Model Risk and Importance of Validation

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Abstract

The article focuses on presenting the evolution of the credit risk modelling and practices as well as sets supervisory expectations around the validation of the models build in accordance with the expectations set by the Basel Accords (Basel I, Basel II and Basel III) or the more recent International Financial Reporting Standard 9 Financial instruments (IFRS 9) and Basel III: finalizing post crisis reforms as well as the importance of model risk and model risk management.

Since the introduction of the Basel requirements, the evolution of quantitative models was driven by regulatory expectations and framework id est (i.e.) financial institution's choice to apply the Internal Rating Based (IRB) approach: foundation or advanced for credit risk, market risk or for operational risk.

The IFRS 9 standard requires institutions to use of more advanced modelling techniques in order to be able to estimate both 12 months and lifetime credit losses. The new expected loss model requires financial institutions to ensure more collaboration between the different departments, in comparison to the IAS 39 (International Accounting Standard 39) where the expected credit loss (ECL) computation is no longer the sole responsibility of the finance or accounting department instead, it requires using the input and collaboration of several stakeholders. For example, accounting, risk, macroeconomic departments (if they used in the forecast of macroeconomic conditions) Treasury, IT etc. in order to produce the IFRS 9 outputs.

Given the arguments presented above, we consider this article can be used by a large range of stakeholders such as financial institutions (board of directors, internal audit, the validation function), external auditors or supervisors to understand the importance of model risk and model risk management in the decision-making process to assess the impact on the accuracy of the model's outputs and their limitations.

Keywords

Model risk, Basel, IFRS 9, resilience, strategy, financial crisis
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Introduction

The 2008 crisis has shifted the focus of both academia and supervisors from a decentralized approach of developing, monitoring and assessing models to an integrated approach, based on model risk management. The new view proposes a more risk-sensitive approach towards the quantification, validation and assessment of models and model risk in financial institutions.

Following the 2008 financial crisis, the International Accounting Standards Board (IASB) issued in 2014 the complete version of the International Financial Reporting Standard 9 (IFRS 9) "Financial instruments", which is expected to address the shortcomings of the International Accounting Standard 39 "Financial instruments: Recognition and Measurement" (IAS 39). The IAS 39 standard required "Incurred Credit Losses" to be estimated however in practice this was found to lead to a "too little too late" approach to credit loss provisioning leading financial institutions to be underprovided for to withstand the financial crisis. IFRS 9 seeks to address these shortcomings by requiring institutions to estimate expected credit losses incorporating forward-looking information. The IFRS9 standard came to force starting 1 January 2018.

The paper begins by outlining the evolution of Credit Risk Models, starting with the Basel requirements and focuses on identifying the organizational structure required to ensure an adequate impairment estimation framework is set up. Furthermore, it highlights the concerns around the impact of inadequate models over the institution profitability through model risk management.

From an academic perspective, Derman (1996) defines model risk from a market risk rather than a credit perspective as the risk of using assumptions that are not plausible or realistic. Furthermore, Kato and Yoshida (2000) define and classify model risk by distinguish between market and credit risk models i.e., the risk the market risk model does not accurately assess the price of securities and the risk that the credit risk model does not accurately assess future losses. In addition, Rebonato (2003) considers model risk from a market risk perspective, the focus on being assessment the variability of the assumptions used across institutions; this variability across market participants can lead to large differences between the mark to market models, hence the values/prices of the securities would differ significantly. He also presents the main elements of model risk referring to operational errors, the use of unrealistic assumptions, sudden changes in market conditions that could not be predicted or incorporated in the models. More recently, Morini (2011) noticed that during and following crises, institutions tend to use more simple models which would include the most recent stress conditions within the assumptions used for modelling purposes.

Literature review

Regulatory frameworks interaction - Basel requirements vs IFRS9

The economic environment is characterized by an asymmetrical distribution of information and constraints impact both corporate governance and risk management of the financial institution. Hence the regulations around models and risk management aim on ensuring the models' outputs are reliable and adequately understood due to the increase of the reliance of quantitative models, which results in the decrease of model risk.

