ROBUST TECHNIQUES IN QUANTITATIVE FINANCE
UNIVERSITY OF OXFORD

MODEL RISK, 2018
a practitioner's point of view

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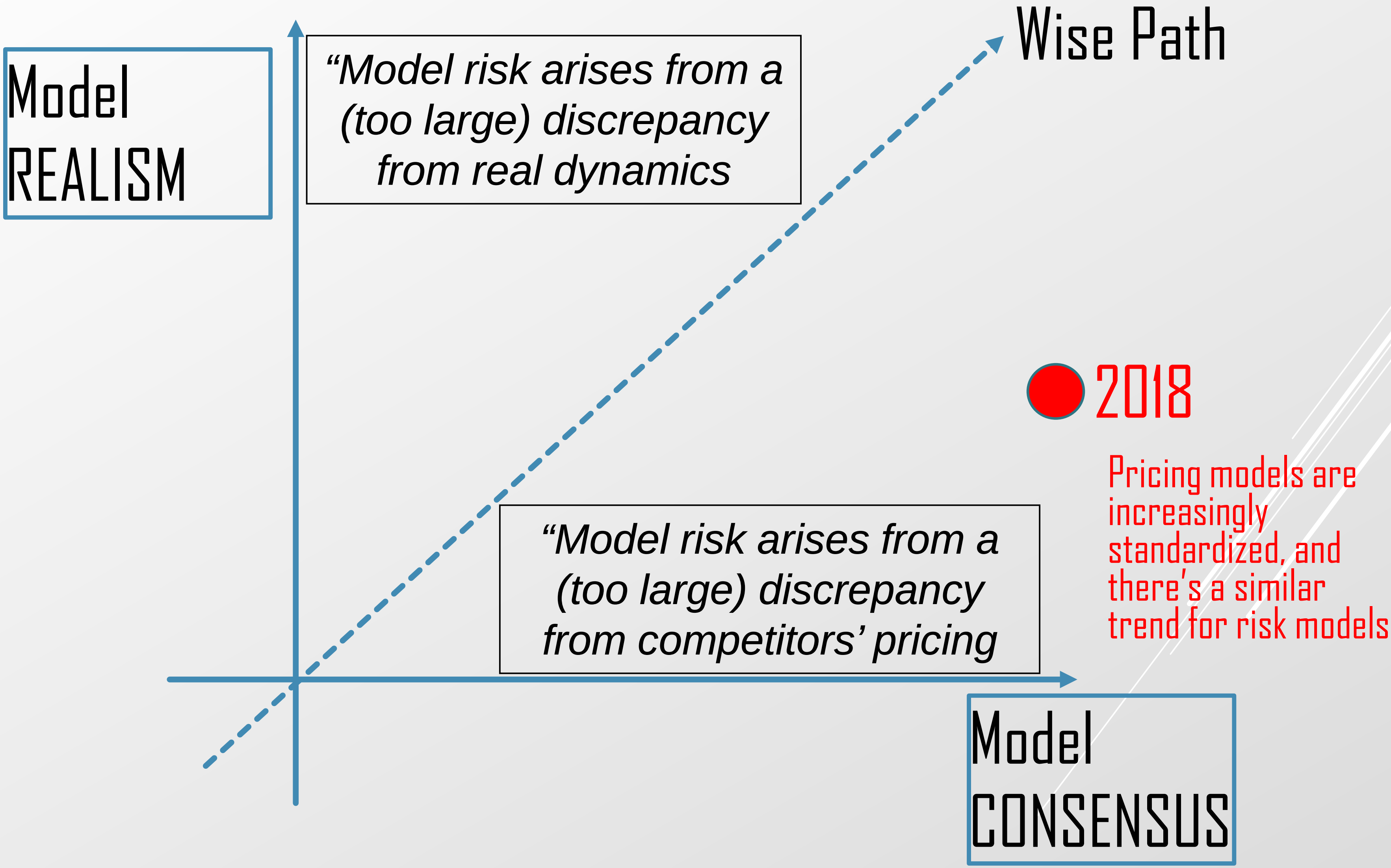
Outline

In spite of increased awareness of pricing model uncertainty, and its consequences, models are still central in investment banking. A model gives sensitivities, interpretation, and a common language among counterparties… but many things have changed.

- **How do banks define model risk? How this vision has evolved?**
- **How do banks see model validation vs model verification?**
- **What have regulators done to address pricing model risk?**
- **What are the current tools of model risk management? What are the consequences for research in model uncertainty and robustness?**
- **First trend in modelling: model standardization. The rise of systemic model risk**
- **Second trend in modelling: from mathematical assumptions to data crunching**

Different Dimensions in Model Risk



REALISM: Derman's Value Approach

"Model risk is the risk that the model is not a realistic (or at least plausible) description of the factors that affect the derivative's <u>value</u>"

By E. Derman

- It is clear that "*a model is always an attempted simplification*" of reality, yet modellers should avoid the following errors:

"You may have not taken into account all the factors that affect valuation. You may have incorrectly assumed certain stochastic variables can be approximated as deterministic. You may have assumed incorrect dynamics. You may have made incorrect assumptions about relationships".

By E. Derman

CONSENSUS: Rebonato's Price Approach

The **Price** Approach

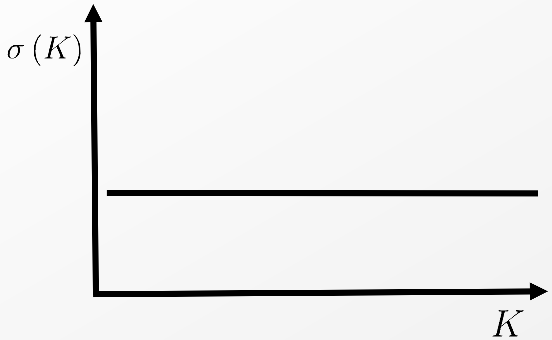
"Model risk is the risk of a significant difference between the mark-to-model value of an instrument, and the price at which the same instrument is revealed to have traded in the market"

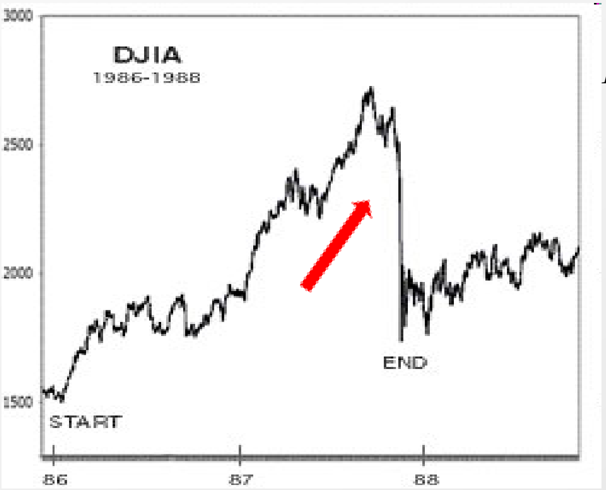
By R. Rebonato

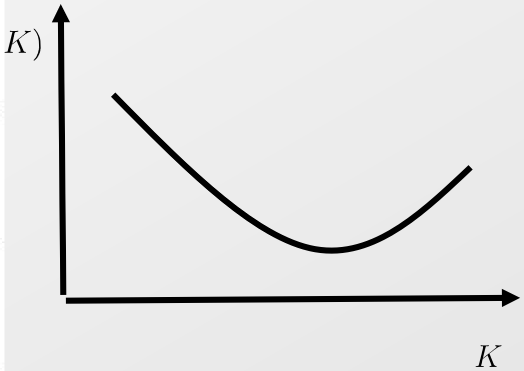
- Real losses do not appear "*because of a discrepancy between the model value and the `true' value of an instrument*", but between the model value and the price of an instrument when it gets marked-to-market.
- As long as the market agrees with our valuation, we do not have large losses due to models, even if "*market prices might be unreasonable, counterintuitive, perhaps even arbitrageable*". We can sell at book value. Losses start when a gap emerge between model value and market price.
- **Focus must be on market intelligence and standards (today Markit, market practices about XVAs, collateral reconciliation, CCP and ISDA models)... with some attention to sudden changes in consensus...**

How can market consensus on models change suddenly?

