VPBank
Vietnam Prosperity Bank

Clarity in Complexity
ENTROFINE

Workshops for Vietnam Prosperity Joint-Stock Commercial Bank — Model Validation

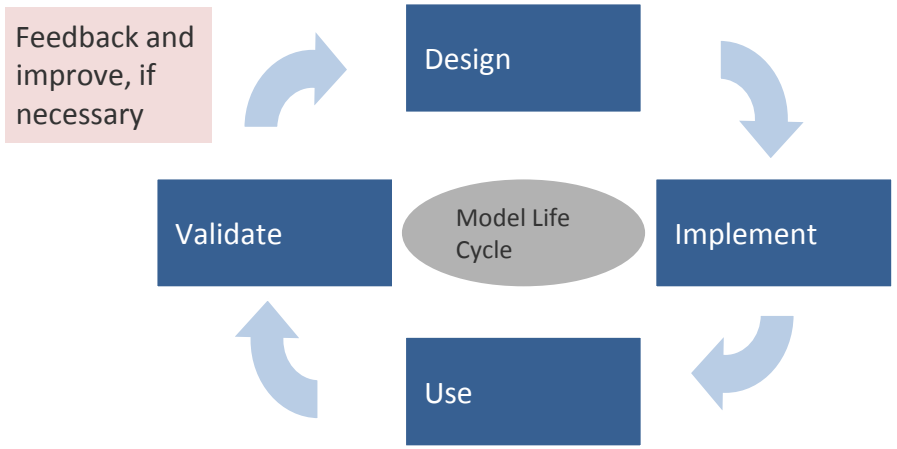
Agenda

Model Validation

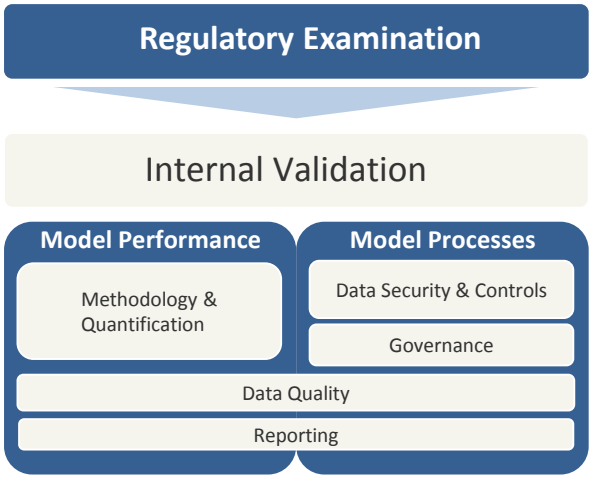
1. **Overview of Validation**
2. **Key Dimensions of Model Validation**
3. **Model Validation Process and Method**

Introduction
Overview

- Validation of internal credit risk models is an increasing focus under Basel II
- Institutions are expected to have frameworks in place to enable:
  - Initial model validation: review of model development, ongoing validation procedures, and the processes surrounding the operation of the model
  - Ongoing model validation: procedures to verify performance of model predicted values against actual outcomes and benchmarks



Validation is an integral part of the model life cycle



Validation focuses on the integrity of both model performance and processes

- Goal of model validation is to
  - Confirm that the model is functioning as expected
  - Identify model inadequacies, and determine situations where the application of the model is inappropriate
  - Validation is a balance of mathematical/statistical foundation and risk judgment; a standard process needs to be developed incorporating these elements

Introduction
Validation Definition

- While individual organizations may define model validation differently we distinguish between three types of validation:
  - Initial independent validation
  - Ongoing monitoring/validation
  - Ongoing independent validation

- Focus of independent validation is characterized by
  - Effective challenge to the model methodology
  - Structural and functional independence from model builders
  - Incentive of independent validation group not being linked to model performance

Introduction

"Rating systems are a cornerstone for the calculation of banks' regulatory capital charge in the internal ratings-based (IRB) approach of the revised Framework (Basel II) because they are the basis for the determination of a borrower's probability of default (PD). The PD and the other two risk components, loss given default (LGD) and exposure at default (EAD), are key input parameters to the regulatory capital calculation. As a consequence, validation of these three parameters and the underlying rating system is a key component of the supervisory review process."

Regulatory Requirements on "Validation of internal estimates" (BII §§500-505)

"Banks must have a robust system in place to validate the accuracy and consistency of rating systems, processes, and the estimation of all relevant risk components…" [Basel II, §500]

"…a bank must demonstrate to its supervisor that the internal validation process enables it to assess the performance of internal rating and risk estimation systems consistently and meaningfully." [Basel II, §500]

"Banks must regularly compare realised default rates with estimated PDs for each grade and be able to demonstrate that the realized default rates are within the expected range for that grade." [Basel II, §501]

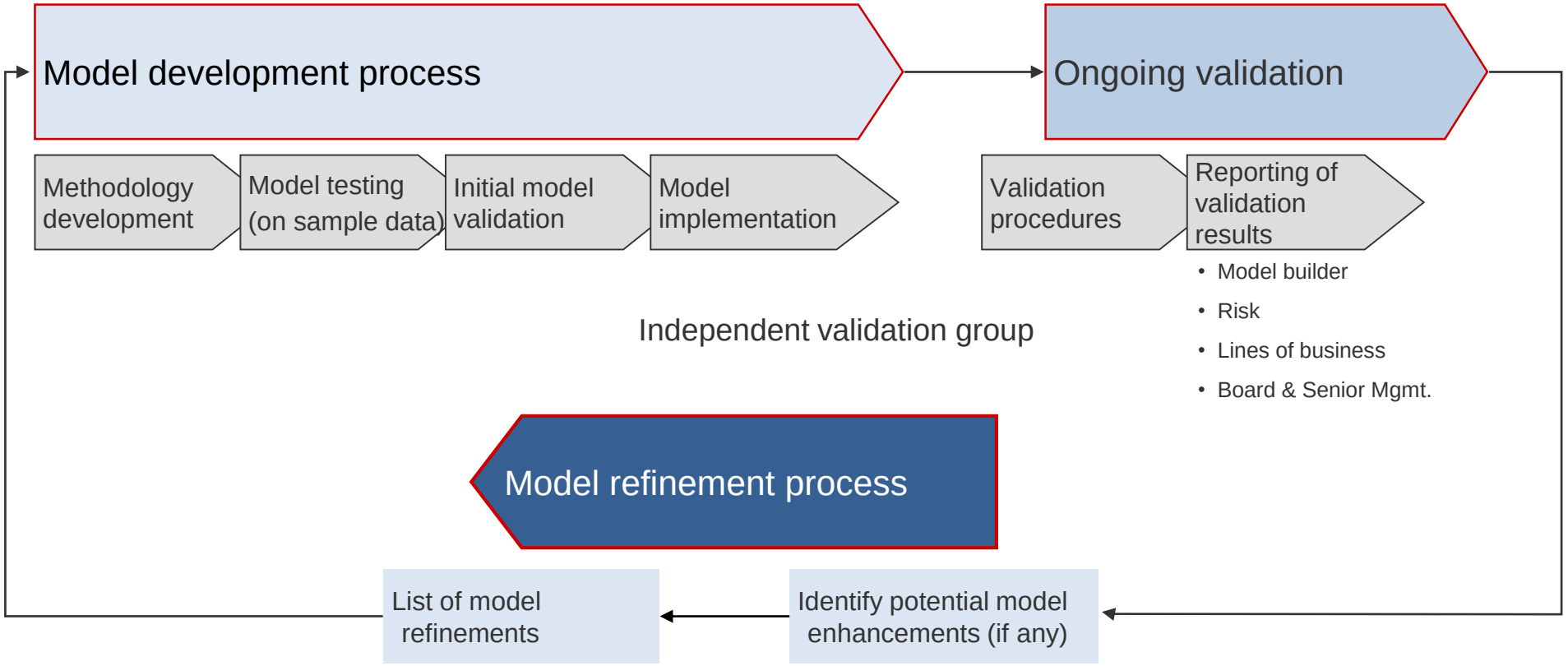
"Banks must also use other quantitative validation tools and comparisons with relevant external data sources. The analysis must be based on data that are appropriate to the portfolio, are updated regularly, and cover a relevant observation period." [Basel II, §502]

Introduction
Pre and Post Basel II

- Previous Industry Perspective on Model Validation
  - A secondary aspect of Model Building
  - Generally a domain of modellers only
  - A technical review of models, typically triggered by crises – not a complete review
  - Performed within the Model Developer units, ad hoc procedures and methodologies
  - No senior management involvement

- Basel II Regulatory Perspective
  - A key requirement for IRB compliance
  - A key element of board and senior management reports
  - A well defined, actionable process around ongoing reporting on model quality with clearly defined responsibilities, metrics, thresholds for acceptable quality.
  - Independent of model development
  - The responsibility of banks, not supervisors

Introduction
Model Life Cycle



Introduction

The Six Principles from Basel II Validation Sub-Group

- The Bank has primary responsibility for validation.
- Validation is fundamentally about assessing the *predictive ability* of a bank's risk estimates and the *use of ratings* in credit processes.
- There is no single validation method
- Validation should encompass *both* quantitative and qualitative elements
- Validation is an iterative
- Validation processes and outcomes should be subject to *independent*

