Model Risk, Solvency and Risk Aggregation

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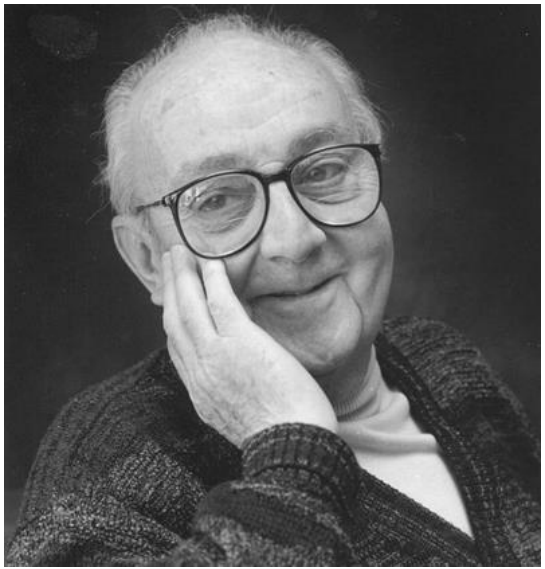
About the speaker

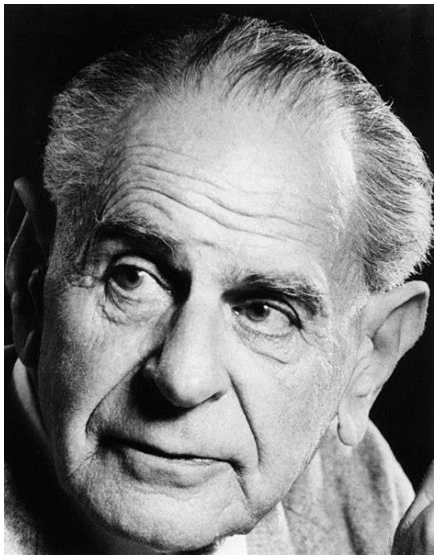
- **Paul Embrechts**
- Professor of (Insurance) Mathematics since 1/11/1989
- See CV on www.math.ethz.ch/~embrechts

- **ETH Zurich**
- RiskLab
- Department of Mathematics

Some quotes on **Model** Risk (1) from:



George E.P. Box, 1919 - 2013



Karl Popper, 1902 - 1994

Some quotes on **Model** Risk (1):

1. **George E.P. Box** (1976): "Since **all models are wrong**, the scientist cannot obtain a "correct" one by excessive elaboration. On the contrary following William of Occam he should seek an economical description of natural phenomena. Just as the ability to devise simple but evocative models is the signature of the great scientist so over-elaboration and over-parameterization is often the mark of mediocrity."

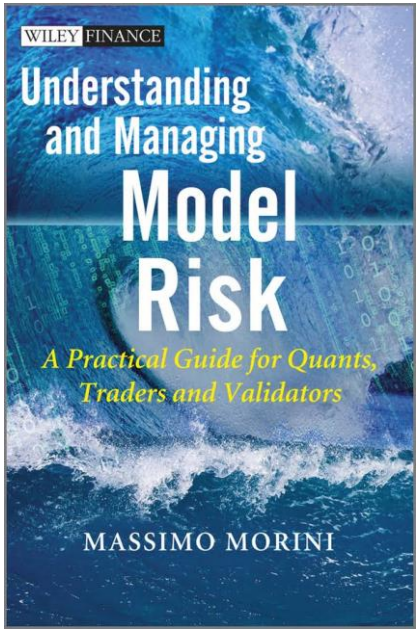
Some quotes on **Model** Risk (1):

2. **Karl Popper** (1902-1994): "Scientific models cannot be validated, they can only be falsified as soon as predictions of the model fail to match observations, in which case the models need to be reviewed and amended to extend their scope."

