce experience rating, and their incentive properties are still less clear-cut.
- Bonus-Malus scales provide an information available to all the competitors in a market.
- Reducing the information rents owned by the insurers on the policyholders is the role of BM scales.

The informational content of Bonus-Malus scales

- A Bonus-Malus scale does not enforce experience rating if the basic premium may use the individual history.
- Twenty years ago, France won against the European Commission on this subject.
- BM scales are unbalanced. Once the lowest level can be reached (13 years in France or Italy), the policyholders cluster at the lowest level, and the informational content of the BM scale deteriorates.
- Improving the BM scale in this respect is easy: create supplementary levels under the floor.
- The magnitude of the discount does not matter.

Reducing the information rents decreases the informational barriers to entry

- The BM scale provides an information available to all the competitors in a market.
- Reducing the information rents owned on the policyholders by their incumbent insurers is the role of BM scales.
- Reducing the information rents decreases the informational barries to entry.
- Thus, this would be detrimental to well-established insurance companies, with low turnovers of their portfolio.

The informational content of individual histories in non-life insurance

- A brief case study from the history of Jean Pinquet.
- More than 40 years as a policyholder in the same mutual, with zero claim at fault.
- My « coefficient de réduction-majoration » equals 0.5, but the average CRM is about 0.6 for senior policyholders, and my mutual does not provide any supplementary discount.
- Is a 15% discount (with respect to my siblings in terms of seniority) actuarially fair?
- An answer is obtained with the derivation of credibility weights.

The information flow in a frequency risk model

- What is the information flow brought by an individual history if the dynamic is governed by the revelation effect?
- First, it depends on the observable frequency risk (expressed by rating factors), and on the importance of hidden information (expressed by the variance of a random effect).
- Credibility predictors have an affine shape and are easily derived from the frequency risk and the variance.
- Seniority effects (a favorite research topic of mine): the predictive ability of claims decrease with their seniority.
- Integrating a seniority effect in a credibility formula is easy, with moment-based derivations.

The predictive ability of claims decreases with the seniority

- The predictive ability of claims decreases with the lag between risk exposure and the period of prediction.
- The estimated variance of a random effect can be distentangled with respect to the lag. This leads to estimated autocovariances (gamma) that are functions of the lag.
- Example drawn from a Spanish database. Time unit: year.

Lag	0	1	2	3	4	5	6
gamma	1.269	0.802	0.615	0.586	0.553	0.457	0.442

Interpretation of the decreasing shape of the estimated autocovariances

- The predictive ability of the accidents and of risk exposure decreases with the lag.
- Using the seniority of accidents in experience rating reduces the memory. However, I still deserve much more than a 15% discount for my 40 years without claims at fault.
- By increasing length of memory in the automobile insurance world, we have: bonus-malus scales, real-world rating structures, and frequency premiums derived by statistical models.

Recent research of mine: positive affine prediction of nonnegative risk variables

- My papers can be found on my Researchgate page.
- The objective is to ensure the positivity of affine predictors of the risk variables regardless of the history.
- Autocovariance functions with positivity properties are investigated. In addition, they must be followed by positive random effects.
- The following slides provide more details, as well as references related to my research on this topic.
- Thank you for your attention.

Supplementary material: Stationarity without mathematics

- Supposing that only the lags matter (and not the calendar or contract time) is a stationarity assumption.
- Stationarity is an invariance concept (invariance with respect to time translations).
- Mathematics are a bit scary (for those who are not fond of maths). They won’t be exposed in this presentation.
- Friedrich Nietzsche grasped this concept with « L’éternel retour du même» (« Die ewige wiederkehr des gleichen» in german) from an experience at Sils-Maria (Engadin). The idea is already found in Héraclite.
- The experience was based on the periodicity of natural events (the mist in a Sils-Maria valley).

Stationarity in the mathematical literature

- Mathematicians use a representation of stationary processes by trigonometric functions.
- The godfather of actuarial mathematics (Harald Cramér) has provided a representation of stationary processes as an integral of trigonometric functions with a random measure composed of non correlated increments.
- A duality approach leads to the « time domain – frequency domain » denomination.
- The autocovariance function (defined on the time domain) is the Fourier transform of a spectral measure (defined on the frequency domain).

The length of memory in non-life insurance data (or other longitudinal data)

- The length of memory in the data can be seen from three points of view.
- At the practitioner's level: what is the limit of the no-claims discount when the length of a claimless history goes to infinity (15% for the unfortunate speaker after 40 years)?
- At the average mathematician's level: properties of the autocovariance function of the random effects (related to the predictive ability, depending on the lag).
- At the mad mathematician's level: behavior of the spectral measure (see the previous slides). Actually, it's the cumulant of the spectral measure, whose behavior is investigated in the neighborhood of zero in the frequency domain.