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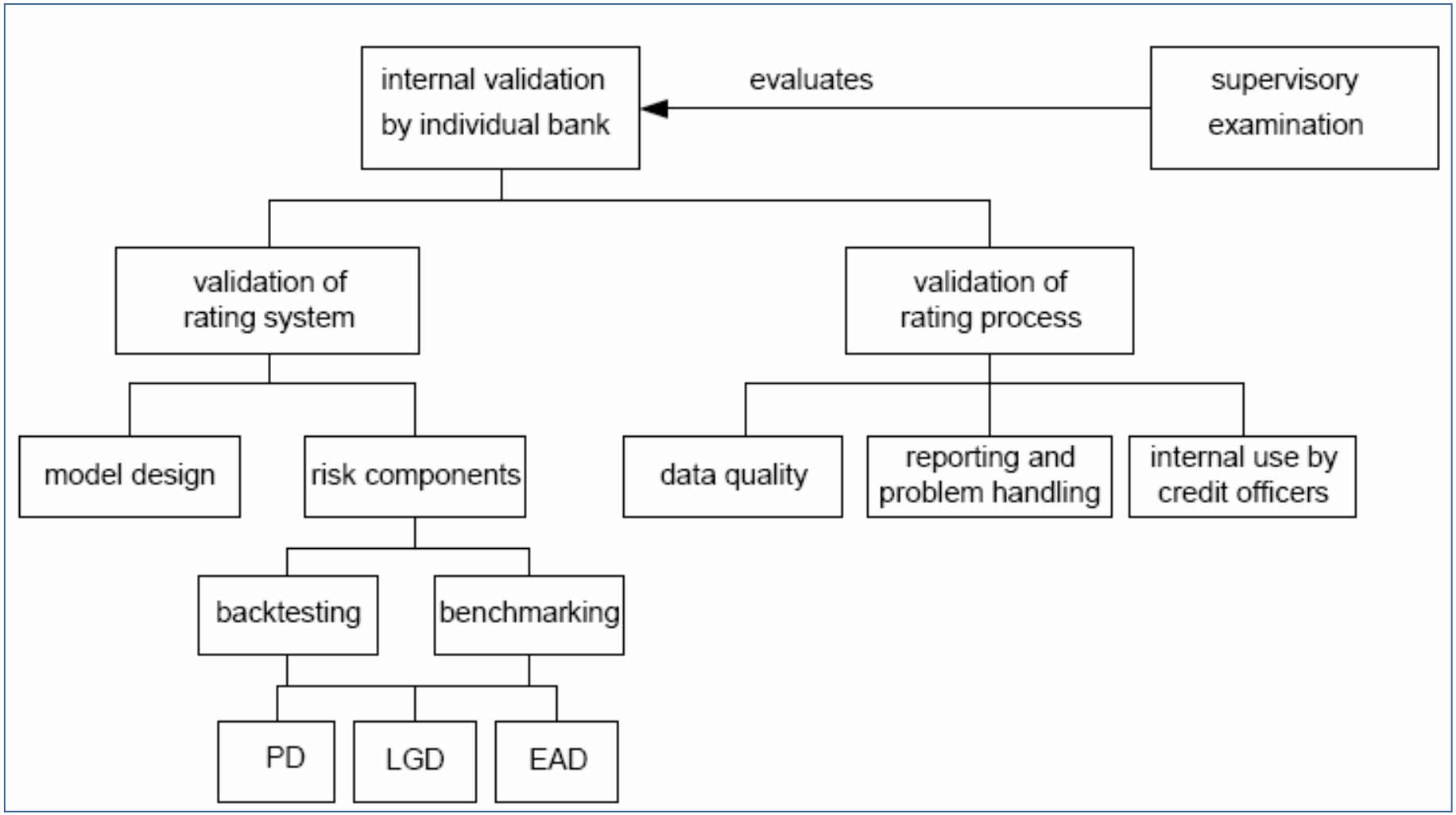
Key Dimensions of Credit Rating Validation



Key Dimensions of Credit Rating Validation (Continue.)

Methodology & Quantification

- Model Methodology: Reasonableness and appropriateness
- Analytics: Theoretical soundness and accuracy
- Benchmarking: Comparison of results with other models
- Backtesting: Comparison of realized experience with that predicted by model
- Refinement: Review of key risk drivers/assumptions

Reporting

- Inclusion in reporting target audience of key decision-makers and reviewers
- Content matched to audience in depth, granularity, length, sufficiency
- Quality and accuracy appropriate for designated use
- Frequency appropriate for audience and designated use

Data Integrity

- Completeness: Coverage of all transactions and portfolios; missing data protocols
- Appropriateness: Historical data is representative of current portfolio
- Accuracy: Input data validation; frequent information refresh – up to date data; correct technical implementation
- Consistency: Common identification and data definitions across organization

Data Security & Controls

- Audit trails for inputs and outputs
- Access & change controls
- Business continuity procedures

Governance

- Consistency of application by end users
- Use Test
- Transparency of model development, approval and validation processes
- Independence of model operation from transaction/position originator
- Board responsibilities and committee structure and senior management oversight
- Ownership of models, ownership of validation process
- Approval processes for new models
- Documentation standards for
  - Policies & procedures
  - Models and methodologies
  - Validation process
  - Approvals and senior management reporting
- Independent validation

Key Dimensions of Credit Rating Validation
Example Validation Objectives (Obligor Ratings/PDs)

Objectives

Validation Procedures			
	Developmental Evidence *(Soundness of model development procedures)*	**Benchmarking** *(Comparison with other models, i.e. "benchmarks")*	**Backtesting** *(Comparing actual results with model output values)*
Qualitative Validation	• Methodology consistent with theory? • Assumptions tested? • Limitations documented? • CSE/Basel II requirements met?	• Established benchmarking standards: • Measurable? Best practice? • Clear guidelines on use?	• Internal back-testing standards established? • Norms for deviations? • Are results plausible given earlier loss experience?
Quantitative Validation: *Discriminatory Power*	• When run on holdout sample, does model as a whole, and individual factors, distinguish "bads" from "goods"?	• Internal model distinguish "bads" from "goods" as well as benchmark model? • How much, and in what direction, do ratings by the two models differ?	• Are actual default frequencies monotonic by grade?
Quantitative Validation: *Accuracy*	• Are development and holdout samples properly defined? • How accurate are the PDs when compared with holdout sample default frequencies?	• How accurate are model predicted PDs versus other, best practice models?	• How accurate are predicted versus realized PDs across risk grades? • Are deviations significant, after accounting for cyclicality
Quantitative Validation: *Stability*	• Model parameter estimates: Change materially when estimated with holdout sample? (Keeping intended risk horizon in mind - point-in-time vs. through-the-cycle)	• Ratings changes: In line with industry experience, or due to unstable model?	• Chosen risk factors: Good default predictors?