Conclusion: 1. **Parsimony**

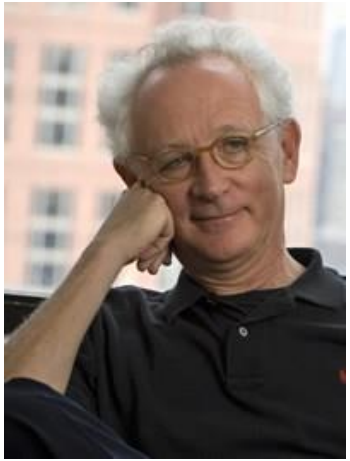
2. **Validation** or better **Falsification**

Some quotes on **Model** Risk (2) from:



Riccardo Rebonato

Emanuel Derman

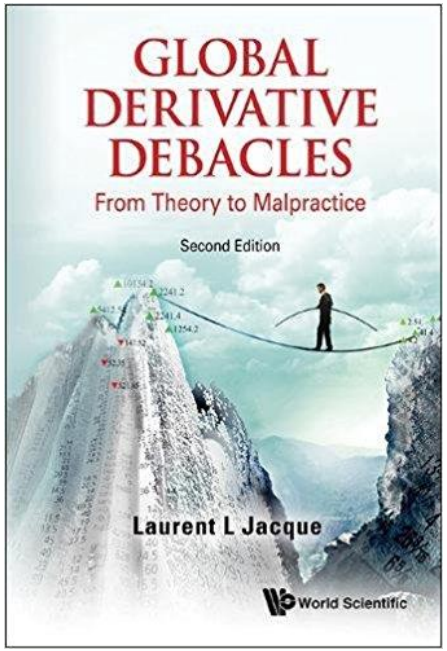


1. **R. Rebonato** (in financial markets): "Model risk is the risk of a significant difference between the mark-to-model **value** of an instrument and the **price** at which the same instrument is revealed to have traded in the market."
2. **E. Derman** (in derivatives markets): "Model risk is the risk that the model is not a realistic (or at least plausible) description of the factors that effect the derivative's **value**."
3. **M. Morini:** "… model losses usually emerge when a sudden **gap opens between market price and model booking**."

Some (Personal) examples:

- (**P**) Investment bank London
- (**P**) Insurance company Zurich
- Swiss Re September 11, Twin Towers
- Many banks worldwide: Warehousing of CDO Senior Tranches
- The Gaussian Copula
- (**J**) JP Morgan „The London Whale“
- (**J**) Long-term Capital Management (LTCM)
- (**J**) AIG … and (unfortunately) many more!

An interesting reference (J):



Model Risk comes in many disguises!

- (**TMR**) Technical MR
- Legal MR
- Political MR
- Demographic MR
- People and market perception MR
- Criminal MR ("Après moi le deluge"-syndrome)
- Plain stupidity MR
- And many more … however all a too often we only look at **TMR**!!!

As a consequence general **Model Risk** defies a specific/precise definition!

- MR typically manifests itself in **times of stress**.
- Hence the need for **tress testing** new models introduced.
- **An advice**: when introducing a new insurance product, always discuss the question: "How can we break the product. Which market conditions will have adverse effects, and (try to) quantify these. Examples include Variable Annuities."
- **A prime example**: the warehousing of CDO senior tranches which were (**model based**) perceived as AAA-investements and even considered **risk free**! ← **Rating agencies**.

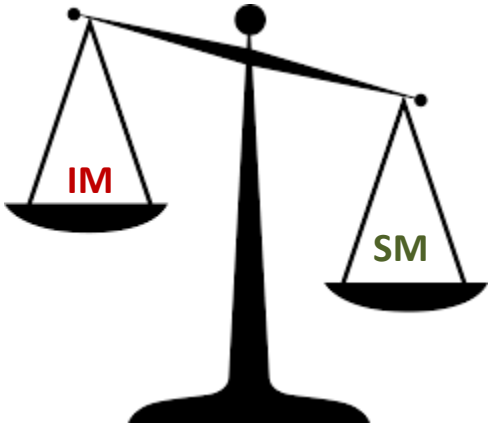
A quote to recall, from

Professor **Steven E. Shreve**
Professor of Mathematical Sciences
Carnegie Mellon University

With respect to TMR I fully agree with:

"**The quants know better than anyone how their models can fail.** For banks, the only way to avoid a repetition of the current crisis is to measure and control all their risks, including the risk that their models give incorrect results. On the other hand, the surest way to repeat this disaster is to trust the models blindly while taking large-scale advantage of situations where they seem to provide trading strategies that would yield results too good to be true. Because this bridge will be rebuilt, **the way out of our present dilemma is not to blame the quants (PE: the actuaries). We must instead hire good ones–and listen to them**." (**S. Shreve**, Forbes, 2008)