Example 1: 1987 Stock Market Crash

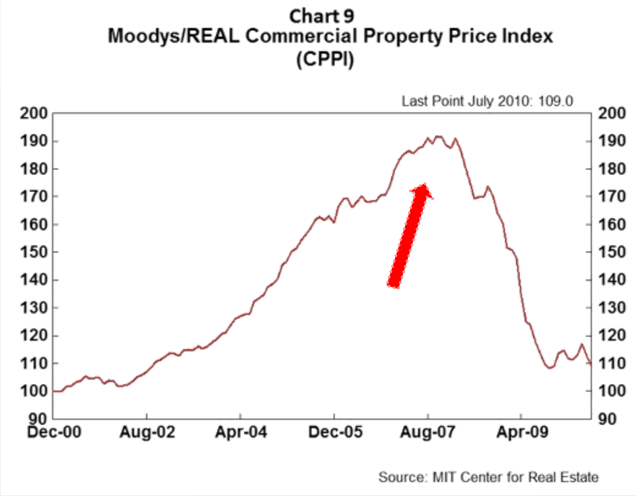






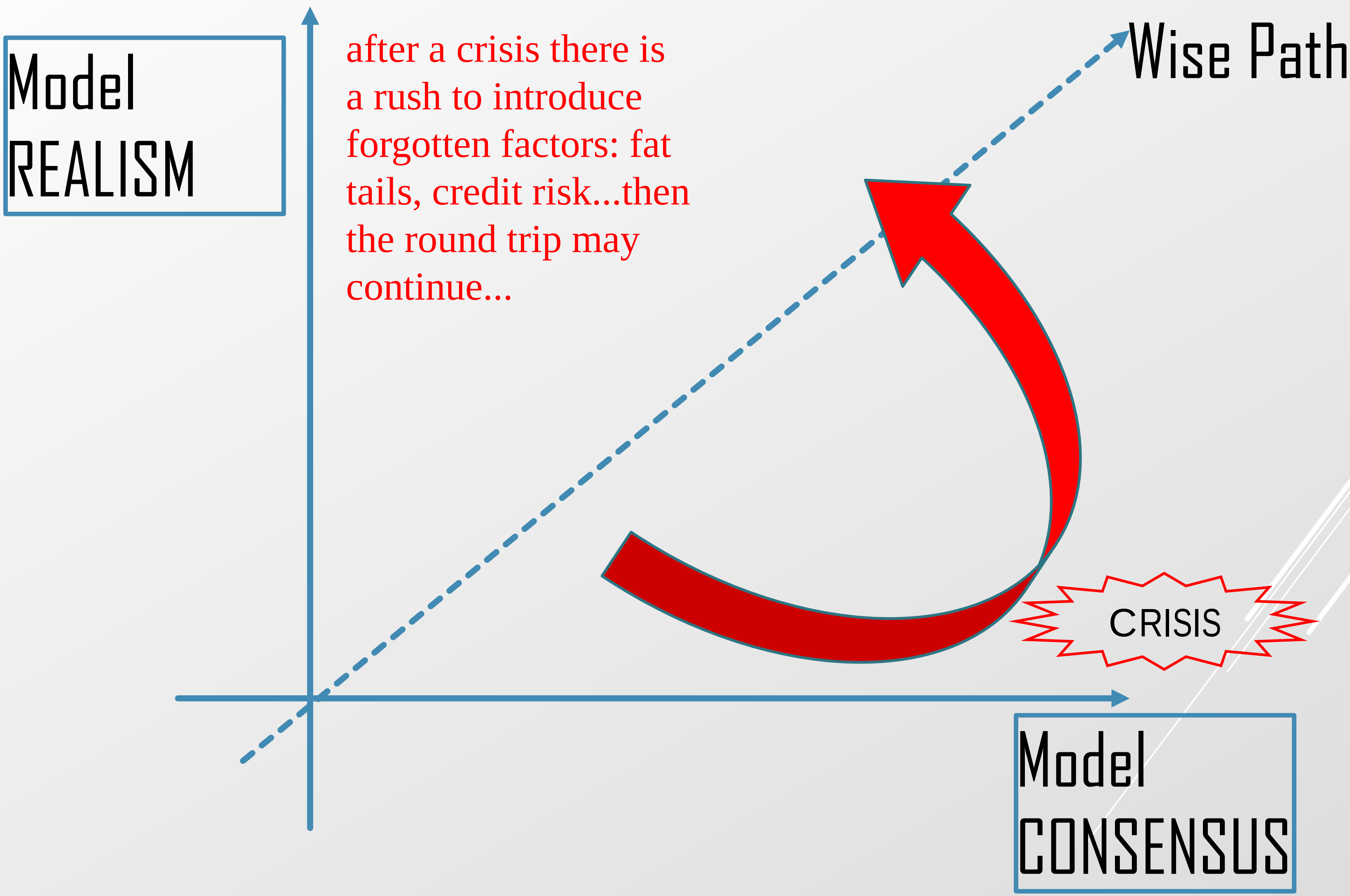
Example 2: 2008 Subprime Crisis

CDO model consensus was Gaussian Copula with estimated correlations, kept low consistently with the assumption of ever-increasing national house prices