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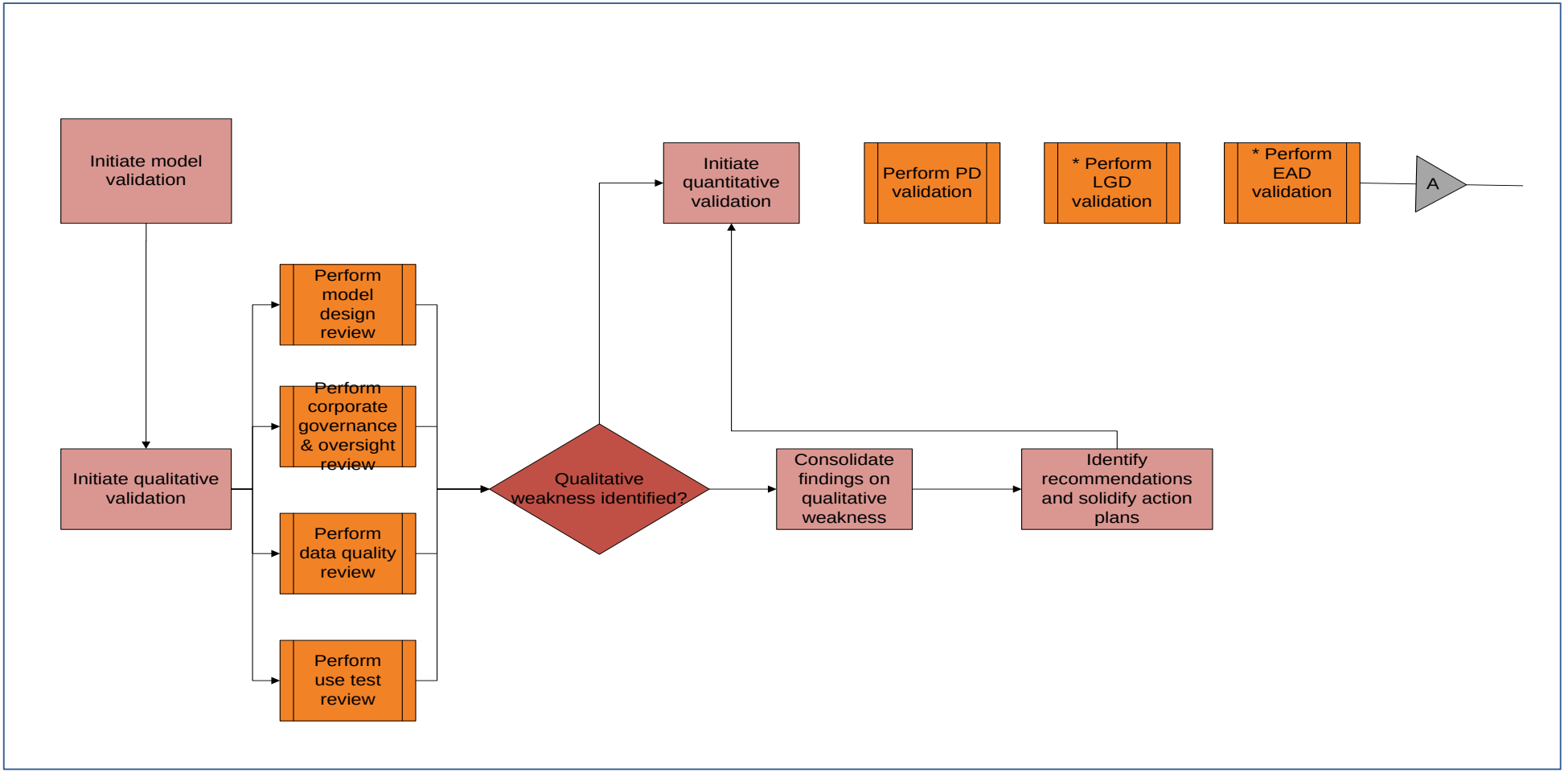
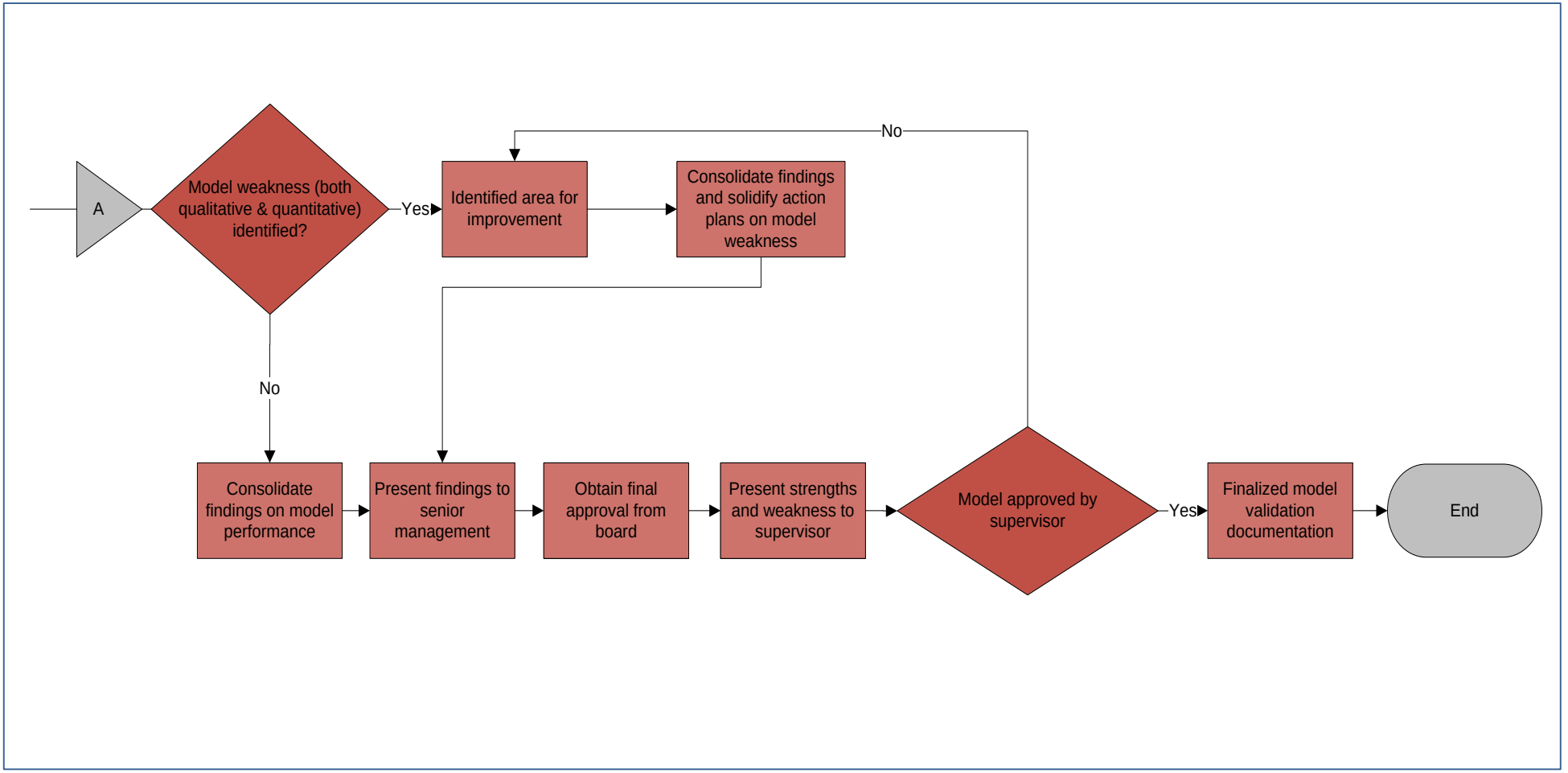
Validation process framework

- High Level Validation



Validation process framework (continue.)



Validation process framework (continue.)

Need to have a Check List to ensure the completeness of the validation

1.1 Organization
Key Objectives:
- ✓ Ensure that there is proper segregation of duties between the origination and validation.
- ✓ Ensure that there are proper skill sets within the validation team
- ✓ Ensure that there are proper policies and procedures for the model validation

Control ref.	Focus areas	Sample checkpo
	Documentation	✓ Are there proper policies an model validation available? ✓ Is it approved by the senior
	Segregation	✓ Is there a proper segregatior the credit origination team a validation team?
	Staff competency	✓ Does the validation team ha sets available within the vali ✓ Is there documentary evider validation team possesses th qualification to carry out the exercise?

1.2 Communication
Key Objectives:
- ✓ Ensure communication to the senior management takes into account quantitative and qualitative aspects of validation.
- ✓ Ensure minimum standards for reporting and frequency are defined in the policy and adhered to.

Control ref.	Focus areas	
	Communication to senior management	✓ Are there which th ✓ Were the the prop ✓ Is there a consister ✓ Are the c clearly e: and the v ✓ Are conc clearly ar

1.3.1 Data and Systems - Data Quality
Key Objectives:
- ✓ Ensure relevant data from source systems has been used by the independent validation team.
- ✓ Ensure that data representativeness is ensured.

Control ref.	Focus areas	Sample checkpoints	
	Data representativeness	✓ Are all data and information elements required for validation clearly defined? ✓ Are there proper checks performed to verify that the data used corresponds to the expected definition? ✓ Is the models target population clearly defined? ✓ Are proper checks included to verify that the	ive of the population?

1.4.1 Process - Initiation
Key Objectives:
- ✓ Ensure that all relevant rating models are covered appropriately by the validation team.

Control ref.	Focus areas	Sample checkp
	(Re-) Validation of rating models	✓ Is there a new model approv clearly identifies the roles ar model validation and which validation as a key element? ✓ Is there a clear definition of difference between new moc models with respect to the e existing models? ✓ Are changed models revalid manner? ✓ Is there a proper plan define perform a validation of mod basis?

1.4.2.2 Process - Model Validation – Standards
Key Objectives:
- ✓ Ensure that proper model validation standards are defined and enforced.

Control ref.	Focus areas	Sample checkpoints	
	Availability of model validation standards	✓ Are there clearly defined model validation standards and policies available? ✓ Are there model validation standards which in particular require validation to distinguish situations where deviations in realized outcomes from estimates of IRBA parameters become significant enough to call into question the predictive power of the estimates of IRBA parameters? ✓ Is there a clear ownership of validation standards? ✓ Is there a proper process which identifies regulatory changes and ensures that such changes are reflected in model validation standards if required?	

Validation process framework (continue.)