Solvency, a battlefield for Model Risk: Internal versus Standard Models

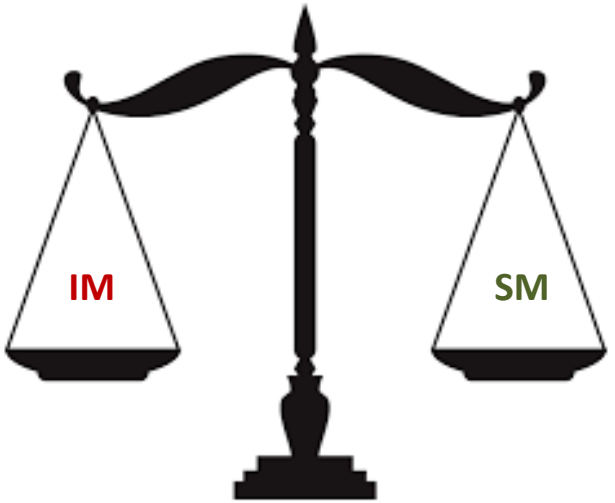


versus

Nineties till about 2006-2009 crisis

Post 2006-2009 crisis

This is a futile battle, we need **both**!

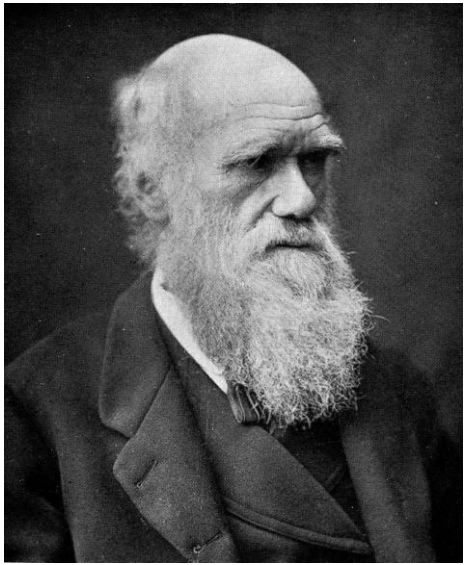


We have to find the right **balance** taking the societal and industry **changes** carefully into account! (see **(*)** on next page)

For a somewhat historical/philosophical discusion on this, see

P. Embrechts (2017): A **Darwinian** view on internal models.
The Journal of Risk, 20(1), 1-21. **(*)**

"It is not the strongest of the species that survives, nor the most intelligent that survives. **It is the one that is most adaptable to change**."
(**Charles Darwin, 1809-1882**)



A typical example: Operational Risk

- The original **Solvency II** definition: "The risk of a change in value caused by the fact that actual losses, incurred for inadequate or failed internal processes, people and systems, or from external events (**including legal risk**), differ from the expected losses". (Similar under Basel II/III for banking)
- Major loss potential: large (investment) banks +/- 10-20% of market capitalization. For Bank of America, about 50%! Less for the insurance industry …
- How to model the US Department of Justice (DOJ)?
- Hence I understand the OpRisk-pendulum swing from IM to SM.

The regulatory treatment of OpRisk capital:

- **Basel III**: use (rather involved) standard formula.
  The Basel II 99.9% one year Pillar 1 OpRisk capital charge turned out to be impossible to be estimated by any reasonable margin of error. Advanced IM-based methodology → Pillar2!
- **Solvency II**: mixture of IM and SM / **SST**: SM
- "It must be emphasized that of all the risks faced by insurers, operational risk is most likely the one risk that has the **strongest qualitative aspects** and where choosing a predominantly quantitative approach could fail to describe and assess the risk appropriately." (Ref: IAA Risk Book, Boller et al. (2016))

Some challenges for the insurance industry:

- **Business interruption** insurance, just-in-time production
- Key example: 2011 **Thailand floods** (158 days)
- **Cyber** insurance/risk
- **Personalised** medicine/whereables/apps
- **Automated** driving/drones
- **Shadow** insurance, e.g. Ohio case in life insurance
- **P2P**/"Facebook" insurance
- The emergence of **cryptocurrencies** (>1400) & ICOs
- The **data deluge**: data science, ML, Neural Newtorks, AI, …

Why do I mention these?