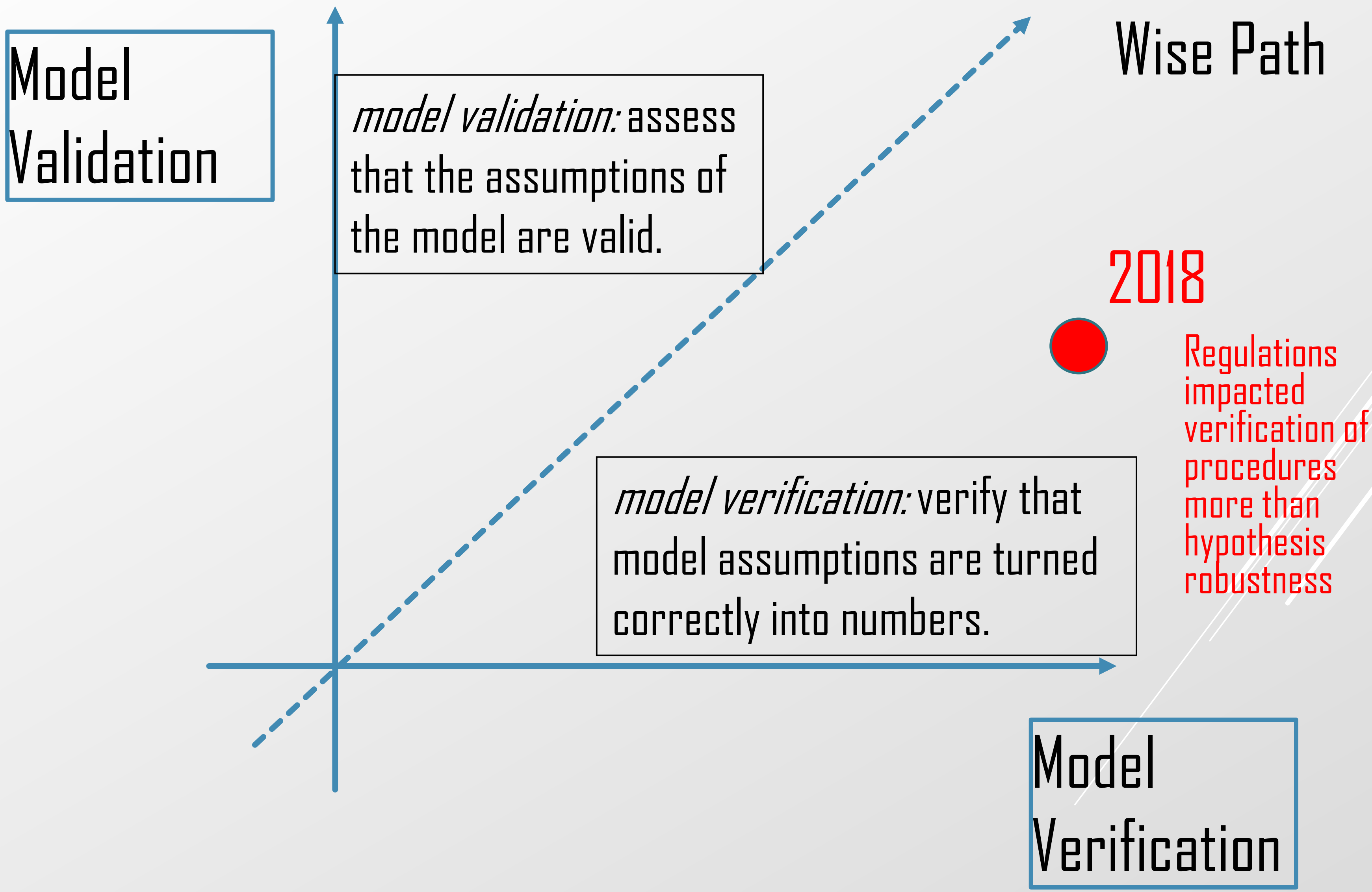


The reversal of the national house trend reveals that mortgage losses can be very correlated, and the Gaussian Copula market consensus collapses.

From Consensus to Realism and back



Different Dimensions in Model Risk



Model Verification vs Model Validation

- **Model Verification**
  - Mathematics
  - Implementation
  - Numerics
  - Correct application to Payoff

- **Model Validation**
  - Calibration
  - Reasonableness
  - Market Intelligence
  - Reality check

Both market intelligence and reality checks are done in a parametric way, via comparing different models, leading to model choice and setting of **provisions** (reserves, model limits, monitors..) for residual **model uncertainty.**

MODEL RISK: REGULATIONS

USA → **SR 11-7**

EUROPE

One may expect a wave of model risk regulation after the crisis. We had USA regulatory letter SR 11-7 in 2011, rest dominated by capital against credit risk.

EBA (European Banking Association), in SREP 2014, defines model risk as:

 risk relating to the underestimation of own funds requirements by regulatory approved internal models

 risk of losses relating to the development, implementation or improper use of any other models by the institution for decision-making

The focus is on Internal Models. It is TRIM (Targeted Review of Internal Models) to give a framework also for pricing or non internal models. Focus:

- A **model inventory** detailing application, model deficiency and their management
- **Roles and responsibilities** on models. From quants to product control to risk managers to senior, to internal audit
- **Documentation requirements** (a lot, on assumptions and usage)
- Some guidelines on Model Validation (**data quality, docs, testing**)
- Heavy and detailed **procedure for any model change**

MODEL RISK: REGULATIONS

The focus on **documentation**, including various numerical tests, on the creation of specific **responsibilities**, with product control checking data, bootstraps, calibrations, and on heavy bureaucratic **procedures** (all so called **Pillar 3 requirements**), favoured **Model Verification practices, now much better than before the crisis.**

On more substantial Model Validation, the outcome is mixed. Above requirements manage to reduce risk by having an effect on:

- Reducing risk-appetite (even the risk that could be managed)
- Slowing down the process to take risk (and the required model changes)

On the other hand, **they absorbs resources in bureaucracy that could be used for increasing robustness, and can create a false sense of security.**

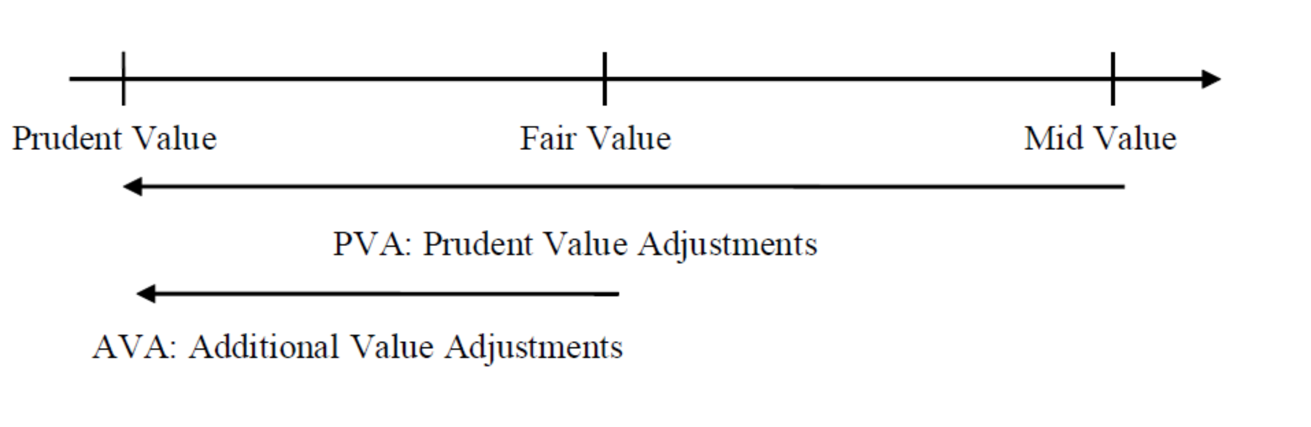
Regulations on capital requirements (**Pillar 1 requirements**) have in part the same effect but also tend to impact more the focus that senior management puts on risk management (although regulatory arbitrage is always luring... but after the crisis the increase of supervision – **Pillar 2 requirements** – has offset this).

Among Pillar 1 requirements there is one addressing also model risk: Prudent Valuation regulation. Although recent and not fully effective, it may strengthen the old and well-founded practice of model risk reserves...

PRUDENT VALUATION

RR/CRD IV (article 34, 105, 2013) requires to apply ‘prudent valuation’ standards to all positions that are measured at ‘fair value’. The different between fair and prudent is that **Fair Value must be the most likely market exit price, associated to the most convenient buyer or seller available. Prudent Value must take into account the extra costs and risks that may arise, with a conservative attitude.**

The difference between Fair Value and Prudent Value leads to AVAs, **Additional Valuation Adjustments.**
AVA=Exposure*(Fair Value-Prudent Value)



Article 34 requires institutions to **deduct from Common Equity Tier 1 Capital the aggregate AVA** made for fair value assets and liabilities.

PRUDENT VALUATION

What the risks or costs that must enter prudent valuation?

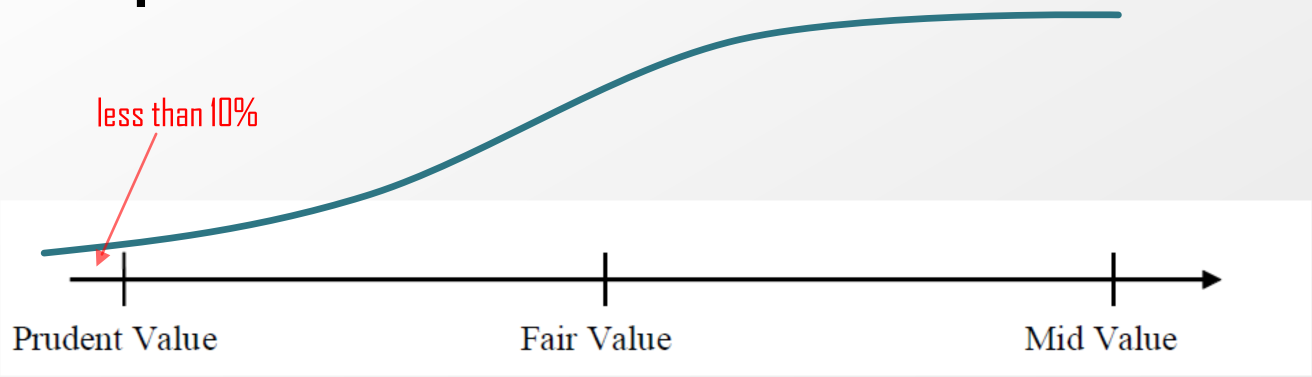
- **Market price uncertainty**
- Close-out costs
- **Model risk**
- **Unearned credit spreads**
- **Investing and funding costs**
- Concentrated positions
- Future administrative costs
- Early termination
- **Operational risk**

The border between Model Risk and Operational Risk/Market Price Uncertainty can be at times rather blurred. «Unearned Credit Spread» has explicitly a part that can be included in Model Risk AVA: it is CVA uncertainty. The same applies to uncertainties in FVA.