Impact Assessment

In addition to identifying the gaps, an significance assessment was also undertaken as part of the project. It represents the significance of the deviation to the market practice which may affect the IRB application. The extent of impact is pictorially represented by heatmaps:

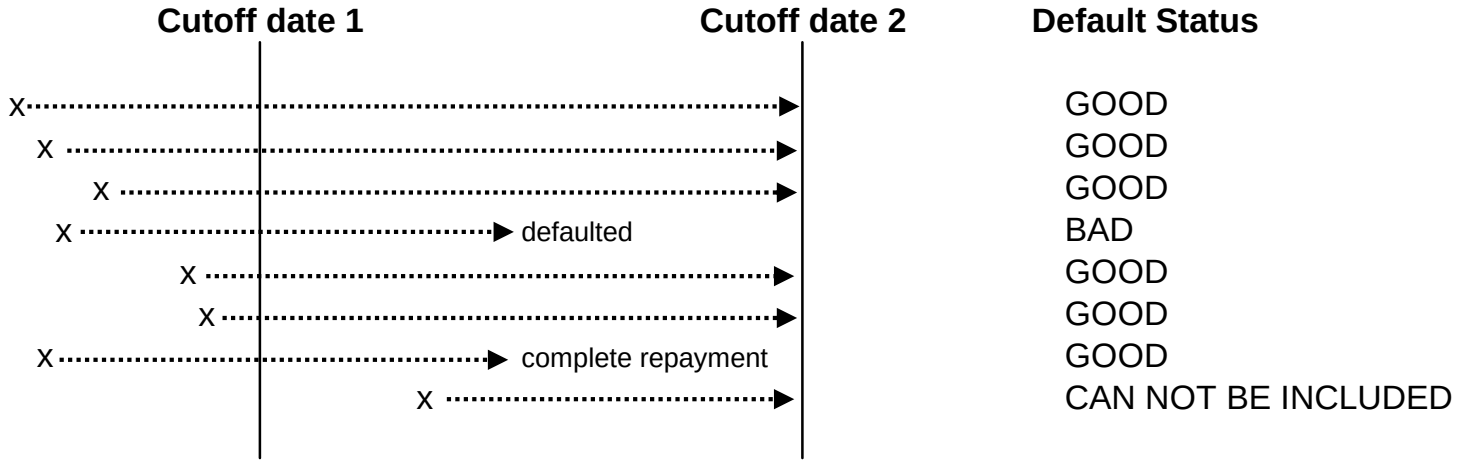
Color	Impact
○	No Gap
●	Low significance
●	Medium significance
●	High significance

Illustrative

Section	○	●	●	●
Model Development	0	3	4	4
Credit Approval Process	3	1	2	0
Data Quality	2	1	7	0
Data Management	1	0	4	0
Data Implementation	0	1	0	0
Governance & Management Oversight	4	1	0	0
Use Test of Internal Ratings	6	1	5	0
Control, Monitoring and Internal Audit	9	0	0	0
Parallel Calculations and Reporting	0	0	1	0

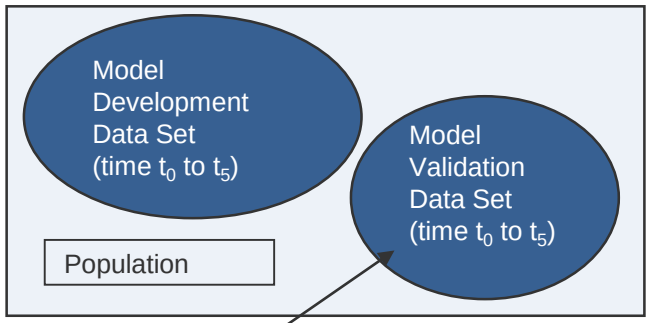
PD Validation
1. Data Sample for Model Validation

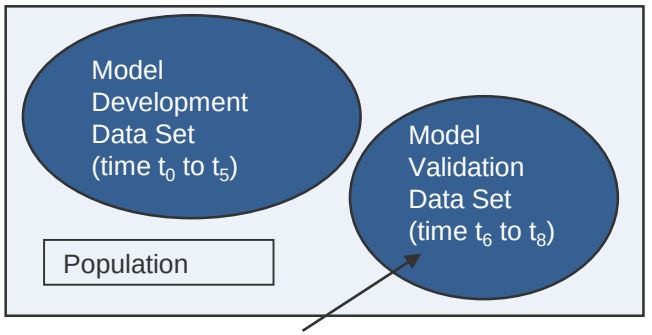
- Select Data which are consistent with default definition for each rating grade.
- Need to define cut-off dates (normally year end)



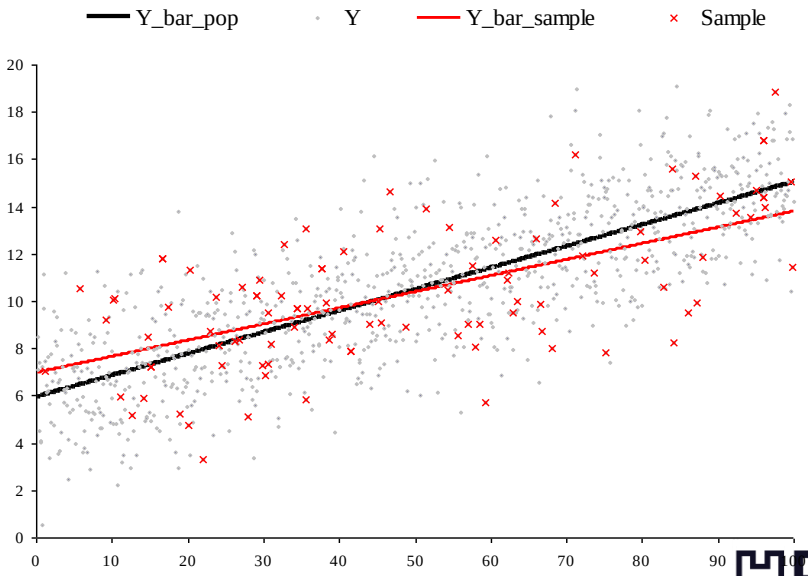
PD Validation
1. Data Sample for Model Validation

- Out-of-Sample and Out-of-Time Sample is required





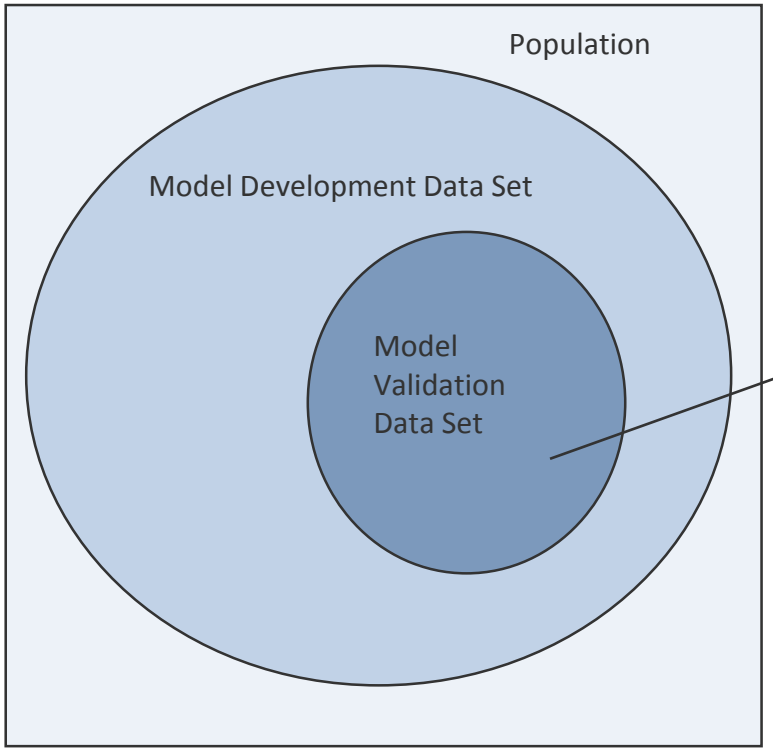
Why do we need Out-of-Sample and Out-of-Time Sample?



PD Validation
1. Data Sample for Model Validation

- If the data used for model development are limited, then how?

The statistical estimates are by design minimize errors within model development sample, but not necessary the "sub-sample". By bootstrapping, we can see if the model has found the "True Relationship"



"Cross Validation and/or Bootstraping"

1. Re-sampling randomly from the model development data set with smaller sample size
2. Repeated to see the stability of the estimated parameters
3. Can be used to construct the Confidence Interval for the Cumulative Accuracy Profile (CAP, explained below)

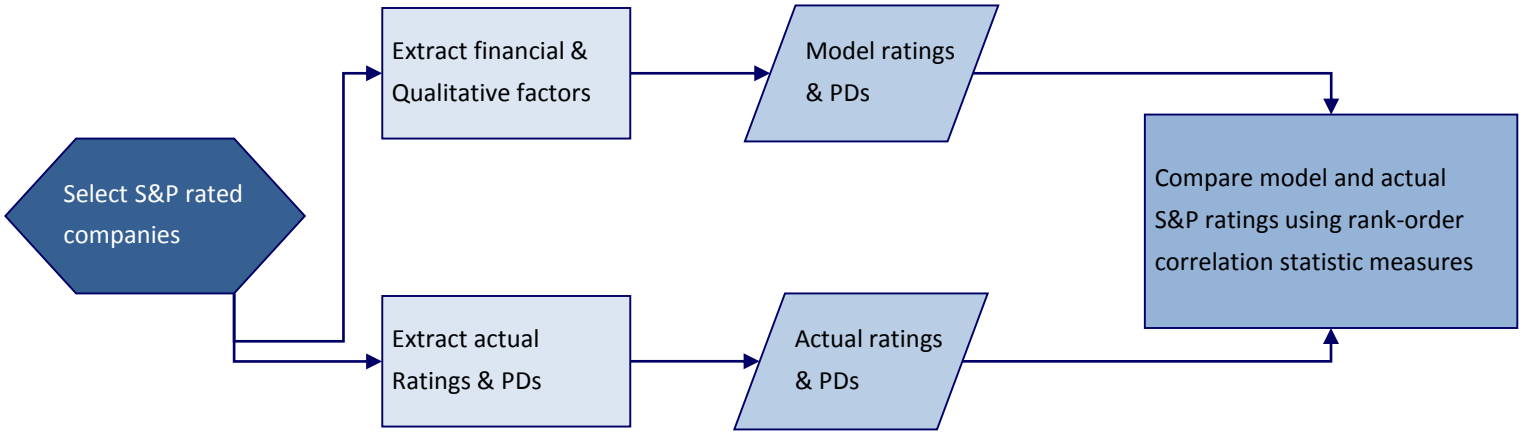
PD Validation
1. Data Sample for Model Validation

- If default data within the 12 months assessment horizon is limited, then how?