- All these developments will lead to **new demands**/products.
- As a result, **special skills** beyond the standard ones will be called for, leading to the **Actuary of the Fifth Kind**!
- Also the regulatory (**solvency**) environment will have to follow suit, e.g. from a more static to a more **dynamic supervision**; this will no doubt take **time** but the actuarial profession/ industry as well as regulation has to **be prepared** for these changes; see **(*)** for some more discussions.
- It will be **more** than a pendulum swing between IM <--> SM!

The actuary of the nth-kind

Professor em. **Hans Bühlmann**
Department of Mathematics
ETH Zurich
Astin Editorial, AB 19(1), 1989, n=3

The Actuary of the Fifth Kind (why nth-kind?)

- First Kind: the (deterministic) life actuary
- Second Kind: the stochastic non-life actuary
- **Third Kind (Hans Bühlmann): the ALM actuary**
- Fourth Kind (PE): the ERM actuary
- **Fifth Kind** (Singapore Actuarial Society, **PE**): "Modern society will no doubt need tomorrow's actuary (whether life or non-life) to go back to this early cradle of our profession, that is as a **data driven and model guided** financial decision maker in a world governed by uncertainty."

A course example: Mario Wuethrich, ETH

Mario Wuethrich (RiskLab, ETH Zurich)
Spring Semester 2018

Data Analytics for Non-Life Insurance Pricing
(with C. Buser). Version March 28, 2017

Newer versions!

https://people.math.ethz.ch/~wueth/books3.html

Some comments on Risk Aggregation

- Quantifiable risk is often perceived through **risk measures**, and this specifically for regulatory/solvency purposes.
- Which risk measures: **VaR** the "**if**" risk measure and **ES**, the more relevant "**what if**" risk measure.
- Given that one wants to use a "number", **ES >>> VaR**
  - equally easy to explain
  - estimation and backtesting properties are well understood
  - ES leads to (more) robust risk allocation properties, …

Risk Aggregation beyond ICA/CIA 2014

The basic problem: given n risk measurements on individual (**marginal**) positions, R(X(1)), … , R(X(n)), calculate the **risk for the aggregate position, i.e.**

R(X(1) + … + X(n))

e.g. VaR (X(1)) + … + X(n)) or ES (X(1) + … + X(n)) at given confidence levels. Under the following conditions:

(C1) Only marginal dfs of X(1), … , X(n) are known

(C2) Assume (C1) and extra interdependence information

Solutions, see www.math.ethz.ch/~embrechts

- Under **(C1)** the problem is by now **fully understood**, either analytically (homogeneous case) for both VaR as well as ES or numerically (for general case) via a fast algorithm, the Rearrangement Algorithm, and this for n large (~ 1000s).
- Under **(C2) considerable progress** has been made: Bernard, Rüschendorf, Vanduffel, R. Wang, Puccetti, … many more; very active research area.
- The results are Uncertainty or Model Risk bounds, often these are **sharp** (typically in the case (C1)).

Recent research: Risk Allocation

- Check website www.math.ethz.ch/~embrechts for papers on quantile-based risk allocation (R below VaR, ES, RVaR, …)
- The problem: n agents, agent i with a risk measure R(i,.)
  Total risk X: allocate X between the n agents so as to **minimise** the sum of the aggregated risk measurements, i.e.

  R(1,X(1)) + … + R(n,X(n))

  over all "allowable" risk allocations X = X(1) + … + X(n).
  Related to Borch's Theorem, Arrow-Debreu Equilibria, Game Theory (cooperative as well as non-cooperative), …

The pleasure of joint work!

Haiyan Liu
(Michigan State)

Tiantian Mao
(UST China)

Ruodu Wang
(Waterloo)

- E.-Liu-Wang, Quantile-based risk sharing
  SSRN: `abstract=2744142`, 2017, forthcoming in Operations Research
- E.-Liu-Mao-Wang, Quantile-based risk sharing with heterogeneous beliefs
  SSRN: `abstract=3079998`, 2017

Conclusions and Take Aways

- Model Risk was there from the beginning, it will remain with us going forward
- Model Risk takes on many guises, there is no unique Ansatz
- Solvency requirements will always be tangented by Model Risk considerations, and this both in the Standard as well as Internal Model Approach for capital adequacy calculations
- Specific examples of the above are to be found in the realm of Risk Aggregation and Risk Allocation

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Thank you very much for your attention!

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