The paper discusses the development of risk management and its role in capital and impairment estimation. The evolution of the credit risk modelling practices is marked by the following milestones: Basel I; Basel II; the 2008 financial crisis, ***Basel III*** and its update and ***IFRS 9***.

The Basel Accord has set up the basis for the prudential supervision by bringing risk assessment, measurement and modelling to the focus of the supervisor's attention. Ever since the drafting of the fist Basel accords it was linked to the evolution of prudential supervision i.e., during the early 1990s, supervisors emphasize market risk and trading portfolios with the amendment in 1996 of the first Basel accord. The second and third Basel Accord has put more emphasis on credit risk and operational risk. In more recent years of the post-crisis reform, i.e., Basel III: Completing post-crisis reforms continues to provide more risk-sensitive solutions to account for the lessons learned during the 2008 financial crisis i.e., providing further clarifications for the modelling requirements and expectations for credit risk, counterparty credit risk, market risk and operational risk.

Among the first models developed and used are pricing models Black and Scholes (1973) option pricing model which considered volatility skew. Adrian and Shin (2008) research focuses on making the assessment of relevant key indicators before and during the 2008-2009 financial crisis. During this period, the financial institution's behavior changes i.e., the risk and leverage indicators increased as

asset prices rose, this led to the institutions having to actively managed and adjusting their balance sheet in order to remain complaint with their internal limits while trying to mitigate the volatility of asset prices. In more recent years, Le Leslé and Avramova (2012) conclude that modelling choices affect the institutions' incentives in the choice of assets i.e., the trade-off between assets carrying a low-risk weight ensuring a strong capital ratio and assets which would have high returns hence high-risk weights due to their increased risk.

The use of models has always been on the agenda of the regulatory and supervisory bodies. One of the proposed solutions to mitigate the risk of having different capitalization for financial institutions bearing similar risks is the use of more straightforward and convergent modelling methodologies as proposed under the Basel III Accord as well as the European Banking Authority (EBA) guidelines. The aforementioned guidance fosters and intends to ensure convergence of the modelling methodologies used across the institutions i.e., the computation of regulatory capital, economic capital, stress testing, impairment, however as there is less stringent guidelines on the IFRS 9 calibration process, initial results highlight that this might not have achieved in practice. Supervisors expect that the models are tailored to the institution's specificities and are risk sensitive. From a supervisory perspective, the convergence of the outputs is desired in order to allow supervisors to understand the reasons behind the variability of results i.e., the differences in the key risk drivers in the riskiness imbedded in the institution' portfolios e.g., loan to vale, days past due, restructuring profiles, geographical distribution and not only the use of a less conservative methodology.

Historically, regulation and supervisory actions have followed the economic cycle, hence in the aftermath of the 2008 crisis the supervisory policy and guidance improved by focusing on enhancing the transparency and ensuring the model outputs are understood by all relevant stakeholders. Furthermore, supervisors want to ensure level playing field across different jurisdictions hence rely on common methodological expectations and guidance given the increase of the role of models in computing capital requirements and impairment.

Basel I set the foundations of the risk framework, even though it was simplistic and risk insensitive.

It introduced the "sandbox" concept i.e., limits in line to the financial institution's risk appetite. This was mostly seen as a reporting requirement and often left in charge of the accounting function which monitored the limits and took actions to ensure they remained within the pre-defined thresholds.

Under Basel I the risk and financial functions worked independently as its requirements were risk insensitive.

Financial institutions had to respond to a challenging environment with complex and evolving financial productions which required the managing of the economic risks included in the risk adjusted profitability metrics (risk adjusted return on capital – RAROC). These models were built using value at risk metrics and were often included in the risk appetite frameworks of the institutions.

After the introduction of Basel I, the risk and accounting functions were working independently and there was no real intent to work towards the convergence of the accounting and risk data.