Prudent Valuation is mostly used for Model Risk including uncertain parts of XVA not included in fair value, that for some institutions includes all FVA.

PRUDENT VALUATION

How much conservative should one be? EBA: be 90% confident, that is **more than 90 out of 100 times you must expect to transact at better price than prudent value.**



EBA gives 2 ways to find this quantile:

- Use alternative appropriate modelling approaches and take point within resulting range of valuations associated to 90% confidence level.
- Use expert-based approach considering payoff complexity, alternative math, uncertainty on parameters, hedgeability, liquidity

Often banks use a mix: they always get the number from an alternative model (including ≠ pars) **but use expert judgement to state it is 90% confidence.** Mostly it is just the **most conservative reasonable model.**

Robust finance techniques could help improving this practice.

HOW TO DEAL WITH MODEL UNCERTAINTY?

- Traditional Model Reserves and more recent Prudent Valuation to manage Model Uncertainty have justification in theory and practice
- Simplest example on **what Model Uncertainty is not, and how it should NOT being dealt with**: Brigo, Gatarek, Mercurio Uncertain Volatility Model:

$$dS(t) = rS(t)\,dt + \sigma^I S(t)\,dW(t)$$

$$\sigma^I = \begin{cases} \sigma^1 \text{ with prob } p_1 \\ \sigma^2 \text{ with prob } p_2 \end{cases}$$

- Scenarios depend on random variable ***I***, drawn at *t=ε* infinitesimal after 0, independent of *W*, taking values in *1,2* with probability

$$Prob(I = i) = p_i.$$

HOW TO DEAL WITH MODEL UNCERTAINTY?

- An option is easily prices with law of iterated expectation…

$$\begin{aligned}\Pi(K,0,T) &= P(0,T)\,\mathbb{E}\left[(S(T)-K)^{+}\right] \\ &= P(0,T)\,\mathbb{E}\left[\mathbb{E}\left[(S(T)-K)^{+}|\sigma^{I}\right]\right] \\ &= P(0,T)\sum_{i=1}^{2} p_i \mathbb{E}\left[(S(T)-K)^{+}|\sigma^{I}(t)=\sigma^{i}(t)\right].\end{aligned}$$

- One gest a mixture of Black and Scholes prices

$$p_1 BS\left(S(0),K,T,\sigma^1\right)+p_2 BS\left(S(0),K,T,\sigma^2\right)$$

- Is this an example of model uncertainty? NO. Here there is only ONE model, with a sketchy random volatility. Volatility is a random variable with a simple distribution which must be drawn before simulating *S*.

HOW TO DEAL WITH MODEL UNCERTAINTY?

- Real Model Uncertainly looks more like

$$dS(t) = rS(t)\,dt + \sigma S(t)\,dW(t)$$

with us not knowing if $\sigma = \sigma^1$ OR $\sigma = \sigma^2$

- What has changed from above?
  - **at ε we will not draw the right volatility**
  - **we have no idea of what *p_1* and *p_2* are**
  - **other players may know what is the real value of *σ* or they may have even less information than us** (we will go back to this)

MODEL UNCERTAINTY vs RISK

- Cont (2006) treats model uncertainty as multiple probability measures

$$(\Omega, \mathcal{F}, P_i \mapsto Q_i)\,,$$

$$P_i \;\; \mapsto \;\; Q_i = P_1 \mapsto Q_1, \ldots, P_N \mapsto Q_N$$

as opposed to *risk*, where we are uncertain about realizations but we know the probability distributions (the roulette for a standard player).

- The Bayesian approach averages out expectations under different measures, treating uncertainty *about* the model in the same way as uncertainty *within* the model, in spite of the above differences.

Conservative Approach Glorified

- Cont (2006) notices that the typical approach of banks is not to average across models but to adopt a worst case approach. Only one (prudent) valuation protects you from any model loss: with $\sigma^2 > \sigma^1$,

$$P^{liability} = BS\left(S(0), K, T, \sigma^2\right), \; P^{asset} = BS\left(S(0), K, T, \sigma^1\right)$$

Gilboa and Schmeidler (1988) show that under uncertainty aversion, where uncertainty is different from risk since it is ignorance of the probability and not only of the outcome (Knight (1921)), the expected utility of an outcome X is computed as

$$\inf_{\mathbb{P}\in C} E^{\mathbb{P}}[U(y)]$$

where C is the set of possible probability measures. As Cont (2006) says, banks treat differently «market risk» from «model risk», «the former being valued by risk neutral pricing (average across scenarios) while the latter is approached through a worst case approach».

Model Comparison for Model Validation, and for Reserves

Classic examples of Model Comparison in the literature are:

Credit

Structural Models **VS** **Reduced-form Models**

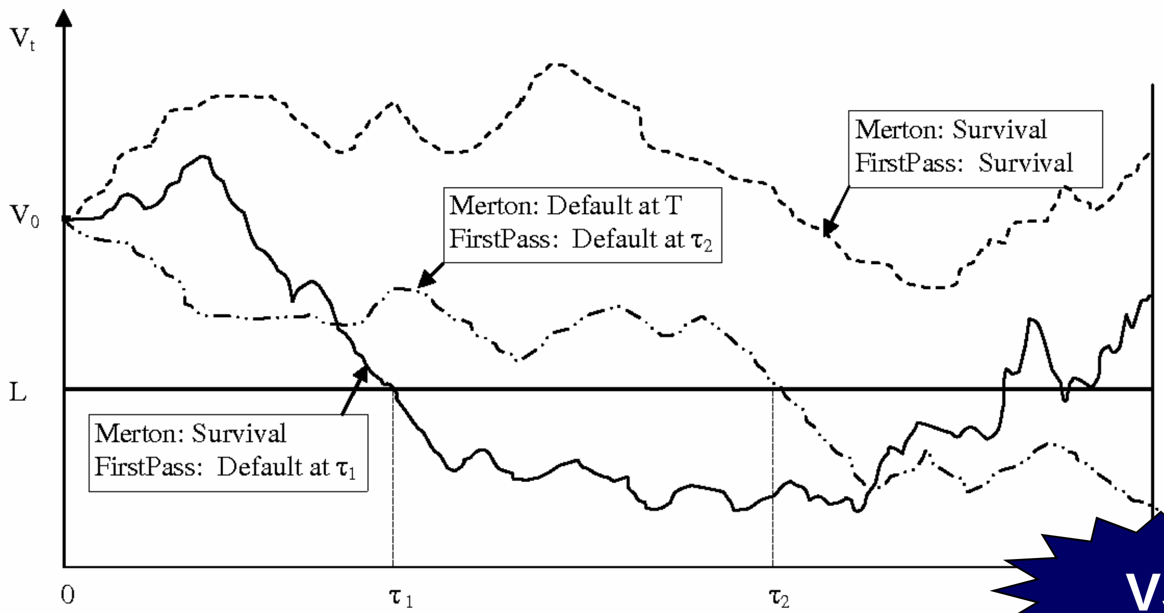
Rates

Low factor Short Rate **VS** **Multifactor BGM/HJM**

Equity

Stochastic Volatility **VS** **Local Volatility**

Structural First-Passage models vs Reduced-form Intensity Models



Structural Models

$$dV_t = (r - q)\, V_t dt + \sigma V_t dW$$

$$\tau = \inf \{t | V_t \leq H_t\}$$

V is the firm value, **H** is the default barrier.