Data from a sample of companies which have external ratings (i.e. S&P) needs to be collected as the data set for PD validation which is called the "Proxy PD Approach".

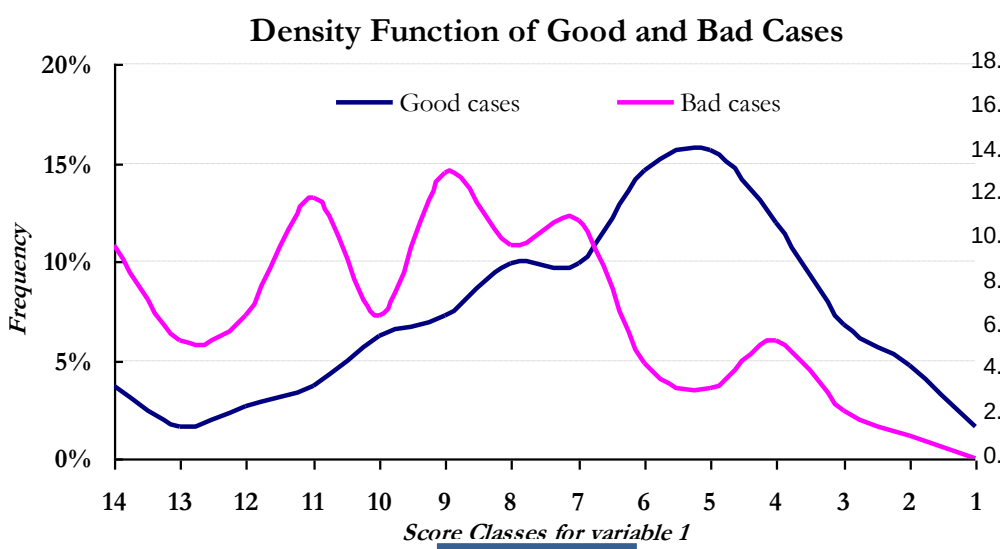
Step-by-step approach to perform PD validation using Proxy PD Approach:

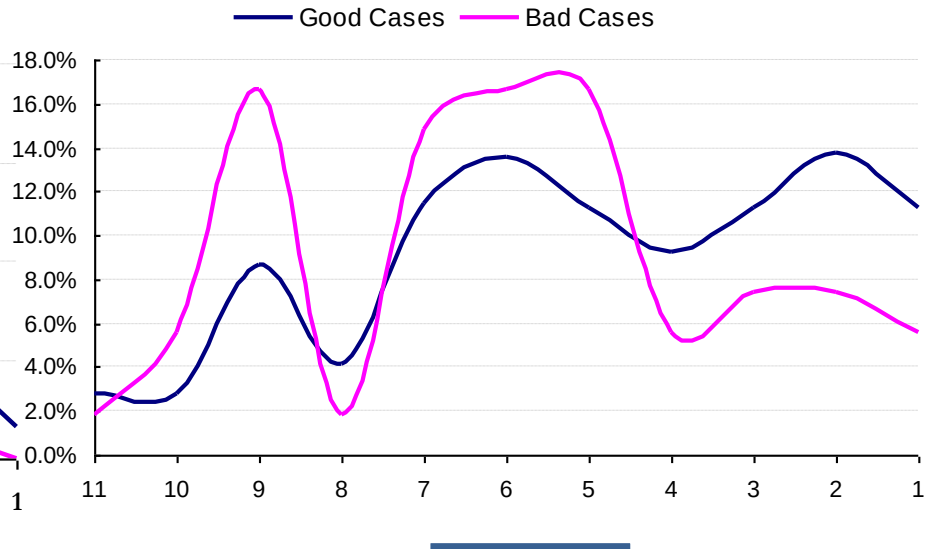
- Select the appropriate number and type of external rated companies as sample data (i.e. sensitive to country rating and portfolio mix);
- Extract financial data, qualitative factors and actual ratings & PDs from S&P reports;
- Input these financial and qualitative factors into benchmarking rating models to generate model ratings and PDs;
- Compare model results to actual results from S&P using certain statistical measures (i.e. Kendall's Tau or Somer's D)