The critical moment in the development of risk models was the introduction of the Basel II requirements. The Internal Rating Based (IRB) approach ensured the Pillar 1 capital requirements became risk-sensitive and specific to the risk profile of each financial institution. Furthermore, by defining the Pillar II and the Internal Capital Adequacy Assessment Process (ICAAP) the updated supervisors require institution to develop models that capture both normative and economic perspective of the capital needs ensuring that the two perspective inform each-other. This change made the risk and accounting functions to collaborate to ensure both economic capital and regulatory capital requirements are always met. Furthermore, institutions started aim to factor the capital impact in their pricing strategies and ensure they remain compliant both from an economic and normative perspective. However, no consistency was ensured between capital planning and economic and regulatory capital requirements.

The lack of integration between the strategy, finance and risk areas lead to financial institutions taking risk above the acceptable risk levels.

The supervisory reaction to the 2008 financial crisis led to the development of the Basel III and Basel III completing post-crisis reforms which provide more guidance on the requirements set up by Basel II, without having a significant impact on modelling techniques.

Furthermore, from an accounting perspective the IFRS 9 standard was introduced to share a new perspective of the impairment modelling practices. The standard requires the impairment models to be risk sensitive, based on economic forecasts, considering multiple scenarios and ensuring the accounting and risk functions interact in order to capture the entire suite of risks faced by the institutions concerning its exposure to credit losses. The expectation is that the IFRS 9 model interacts with the stress testing, budgeting, economic capital and regulatory capital frameworks.

The regulatory and accounting changes have led to organizational changes to support the processes i.e., integration between the risk, finance and strategy functions, this dissolved the traditional boundaries, in order to enable an integrated risk framework and capital management.

In the post-crisis global environment, where financial institutions operate across multiple regions and business lines, this approach allows financial institutions to benefit from an integrated risk framework and become more risk resilient. Under this framework, the business functions help identify and capture synergies among the financial institution's different business units while the risk function also makes sure that economic and regulatory capital are calculated consistently by the institution.

Research methodology

One of the first research techniques used for the purpose of this article is the literature review. This was carried out by reviewing previous studies such as the results of academic papers as well as the research and guidance presented by the International Accounting Standard Board, the European Banking Authority, the European Central Bank or the Federal Reserve Board in order to understand what the model limitations and their implications on the macro-economy are as well as on an idiosyncratic basis. Furthermore, the authors have used the previous research and guidance to understand the current requirements and expectations set around models and model management as well as to form a view on the limitations of the current framework.

Following the research and information stage, the authors focused on providing a discussion using qualitative methods. The study focuses on presenting the results of the outcome of the data collection i.e., focus group and one to one interview with experts in model risk from various countries i.e., named the outcome of the review of 28 experts carried out between May-August 2020 as presented in Table 1 below:

Table no 1. List of experts interviewed for the IFRS 9 assessment

Experience/ Field of expertise	Number of experts
Over 15 years	13
External Audit	1
Accounting	4
Validation	3
Internal Audit	5
Between 11-15 years	5
External Audit	1
Accounting	2

Validation	1
Internal Audit	1
Between 5-10 years	8
External Audit	4
Accounting	1
Validation	2
Internal Audit	1
Less than 5 years	2
External Audit	1
Validation	1
Total	28

Source: Authors' processing 2021

However, from the 28 persons which were initially selected for the scope of the interviews/focus groups, only 25 have accepted and communicated their views with the authors.

As part of the research the following questions have been addressed:

Question 1: "Do you consider that the corporate governance arrangements have changed significantly over the last 10-15 years?"

Question 2: "Do you consider that model validation and model risk should be the focus of corporate governance over the next few years?"

Question 3: "Do you consider that there is a stronger connection between the accounting and the risk functions?"

Question 4: "Have you identified significant synergies between the IRB and IFRS 9 models?"