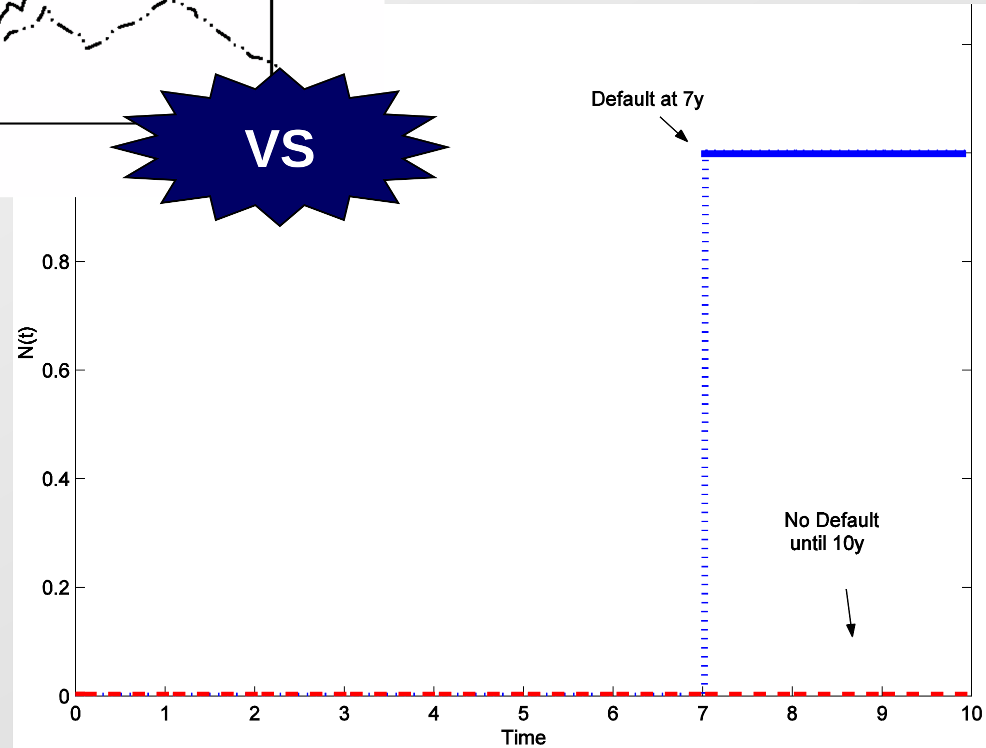
VS

Intensity Models

$$\tau = \inf \left\{ t : \int_0^t \lambda(s)\, ds \geq \varepsilon \right\}$$

$$\Pr(\varepsilon \leq z) = 1 - e^{-z}.$$

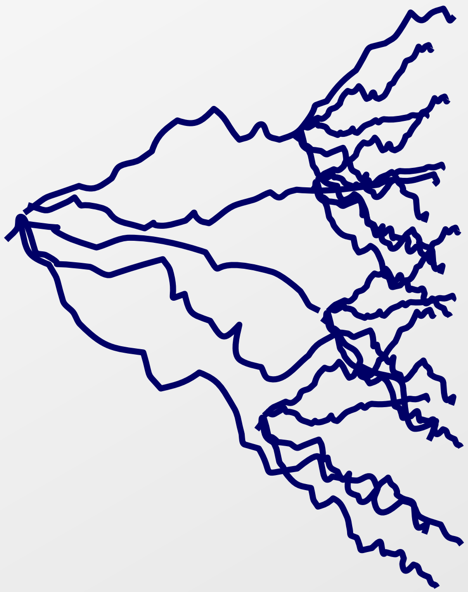
λ(t) is the intensity or instantaneous default proability, giving credit spreads, **ε** is the impredicable default trigger.



Low factor Short Rate vs Multifactor BGM/HJM

- Popular debate around 2000. The paper "How to throw away a billion dollar" claims bermudan swaptions are undervalued by 1-factor interest rate models, that have have instantaneous correlations among rates set to 1.

$$dr_t = k(\theta - r_t)\,dt + \sigma dW_t$$



- They say: for getting real value one needs multifactor models with lower correlations.

$$\begin{aligned} dS_{a,b}(t) &= \mu_a(t)\,dt + \sigma_a(t)\,dW_a(t), \\ dS_{a+1,b}(t) &= \mu_{a+1}(t)\,dt + \sigma_{a+1}(t)\,dW_{a+1}(t), \\ &\vdots \\ dS_{b-1,b}(t) &= \mu_{b-1}(t)\,dt + \sigma_{b-1}(t)\,dW_{b-1}(t). \end{aligned}$$

Stochastic vs Local Volatily Models

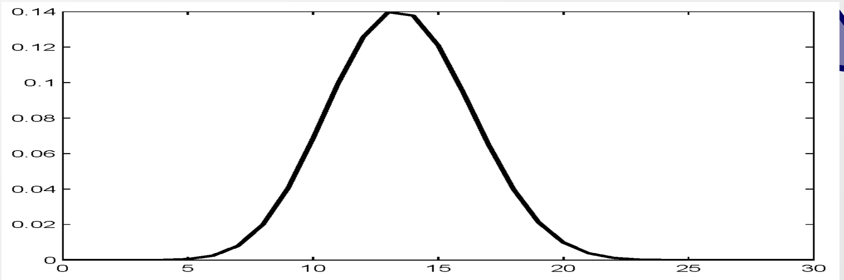
Sort of Stoch Vol?

$$X^A(0) = X(0)$$
$$X^A(t_1) = \mathbb{N}(0,1)$$
$$X^A(t_2) = \mathbb{N}(0,1) \perp X^A(t_1)$$
$$X^A(t_3) = \mathbb{N}(0,1) \perp X^A(t_2) \perp X^A(t_1)$$
$$\vdots$$

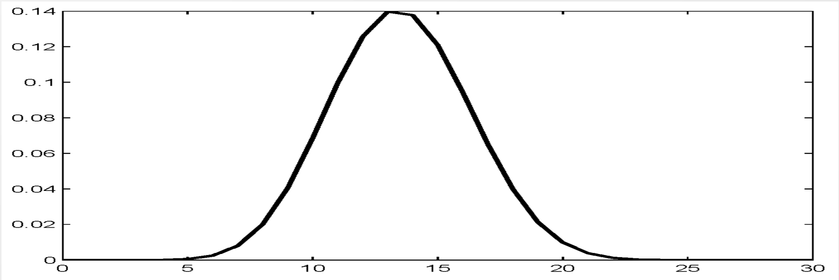
VS

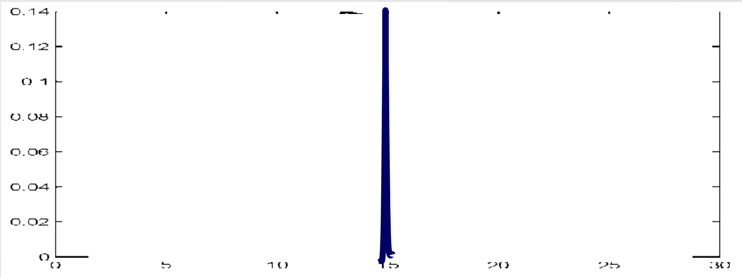
Sort of Local Vol?

$$X^B(0) = X(0)$$
$$X^B(t_1) = \mathbb{N}(0,1)$$
$$X^B(t_2) = X^B(t_1)$$
$$X^B(t_3) = X^B(t_2) = X^B(t_1)$$
$$\vdots$$



Same Marginals





Totally different transition densities

Model risk management: Model Reserves

- Simplest case: model uncertainty is parameterized by ***γ*.** Suppose **0**≤ ***γ*** ≤**1** and value

$$\Pi_t^T(\gamma)$$

of the derivative increases with ***γ***.