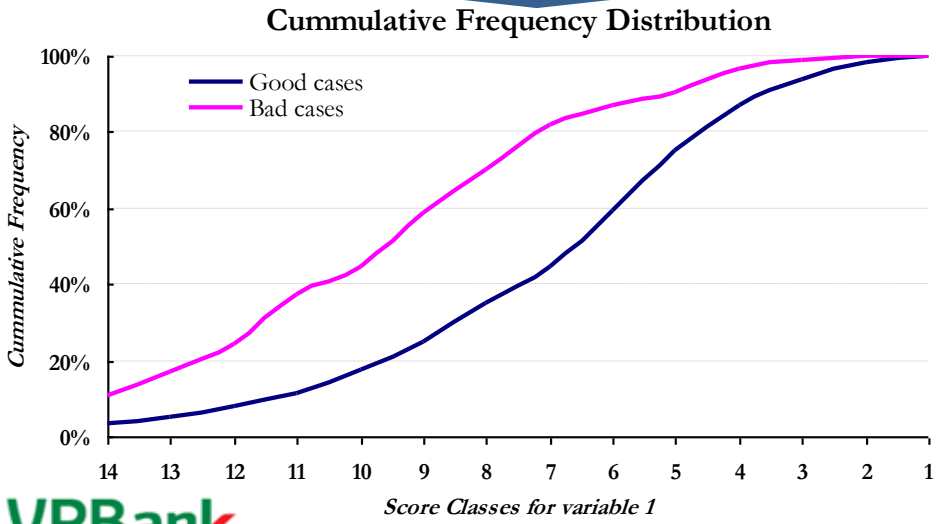


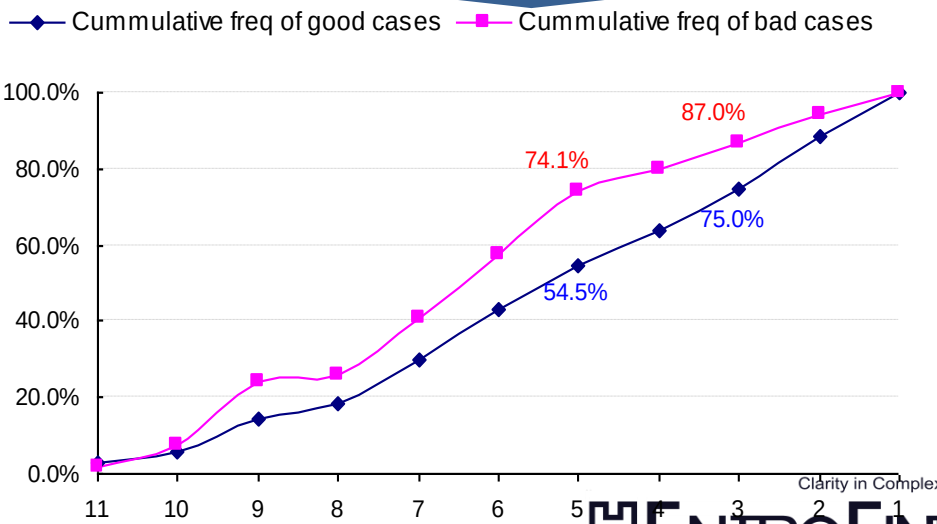
PD Validation

2. Discriminatory Power: Probability Distribution of Good and Bad Cases



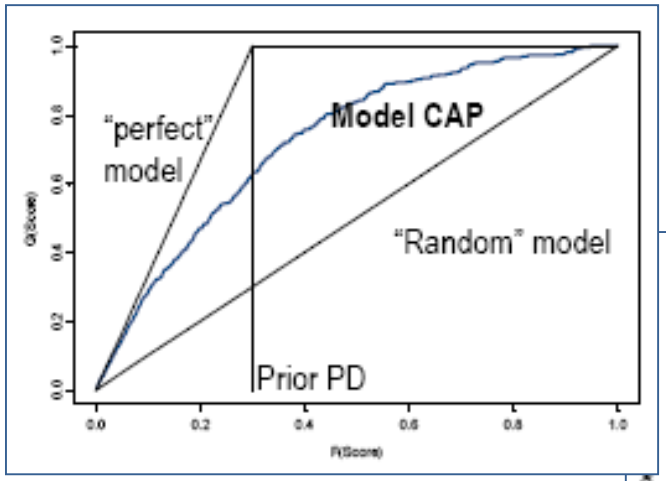




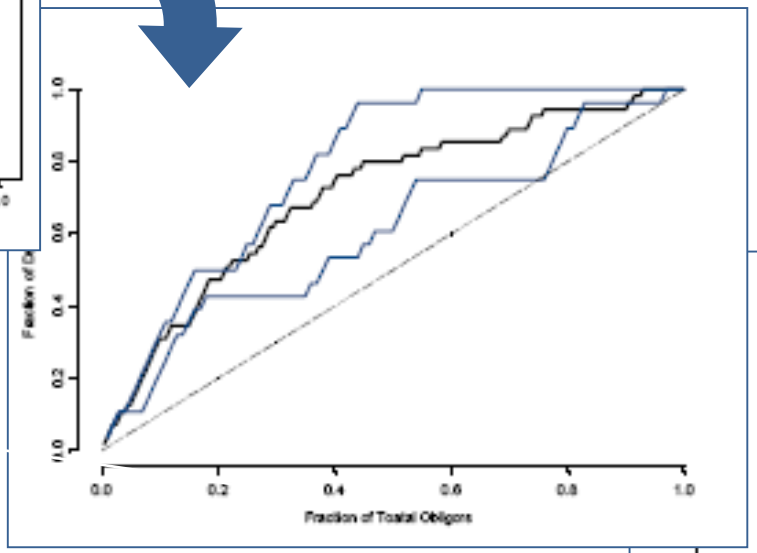


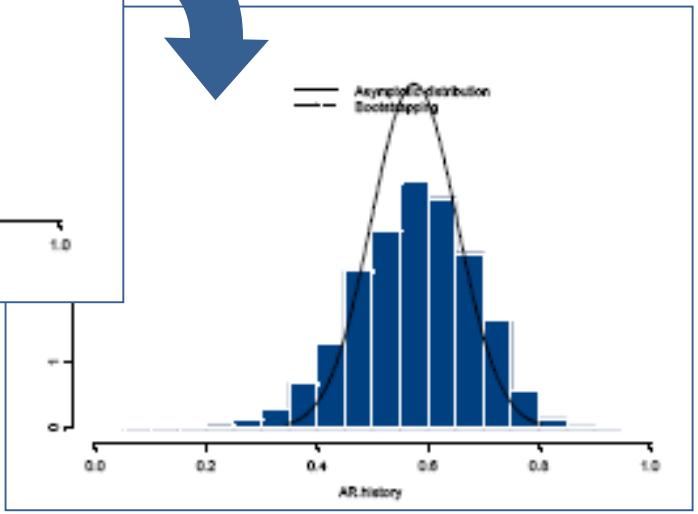
PD Validation
2. Discriminatory Power: Accuracy Ratio (AR)

- Accuracy Ratio is also an Random Variable, and hence has confidence interval



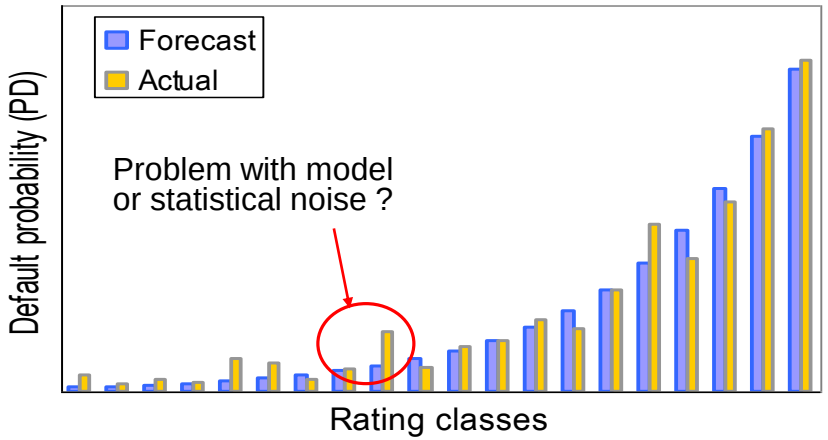
This area divided by the triangle is called Accuracy Ratio (AR)





PD Validation
3. Homogeneity Test / Accuracy of PD Calibration Test

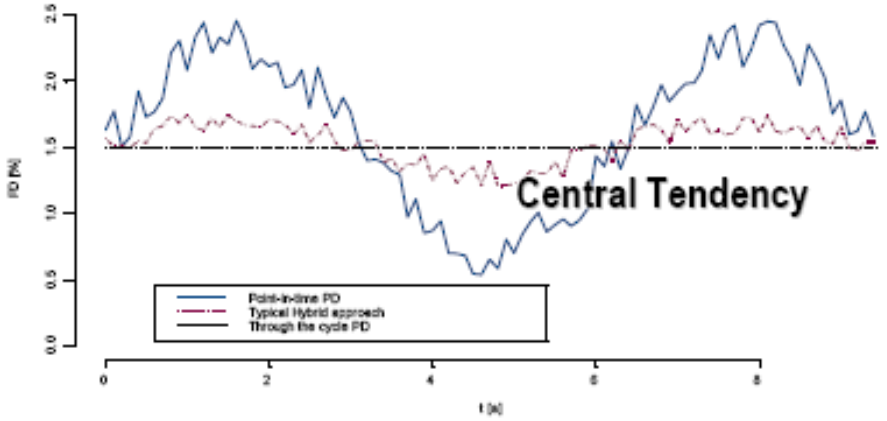
- The ultimate goal of any rating model is to predict the probability of defaults for new applicants
- PDs are either produced by the model or obtained via mapping of internal grades to external default experience
- The accuracy of these estimates needs to be validated
- Realized Default rates will deviate from estimated ones. Validation procedures need to examine whether the deviation is substantial and should lead to a review of the model or can be attributed to statistical noise. Focus :
  - Significance of Deviations
  - Monotony of PDs with regards to “risk”



PD Accuracy: Observed Default Rates versus Predicted

- Binomial test / Normal test. Determine probability of observing the realized default rate under the hypothesis that the estimated value is correct
- Others….

PD Validation
Through-the-Cycle



- The volatility of observed PDs within rating grades and the migration frequency of obligors across rating grades are determined by the adopted "rating philosophy".
- When interpreting the previously discussed PD Accuracy measures, one has to take into account the philosophy underlying the estimations:

Point-in-time: Rating and PD estimate is based on current condition of the obligors' risk characteristics, typically including the economic environment. This should result in **high rating migration frequency**. **Default rates** within rating classes **should remain stable**.

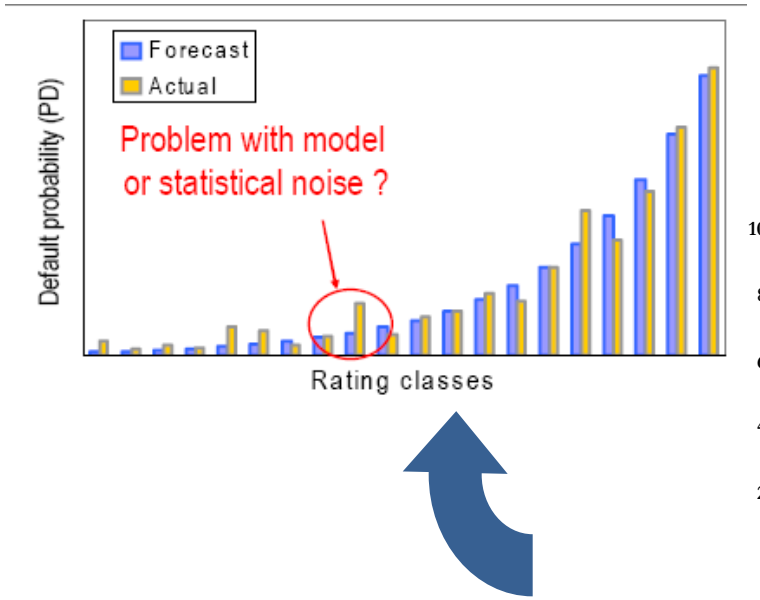
Through-the-cycle: Obligor ratings are not influenced by short term risk characteristics. Ratings do not change frequently, default rates vary.

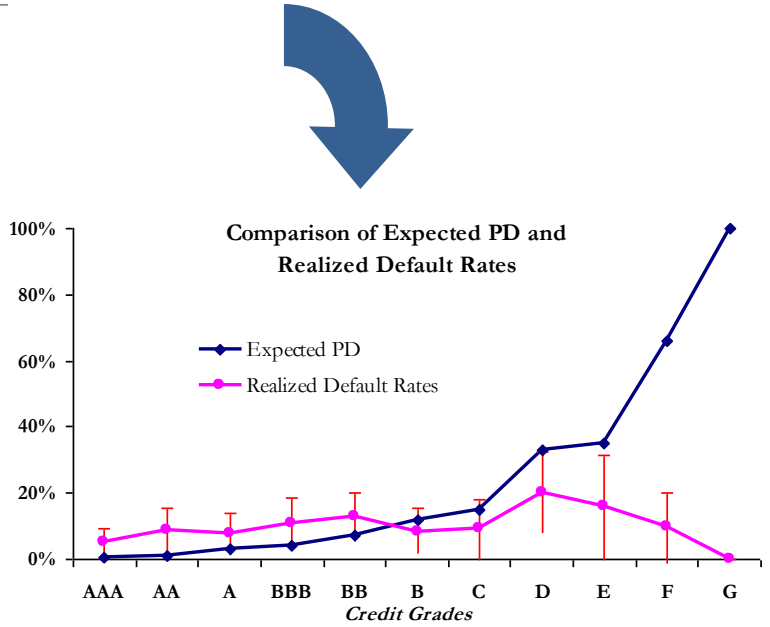
Hybrid Approach: Mixture of both "pure" philosophies. The rating system incorporates current condition elements of obligor idiosyncratic and systematic risks. Data limitations force a "medium term" PD forecast.