Three levels of memory for stationary processes and for the data

- The three points of view: a) practitioner ; b) average mathematician ; c) mad mathematician.
- Short memory: a) The no-claim discount has a limit less than one when the duration of risk exposure goes to infinity. This corresponds to real-life rating structures.
- Short memory: b) The autocovariance function is summable. Example: AR(p) specifications.
- Short memory: c) The cumulant of the spectral measure (an increasing function) is differentiable at zero.

Long memory, and the ARFIMA(0,d,0) specifications

- a) The no-claim discount converges to one (i.e., the experience rated premium vanishes) at infinity.
- b) The autocovariance function is not summable, but vanishes at infinity (it is said to be ergodic). This is the case for the ARFIMA(0,d,0) specifications, introduced by Granger & Joyeux.
- c) The cumulant of the spectral measure is continuous, but not differentiable at zero.
- The highest level of memory encompasses the simple case of time-invariant random effect (no dynamic in the hidden information).

The future belongs to those with the longest memory (Friedrich Nietzsche)

- a) Same result as in the previous case: the convergence of the no-claim discount towards one is just faster.
- b) The autocovariance function has a positive limit at infinity (ergodicity is lost), which corresponds to the variance of a time-invariant component of the random effect.
- c) The cumulant of the spectral measure is not continuous at zero: the jump of this increasing function is the aforementioned variance.

Positivity levels of variance-covariance matrices (from lowest to strongest)

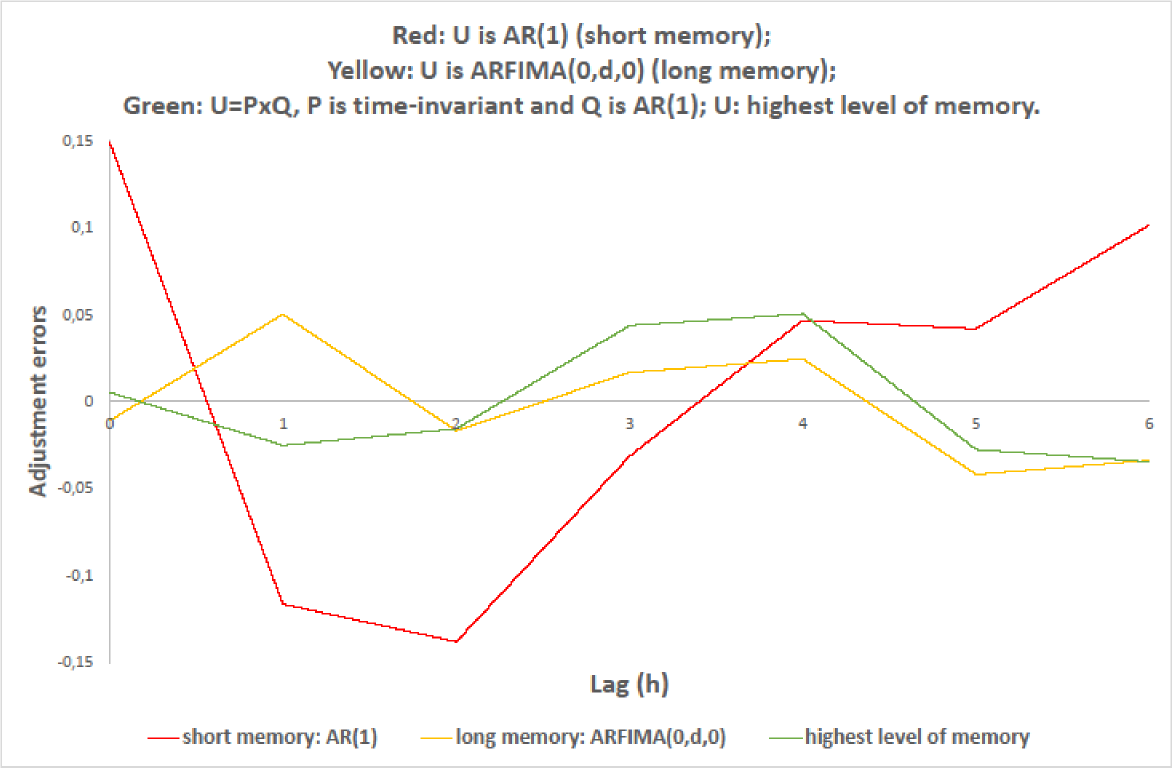
1. Nonnegativity entrywise.
2. Nonnegative linear filtering (uses the Levinson-Durbin recursion for stationary time series).
3. IM-property: the off-diagonal entries of the precision matrices (i.e., inverses of the variance-covariance matrices) are nonpositive.
4. Potential property: in addition, the precision matrices are diagonally dominant.