- The model validation process **validates the model with *γ=0.5*** but recognizes that there is a **residual model uncertainty, reasonably up to *0.75***

- If counterparty is eager to to buy the derivative at ***γ=0.75***, the difference

$$Res = \Pi_t^T(0.75) - \Pi_t^T(0.5)$$

could be **day-0 profit for shareholders and bonus for sales and traders who sold it**

- How to trust this is not just due to our model error? *Res* can be used to create a **model capital reserve** (at least retained profits) to be released to traders or dividends only along the life of the derivative, for example from time ***t1*** to ***t2*** he may linearly receive only

$$Res\,(t_2 - t_1)\,/T$$

Model risk management: Reserves & Prudent Valuation

- The model validation process **validates the model with *γ=0.5*** but recognizes that there is a **residual model uncertainty up to** *0.75 (today, a proxy for 90% percentile)*
- The counterparty is eager to to buy the derivative at ***γ=0.75***,
- Today $\Pi_t^T(0.75)$ could be Prudent Value, $\Pi_t^T(0.5)$ fair value, **and the difference is subtracted from equity**.
- Since $\Pi_T^T(0.75)]$ ≈ $\Pi_T^T(0.5)$, this also forces realease through time.
- Heavier than model reserves since profit is erased from from equity, not only unreleased.
- Heavier than RWA capital (e.g. Internal Model capital for credit risk), which requires additional capital for new risk. Banks raise new capital and charge KVA. **With Prudent Valuation there is immediate balance sheet effect, KVA not enough.**
- It is still largely unapplied. If applied thoroughly, **it forces banks to charge prudent value, not fair value, moving attention from "modal model" to robust bounds** (banks are obtaining a 50% discount due to considering netting effects)

Model risk management: Model Lines

- Model *position limits* or *lines* are analogous to the credit lines used to manage credit risk. If a model is considered subject to high model risk, the bank can set a limit to the exposure built through the model.

1. First decide first the **total model line** - the maximum exposure to model uncertainty allowed.
2. Then compute the how much a single deal contributes to filling the total line. It is the potential loss due to model uncertainty.

- For a product where fair value plus model reserve is $\Pi(\gamma)$ an estimate is

$$Notional * \left[\Pi_t^T(1) - \Pi_t^T(\gamma)\right]$$

- If a deal is sold at the conservative price $\Pi_t^T(1)$ and profit is not released, there's no line consumption. Even less in use.

- Model risk management in banks is now not the main focus neither internally not for regulators. This is related to other trends in modelling...

THE TREND TOWARDS STANDARDIZATION

In order to understand this trend, let us reanalize the theoretical foundations for uncertainty aversion.

Gilboa and Schmeidler start from Ellsberg (1961): empirically **a player shown two urns prefers to bet on a red ball from an urn with 50% red and 50% balls, than from an urn with unknown percentage of red vs black.** Under aversion to uncertainty, the expected utility of an outcome X is computed as

$$\inf_{\mathbb{P}\in C} E^{\mathbb{P}}[U(y)]$$

where C is the set of possible probability distribution. **This approach is called CONSERVATIVE or WORST-CASE in banking, and is standard when banks deal with model risk.** As Cont (2006) says, banks treat differently «market risk» from «model risk», «the former being valued by risk neutral pricing (average across scenarios) while the latter is approached through a worst case approach».

ASIMMETRY AVERSION

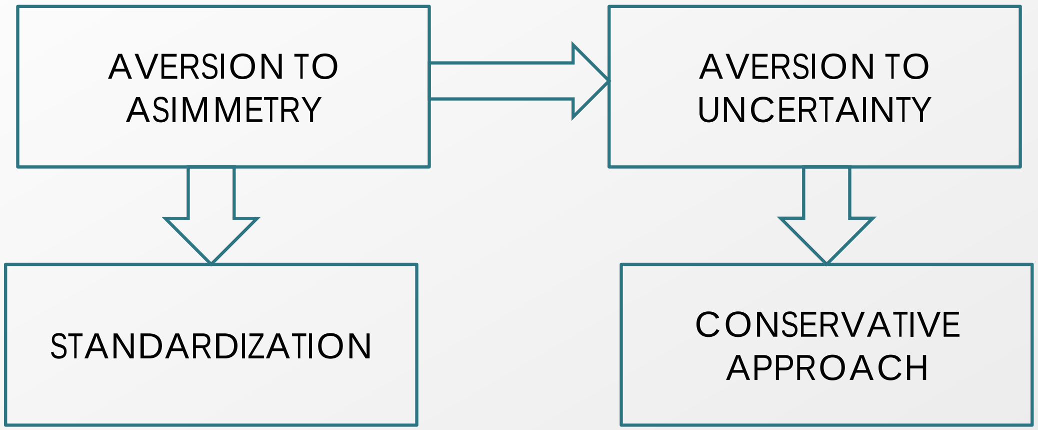
From my experience of real markets, Gilbo and Schmeidler (1988) example raises additional thoghts: **"Subject is shown two urns… A contains 50 black balls and 50 red ones, while there is no additional information about urn B"**

Every market player would choose **A**, but here **uncertainty aversion compounds with an underrated issue: aversion to information asimmetry (or…scam).**

What more the dealer knows? What to other players know? Such issues are crucial in markets. Pure risk is free of fraud/asymmetry, uncertainty leaves all the room for asymmetric information and scam.

How aversion to uncertainty would change if player was sure of no information asimmetry? What would be the answer if the choice was between a 50%-50% urn and an uncertain urn that, however uncertain, **is the same all other players use?**

MODEL STANDARDIZATION



Conservative approach protecs from information asymmetry: it avoids being fooled by a more expert player, which is more painful than a loss shared with competitors.

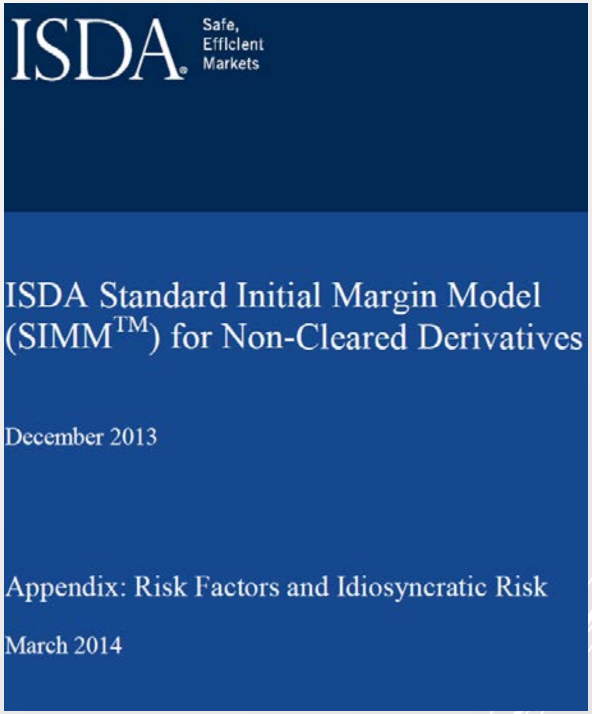
If information asymmetry is crucial driver, however, **there is an alternative solution to conservativeness: move to using a market-wide model standard.**

This explains the importance of CONSENSUS in model risk management**, and** a phenomenon happened in the past and potentially returning now in new form: **herding towards model standardization.**

MODEL STANDARDIZATION

After the crisis, weaker and under stronger regulations, banks shifted to standardization. Just a handful of banks still have the attitude of making money by having «best models», while largest part have actively seeked to reduce the heterogenity of model hypotheses:

- Banks have **reduced spending and investment on new models**
- Banks pay for services like **Markit Totem that gives anonymous pricing consensus** (and now even provide 10% and 90% quantiles for AVAs)
- Banks have accepted with limited complains to **use standard models chosens by CCPs** for large part of their business (cleared), even if this means being subject to unanticipated (and often obscure) model changes.
- Banks have favoured **ISDA effort for one single initial margin model**, used by every one and driving XVAs and value for the other half of the business (non cleared). Recent, effects still to be observed.
- Regulators have shown to favour standardize models even in their recnt choices about risk models. FRTB was the most amazing example.