	Default Rate Volatility	Rating Migration Frequency
Point in Time	Low	High
Through the Cycle	High	Low

PD Validation
3. Homogeneity Test : Binomial Test

- Focus on Through-the-cycle PD
  - If short period of data are available (for instances one year realization), adjustment should be made to the observable default before the test.





Notes:

1. Test PD per grade individually.
   ➔ If PD for one grade is significant while the others are not, then how?
2. Assume Independent default event.
3. ➔ Defaults are not independent ➔ Binomial Test is conservative !

PD Validation
3. Homogeneity Test : Granularity Adjustment & Moment Matching

- To relax the assumption of independent default.
  - Need the correlation figure…..
  - The formula is much more complicated comparing to Binomial Test

Granularity Adjustment ➔ based on assumption that default probability follows Normal Distribution

$$p_c^{observed} > Q + \frac{1}{2N_c}\left(2Q - 1 - \frac{Q\cdot(1-Q)}{\phi\left(\sqrt{\frac{\rho\Phi^{-1}(1-q)-t}{\sqrt{1-\rho}}}\right)}\left(\frac{(1-2\rho)\cdot\Phi^{-1}(1-q)-t\sqrt{\rho}}{\sqrt{\rho(1-\rho)}}\right)\right)$$

Moment Matching ➔ based on assumption that default probability follows Beta Distribution

$$q(\alpha, D_n) \approx n\, q(\alpha, Z),$$

Where Z is a Beta distribution with the following parameters:

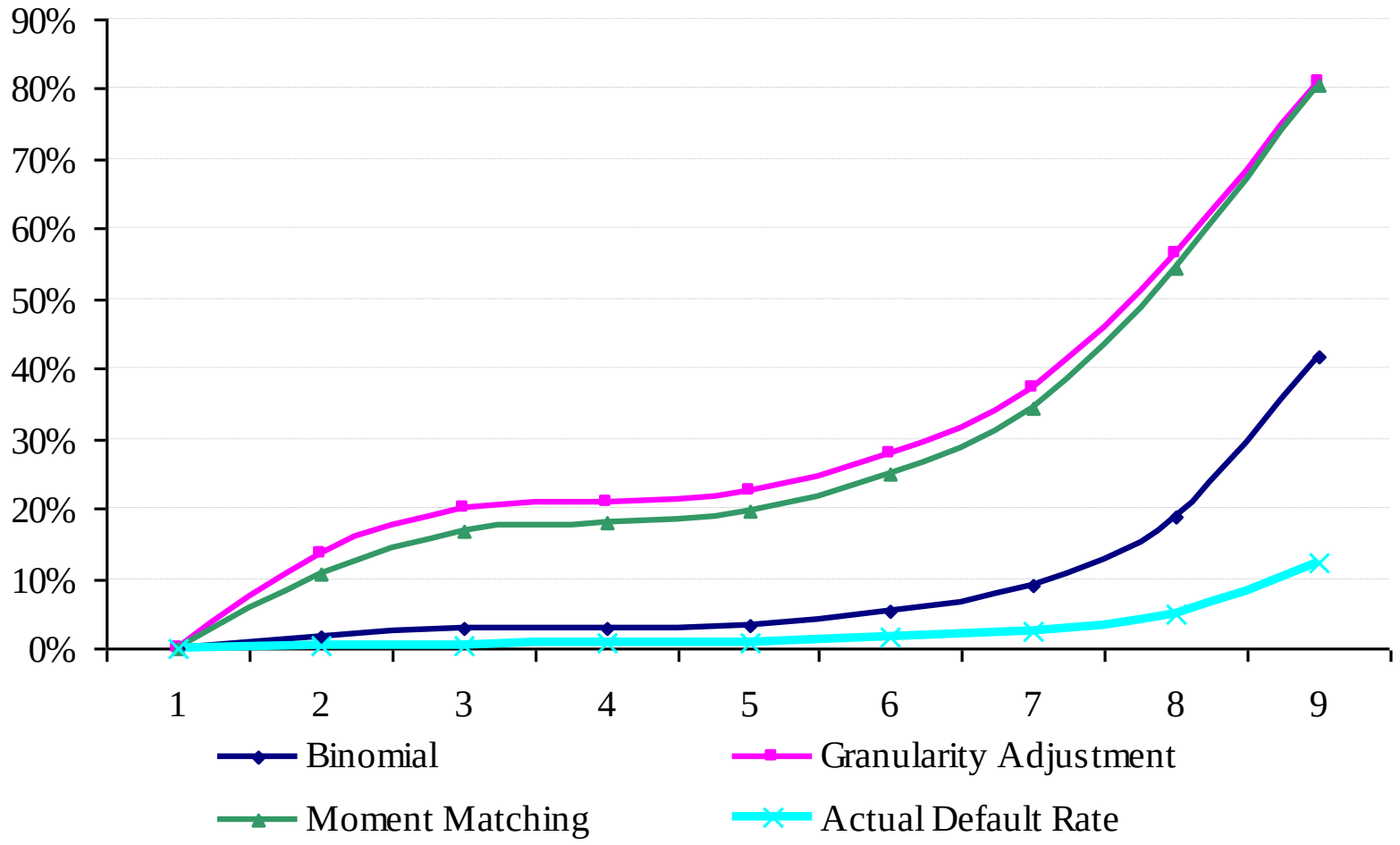
$$\mathrm{E}[Z] = \frac{a}{a+b},$$
$$\mathrm{var}[Z] = \frac{a\,b}{(a+b)^2\,(a+b+1)}$$

$$a = \frac{\mathrm{E}[R_n]}{\mathrm{var}[R_n]}\left(\mathrm{E}[R_n]\,(1-\mathrm{E}[R_n]) - \mathrm{var}[R_n]\right)$$
$$b = \frac{1-\mathrm{E}[R_n]}{\mathrm{var}[R_n]}\left(\mathrm{E}[R_n]\,(1-\mathrm{E}[R_n]) - \mathrm{var}[R_n]\right)$$

$$\mathrm{E}[R_n] = p$$
$$\mathrm{var}[R_n] = \frac{n-1}{n}\,\Phi_2(t,t,\rho) + \frac{p}{n} - p^2$$

$$\Phi_2(t,t,\rho) \approx \Phi(t)^2 + \frac{e^{-t^2}}{2\,\pi}\,(\rho + 1/2\,\rho^2\,t^2)$$

PD Validation
3. Homogeneity Test : Comparison



PD Validation
3. Homogeneity Test : Testing all PD's simultaneously

Other statistical test, for instance: Hosmer-Lemeshow (HL) statistic and Brier Score (BS)

Hosmer-Lemeshow Statistics

$$HL = \sum_{k=1}^{K} n_k \frac{(p_k - \hat{p}_k)^2}{\hat{p}_k(1-\hat{p}_k)} \qquad HL \sim \chi^2_K$$

Where:

Nk = number of obligor in rating class k

Pk = forecast of PD for rating class k

Pk_hat = realized PD in rating grade k

Brier Score

$$BS = \underbrace{p^{observed}(1-p^{observed})}_{\text{Uncertainty/variation}} + \underbrace{\frac{1}{N}\sum_{c=1}^{K} N_c\left[(p_c^{forecast} - p_c^{observed})^2\right]}_{\text{Calibration/reliability}} -$$

PD Validation
4. Stability Test

Ratings migration martix for KMV model („point-in-time" type)

Initial Rating	Rating at year-end (%)							
	AAA	*AA*	*A*	*BBB*	*BB*	*B*	*CCC*	*Default*
AAA	66.26	22.22	7.37	2.45	0.86	0.67	0.14	0.02
AA	21.66	43.04	25.83	6.56	1.99	0.68	0.20	0.04
A	2.76	20.34	44.19	22.94	7.42	1.97	0.28	0.10
BBB	0.30	2.80	22.63	42.54	23.52	6.95	1.00	0.26
BB	0.08	0.24	3.69	22.93	44.41	24.53	3.41	0.71
B	0.01	0.05	0.39	3.48	20.47	53.00	20.58	2.01
CCC	0.00	0.01	0.09	0.26	1.79	17.77	69.94	10.13

Rating migration matrix used by rating agencies („through-the-cycle" type)