- These positivity levels are investigated on random effects, in order to obtain positive affine predictors of risk variables in mixture models.

Autocovariance functions of random effects with the highest positivity level

1. Autoregressive specifications with nonnegative and decreasing filtering coefficients (short memory).
2. ARFIMA(0,d,0) specifications (long memory). All these ergodic specifications are followed by positive random effects.
3. A combination of the previous ones with a time-invariant random effect (highest level of memory).

- These specifications are fitted with the estimations given in slide 14 with the generalized method of moments.
- The following picture is related to the adjustment errors (raw autocovariances – fitted autocovariances).


Red: U is AR(1) (short memory);
Yellow: U is ARFIMA(0,d,0) (long memory);
Green: U=PxQ, P is time-invariant and Q is AR(1); U: highest level of memory.
Adjustment errors
0,15
0,1
0,05
0
-0,05
-0,1
-0,15
0
1
2
3
4
5
6
Lag (h)
short memory: AR(1)
long memory: ARFIMA(0,d,0)
highest level of memory

Comments on the adjustment errors

- The short memory AR(1) specification provides a poor fit to the raw estimations of slide 14, as compared to the two other specifications.
- An exponential decay of the autocovariance function provides a good fit to the raw estimations only if the ergodicity assumption is relaxed (ergodicity: vanishing autocovariance function, no time-invariant random effect).
- The ARFIMA(0,d,0) specification is by far the best of the two ergodic choices for the autocovariance function.

Long memory on the data, short memory in real-life rating structures

- The limit credibility (no claim-discount) is less than one in real-world rating structures.
- This is in contradiction with the statistical analysis.
- Main reason: senior policyholders subsidize newcomers, due to information rents owned by the incumbent insurers.
- By increasing length of memory, we have: bonus-malus scales, real-world rating structures, and frequency premiums derived by statistical models.

Research of my own (and with coauthors) on this topic (I)

- Allowance for the age of claims in bonus-malus systems (2001) J. Pinquet, M. Guillén, C. Bolancé, *ASTIN Bulletin* **31**, 337-348.
- Time-varying credibility for frequency risk models: Estimation and tests for autoregressive specifications on the random effects (2003) J. Pinquet, M. Guillén, C. Bolancé, *Insurance: Mathematics and Economics* **33**, 273-282.
- Bonus-malus scales in segmented tariffs with stochastic migration between segments, N. Brouhns, M. Denuit, M. Guillén, J. Pinquet (2003), *The Journal of Risk and Insurance* **70**, 577-599.

Research of my own (and with coauthors) on this topic (II)

- Moral hazard and dynamic insurance data, J. Abbring, P.A. Chiappori, J. Pinquet (2003), *Journal of the European Economic Association* **1**, 767-820.
- Adverse selection and moral hazard in insurance: Can dynamic data help to distinguish? (2003) J. Abbring, P.A. Chiappori, J. Heckman, J. Pinquet, *Journal of the European Economic Association, Papers and Proceedings* **1**, 512-521.
- Incentive mechanisms for safe driving: A comparative analysis with dynamic data (2011) G. Dionne, J. Pinquet, C. Vanasse, M. Maurice ", *The Review of Economics and Statistics* **93**, 218-227.

Research of my own (and with coauthors) on this topic (III)

- A review of recent theoretical and empirical analyses of asymmetric information in road safety and automobile insurance (2013) G. Dionne, P.C. Michaud, J. Pinquet, *Research in Transportation Economics* **43**, 85-97.
- Poisson models with dynamic random effects and nonnegative credibilities per period (2020), J. Pinquet, *ASTIN Bulletin* **50**, 585-618.
- Positivity properties of the ARFIMA(0,d,0) specifications and credibility analysis of frequency risks (2020), J. Pinquet, *Insurance: Mathematics and Economics* **95**, 159-165.

Research of my own (and with coauthors) on this topic (IV)

- Hereditarity of potential matrices and positive affine prediction of nonnegative risks from mixture models (2022), J. Pinquet, *Scandinavian Actuarial Journal* **2022-8**, 659-681.
- Autocovariance functions with nonnegative linear filtering are compatible with positive time series, J. Pinquet, working paper.