ISDA. Safe, Efficient Markets

ISDA Standard Initial Margin Model (SIMM™) for Non-Cleared Derivatives

December 2013

Appendix: Risk Factors and Idiosyncratic Risk

March 2014

When few one-size-fits-all models that are used by all players for most of their exposure, should we start speaking of **SYSTEMIC MODEL RISK?**

CCP SYSTEMIC MODEL RISK

- On August 2, 2018, news were released of investigation of american regolators into an anomalous surge in CCP margin breaches at Chicago OCC: **38 breaches in Q1 2018 averaging 61.4 Mn$. Before, largest was 9 Mn$ in 2016.** Margin models are Value-at-Risk or Expected Shortfall models, at 99% confidence in case of Chicago OCC.

- Debate is ongoing on whether breaches are in line with 99% confidence considering the growth of the number of business lines and clients. But the issue is more serious, as pointed by Darrel Duffie since 2011: **can we afford that institutions whose exposure drive enormous sizes of the market to be run at 99% confidence? How dramatic can the impact of model risk be in this case?**

- **Regulators** (more recently Basel Committee jointly with IOSCO) continue to call for tighter standards to be applied to CCP risk management. But the issue is **the size of the risk exposures, the sheer concentration of risk upon few margin models**.

SYSTEMIC MODEL RISK

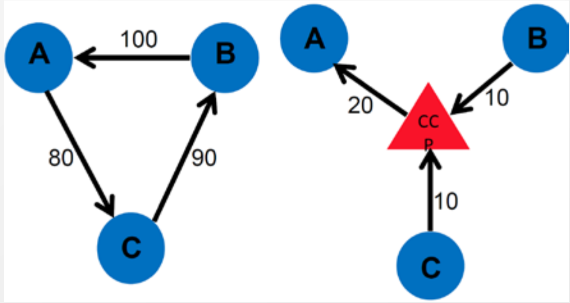
European Commission

There are other issues associated to CCP models.

- Parts of them are often obscure to the same banks that pay enormous amounts of margin based on this model. As Risk Magazine reported in 2017, «**Banks have long sought greater transparency on clearers' margin models**… The European Commission is seeking to force clearing houses to reveal more details about how they calculate margin requirements… Some remain concerned the proposed rules still do not go far enough, though. »

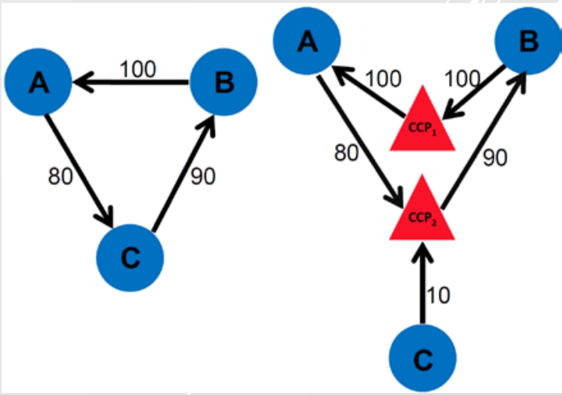
- CCPs are private entities that compete for clients. Their models often adapt to attract more clients or to specialize in counterparties with specific features. **The interplay between CCP competition and banks seeking to minimize margins may create a suboptimal – in terms of netting default risk - allocation of risks across CCPs.**

SYSTEMIC MODEL RISK



Recent research has proposed various solutions

- Change current system by making CCPs a network where margins are computed globally and risk management is different from private institutions (Duffie, 2015).
- Go beyond the current situation where banks do not even treat CCPs as defaultable entities, and at least compute proper CVA againt their risk (Arsndorf, 2017)
- Change models for CCP risk, modelling dynamically the default waterfall model and proposing a risk sensitive method for sizing margins (Bielecki et al., 2018)
- Use technology (smart contracts and distributed networks) to net risk like in CCPs maintaing bilateral trading with transparent, diversified models (Morini et al., 2017)



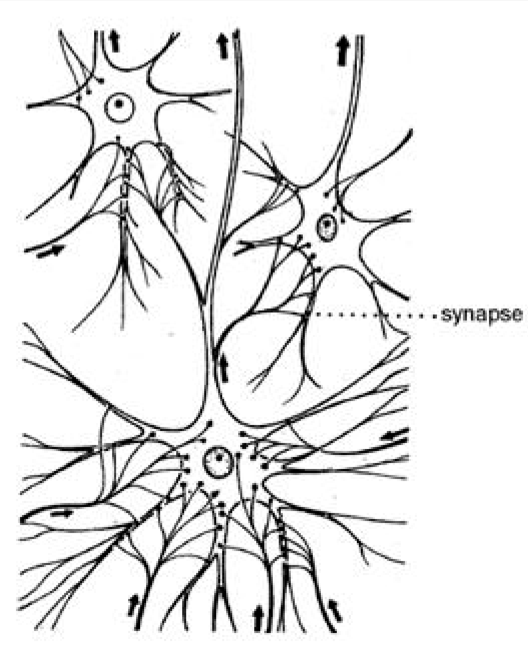
And there is lot of work for theory and practice of model risk management and robust risk computations…

APPENDIX: MODEL RISK WHEN MACHINE LEARNING GETS IN

Now in investment banks everyone speaks of Machine Lerning…

What are we really using it for?

- Data Processing, Risk Factors, Asset Management
- Replacing traditional numerical methods
- Hedging…



- Asset Management is out of traditional modelling… ML is mainly used for predictions
- Risk Management is still getting the lay of the land
- Pricing is not yet affected if not in the numerical part
- The applications to Numerical Methods and Hedging easer to understand…

FROM OPTIMIZATION TO MACHINE LEARNING

Market data → **Levenberg-Marquardt** → Calibrated Model

Market data → **Levenberg-Marquardt** → Calibrated Model

Market data → **Levenberg-Marquardt** → Calibrated Model

. . .

Calibration is repeated thousands of times in the life of a model… using always a general algorithm

Why not using all these data (+ artificial ones) to teach a Neural Network (Random Forest, Nearest Neighbours…) how to calibrate? (Hernandez 2017)

Same logic could also be used for MC, for example

STILL LESS GENERAL - MUCH MORE EFFICIENT

More «Model Risk» in numerics, Verification important

It could free modelling from the obsession of closed-form formulas…

FROM HEDGING TO MACHINE LEARNING

Rather than HEDGING using linear sensies coming from a (simplified) model… Why not using a Machine Learning algo that learns the real relationships observed in market data? Could exploit actual relations between hedges, and minimize a more elaborate loss function (PnL Volatility, Capital…)

UNSUPERVISED +SUPERVISED LEARNING (i.e. neural networks + dimension reduction, already applied)

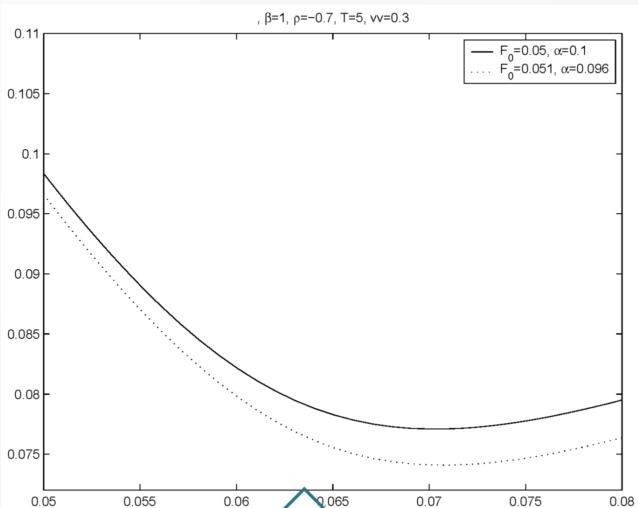
REINFORCEMENT LEARNING(akin to optimal control, appropriate but in infancy, Buhler et al. 2018)

These lead to disturbing fact that **hedging is from a different model than pricing**

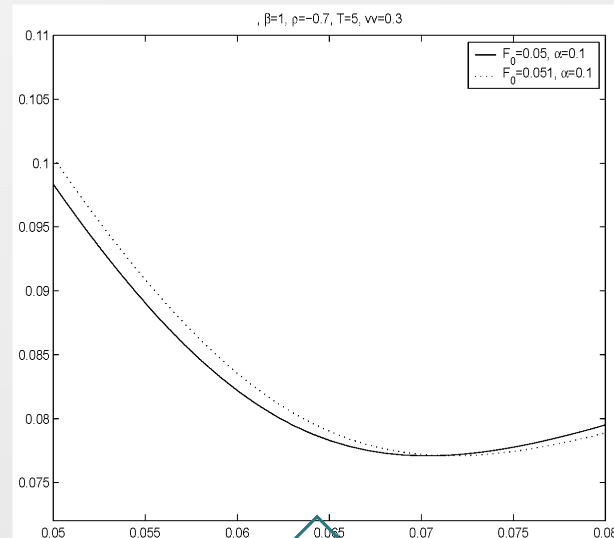
In practice this happens already. In discrete time, with non-uniform hedging costs and different hedges updated at different frequency (delta- vs vega-hedging, rates vs credit in CVA), optimal hedging is not by pricing model first derivatives but requires sensitivities adjusted by empirical relations that may be at odds with model assumptions…
(see Morini and Daluiso 2017).