Initial Rating	Rating at year-end (%)							
	AAA	*AA*	*A*	*BBB*	*BB*	*B*	*CCC*	*Default*
AAA	90.81	8.33	0.68	0.06	0.12	0.00	0.00	0.00
AA	0.70	90.65	7.79	0.64	0.06	0.14	0.02	0.00
A	0.09	2.27	91.05	5.52	0.74	0.26	0.01	0.06
BBB	0.02	0.33	5.95	86.93	5.30	1.17	0.12	0.18
BB	0.03	0.14	0.67	7.73	80.53	8.84	1.00	1.06
B	0.00	0.11	0.24	0.43	6.48	83.46	4.07	5.20
CCC	0.22	0.00	0.22	1.30	2.38	11.24	64.86	19.79

The diagonal – Close to One

PD Validation
4. Stability Test: Mobility Metric

mobility matrix (denoted $\tilde{\mathbf{P}}$)

$$\tilde{\mathbf{P}} \triangleq \mathbf{P} - \mathbf{I}$$

→ Identity Matrix **(I)** is a perfectly stable migration matrix

P = Rating Migration Matrix

Mobility Metric is defined (Jafry & Schuermann, 2004) as average of singular value of mobility matrix:

$$M_{SVD}(\mathbf{P}) \triangleq \frac{\sum_{i=1}^{N} \sqrt{\lambda_i\left(\tilde{\mathbf{P}}'\tilde{\mathbf{P}}\right)}}{N}$$

Mobility Matrix for S&P's rating migration matrix is 0.1 - 0.2 (JCIC calculated the MM for S&P's one year rating migration matrix is 0.1563)

Granularity of the rating class may also affect the calculated MM.

PD Validation
5. Benchmarking: Kendall's τ and Somer's D

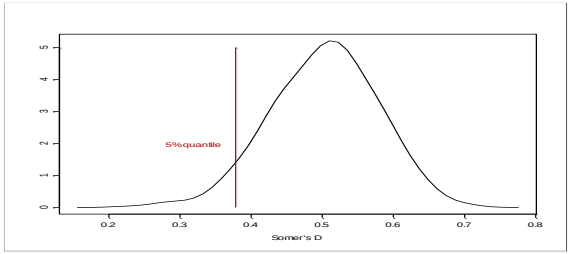
- One of the findings of RESEARCH TASK FORCE (RTF) of Model Validation Group of Basel Committee in the "Studies on the Validation of Internal Rating Systems" :
- " A key result of the first stage was that statistical tests are less meaningful to validate PD estimation than they are in the case of internal market risk models. Therefore, back testing based on statistical tests is generally not powerful enough to determine if an internal rating system is acceptable. Consequently, the focus of the project was extended to benchmarking."
- Benchmarking is aimed to see/test the alignment of the rating grades resulted from internal model to external/benchmark model
- The statistics used to measure the alignment is Kendall's t and Somers' D. These are known as rank order statistics (i.e. non-parametric correlation measures)

If (X,Y) is a pair of random variables, Kendall's τ is defined by

$$\tau_{XY} = P(X_1 < X_2, Y_1 < Y_2) + P(X_1 > X_2, Y_1 > Y_2) - P(X_1 < X_2, Y_1 > Y_2) - P(X_1 > X_2, Y_1 < Y_2),$$

and Somers' D

$$D_{XY} = \frac{\tau_{XY}}{\tau_{YY}}$$



- Somers' D statistics can yield a result equal to the Accuracy Ratio (AR) from CAP curve.

LGD/EAD Validation
Scope of the Validation

		Objective	Standard
Qualitative - Model Design	Model database	• Description of development and validation samples • Separation of default and loss dimensions	• Identification of representative out of sample validation set • appropriateness of any segmentations and filters • default and loss definitions • default weighted averages
	Documentation standards	• Completeness • structured approach • relevance	
	Model structure	• Plausibility of modeling approach	• description of identified loss drivers • adherence to conservative principle • developmental evidence on estimations
Quantitative - calibration	• accuracy of downturn estimates • TTC conservatism		• accuracy: two-sided test applied to mean and median error to establish whether estimates are accurate in times of downturn • degree of conservatism: one-sided test applied to mean and median error to establish whether realizations through the cycle are above estimates • correlation of estimates to economic cycle

LGD/EAD Validation
Statistical Test

- One of the findings of RESEARCH TASK FORCE (RTF) of Model Validation Group of Basel Committee in the "Studies on the Validation of Internal Rating Systems" :

" The studies find that a qualitative assessment of bank's LGD estimation process may be more meaningful validation method than the use of quantitative methods, and provides guidance on the components such an assessment process"

" The obstacle that impede the validation of LGD are also presented when EAD is estimated and validated"

- Based on our previous experience on LGD/EAD validation, the quantitative aspect of the validation only covers 2 main aspects:
  1. Estimates need to be accurate for times of economic downturn if expected or proven to exhibit cyclical behavior
  2. Estimates need to be conservative in normal and benign periods

- Standard Statistical test for mean/median have been applied to test both hypothesis above.

LGD/EAD Validation
Statistical Test

- Define that: $Error = \Pr edicted - Actual$

- One sided test on the conservatism hypothesis for TTC calibration:

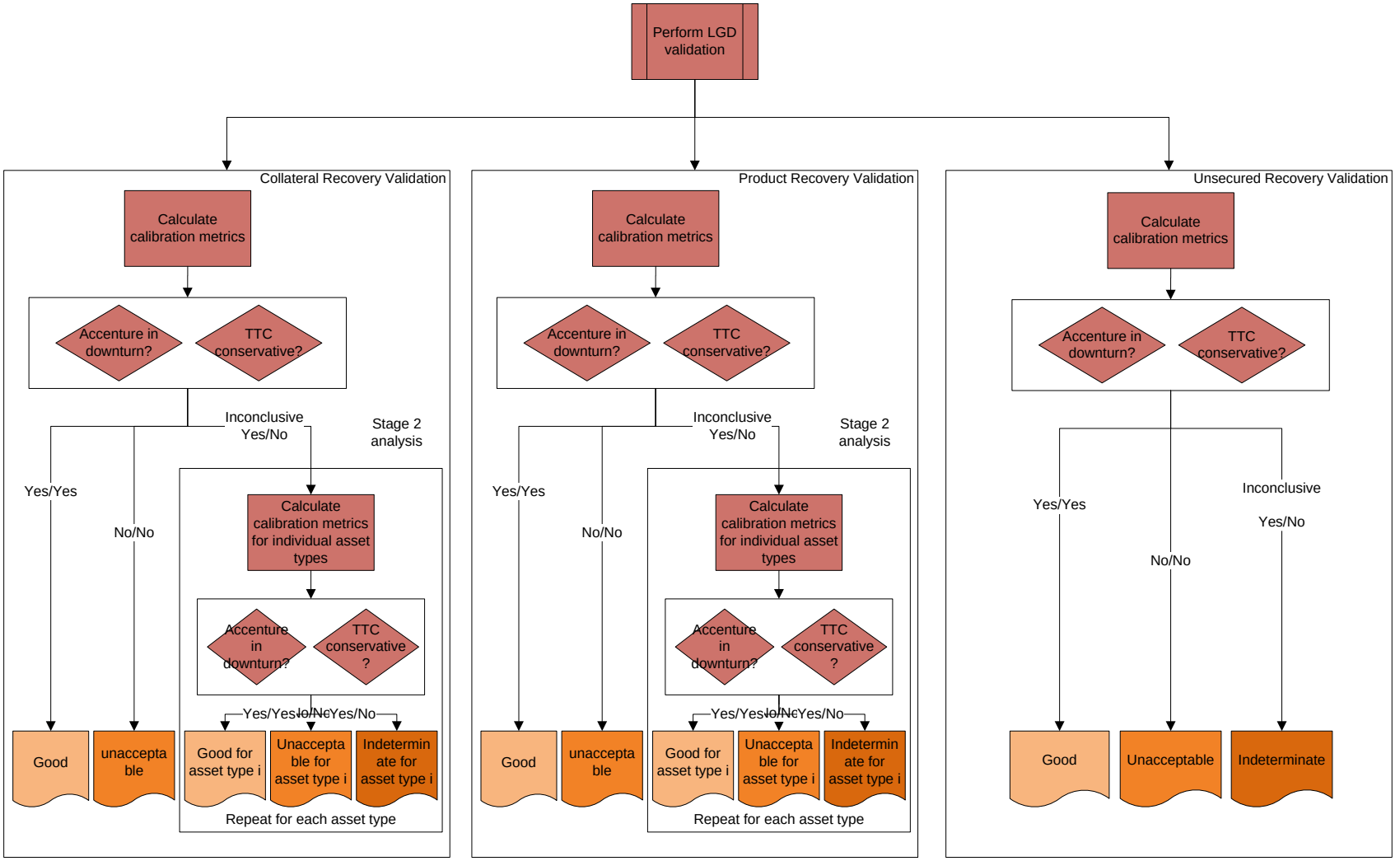
$$H0: \quad Error = 0$$
$$H1: \quad Error < 0$$

- Downturn accuracy is assessed by the following standard two sided test for the crisis year averages :

$$H0: \quad Error = 0$$
$$H1: \quad Error \neq 0$$

- While the test can be conducted in Parametric test via t-test (for the sample mean), or Non-parametric test, via Sign test (for the sample median)

Example
LGD Validation



Example
EAD Validation