PRICING VS HEDGING

This has always been the case in practice. See Morini and Mercurio (2006) for the «pricing-model-inconsistent» hedging which is typical of both local and stochastic volatility models.



It trader uses the negative correlation rates-vol implied by pricing, odd movement of smile when delta-hedging



Traders implicitly adjust their hedges to avoid this effect. It can be interpreted as anticipating the effect of a recalibration…

PRICING VS HEDGING

So models good for pricing are wrong when applied to hedging. **We knew already**.

Hedging is a dynamic activity that requires models that remain valid in time. But standard pricing models are not, **in fact they are recalibrated every few hours**.

Pricing models are still simple with **few factors that must be used to capture large scale relations**: for example,the fact that when there is a price crash volatility jumps up, captured by negative rate-vol correlation leading to skew.

But does it impy that small daily price movements are negative correlated to stoch vol? No. **Hedging works at a different, smaller time scale.** A trading strategy needs other relations than those used in pricing and needs separate model risk assessment.

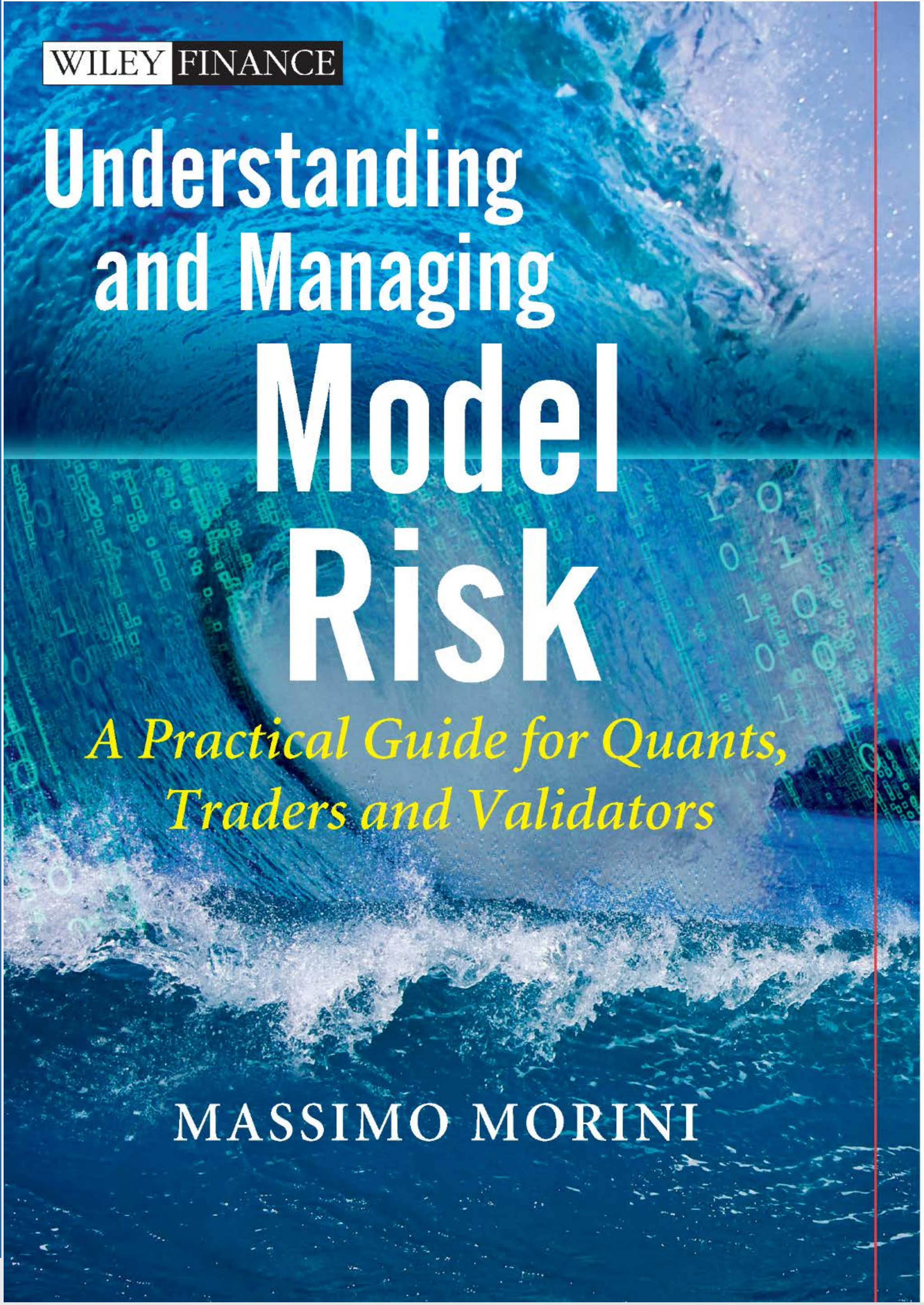
The use of machine learning for hedging just makes this even more obvious, and opens **a new line of research into model uncertainty**.

Disclaimer

Thank you!

(main references is book:)

* This presentation expresses the views of its authors and does not represent the opinion of his employers, who are not responsible for any use which may be made of its contents.



"The most thoughtful and yet practical book I've seen on dealing with model risk."

Emanuel Derman, Professor at Columbia University, former Head of Quantitative Risk Management at Goldman Sachs, and author of *Models.Behaving.Badly*

"Massimo Morini has provided a comprehensive and practical book on model risk that well covers the practitioner's needs in these post-credit-crisis times. The various applications are woven together by a strong conceptual underpinning that provides unity and coherence to the book. Traders, product controllers, regulators, accountants and, in general, students of the reality of financial modelling will greatly benefit from this high-quality work."

Riccardo Rebonato, Head of Front Office Risk Management and Quantitative Analytics, RBS Global Banking & Markets, Visiting Lecturer, Mathematical Finance, Oxford University, and member of the Board of Directors of ISDA and GARP.

"At last, a book (other than my own obviously!) that takes model risk seriously. And does so by hitting the "maths sweet spot," not dumbed down and not trying to impress with complexity. I wish more finance books were this sensible."

Paul Wilmott, Founder of the CQF, the world's largest quant education program.

"The recent credit crisis taught us that model risk can have disastrous consequences if not properly accounted for. This timely contribution by Massimo Morini presents thorough studies on the types of risk that arise when modeling and pricing derivatives across different asset classes. The perfect blend of rigorous modeling and market wisdom makes this excellent book a must have for quants and risk managers: model risk at no book risk."

Fabio Mercurio, Quant Business Manager, Bloomberg L.P., New York.

"Long-neglected by risk managers and regulators, model risk was shown to be a major component of the risk of derivatives portfolios during the recent financial crisis. Massimo Morini's book offers a much-needed resource for practitioners who want to deal with the "invisible" risks associated with the widespread use of quantitative models in finance."

Rama Cont, Columbia University, New York, and CNRS, Paris

continued on back flap