Question 5: "Do you consider that you need additional guidance/supervisory expectations on the treatment of model risk?"

Overall, the role of this qualitative research was to attempt to understand first-hand the impact that models and model management have on the financial institutions. The views of the different professionals have been used to inform the results and discussion section presented below.

Results and discussions

This section of the paper aims at bringing together the information obtained first-hand from practitioners on the impact that models and model management have on the financial institutions. The views of the different professionals have been used to inform the results and discussion section presented below.

Model risk management and the importance of validation in the IFRS 9 context

Financial institutions are considered riskier than other market participants due to their risk-taking activity. The presence of securitizations, asset-back securities, derivatives, financial instruments with embedded optimality expose the institutions to higher risks coming from changes in market conditions; furthermore, due to their broad range of internal and external stakeholders their failure would have a high impact over the entire economy as shown by the 2008 crisis. Furthermore, the institutions' risk increases with the use of more complex models (credit, market or operational risk models) used under the Basel II requirements for the computation of Pillar 1 requirements or, more recently the models used for the computation of impairment losses under the IFRS 9 standard.

The 2008 crisis revealed that senior executives and the management body (board of directors and supervisory committee) possess a limited understanding of the complex risk models in place in their institutions. Hence, as a response to the failure of financial institutions worldwide, corporate governance become the target of both academia and supervisors i.e., the general consensus was that, in order to better quantify the risks faced by financial institutions corporate governance and risk management should be integrated into decision making process.

More specifically, under IFRS 9 model risk arises from either data errors, methodology or assumptions used. The institution could lack sufficient or accurate historical data used for the computation of the key model components i.e., conditional probability of default (PD) and loss given default (LGD) parameters. The forward-looking information used in the estimations might not be representative for the external forecasts (in the case of institutions developing internal estimates). Furthermore, the forecasted elements could lack representativeness for the current and future behavior of the portfolio.

In recent years, supervisors developed guidelines and started setting expectations underpinning the processes and the responsibilities decisions taking in financial institutions, in particular those linked to risk related activities and models in order to ensure the resilience of financial institutions to the complexity of models.

As such, many of the models used by the institutions (additional to the regulatory capital models) are used for managing daily business needs; this includes pricing, strategic planning, asset-liquidity management, impairment computation or capital planning including stress testing.

Hence, the direction is towards implementing an integrated process ensuring the roles and responsibilities are set up clearly, for both development and validation of models according to minimum quality standards. The aim was to ensure the independence between the model development and validation phases, and that the senior executives and management body, understand the limitations of the models and assume them by challenging and approving the models for use.

The Federal Reserve Board set up one of the first supervisory expectations for Model Risk Management (MRM) in 2000 though the SR 11-7 regulation which outlined requirements for model development, validation and governance in order to ensure the robustness of the process. Adequate MRM implies building, implementing a robust model which is used in practice and a sound model validation process to assess the ongoing adequacy of the model outputs. As such, its core is an adequate internal governance structure that sets up a practical framework with defined roles and responsibilities for model development, validation, as well as the identification of model limitations around assumptions and methodologies used. Furthermore, the governance structure should ensure the adequate management bodies have the authority to restrict model usage.

In the European Union among the first legislations that made reference to MRM are the Capital requirements directives (CRD II) and the Capital requirements regulation (CRR IV) in 2013. Hence, financial institutions subject to the CRR and CRD requirements, started assessing and including model risk as part of their operational risk capital quantification. In accordance with articles 3.1.11. and article 85: “institutions manage and implement policies and processes to evaluate the exposure to Model Risk as part of the Operational Risk”.

Furthermore, the European Central Bank and the European banking authority have defined MRM through the Supervisory Review and Evaluation process (SREP). Model risk is an integrant part of SREP assessment though which, among other supervisors assess the institution’s exposure to model risk arising from the use of internal models across its business lines and operations. Particular focuses on being placed to the extent and purpose of the models used as well as their role in making decisions process i.e., integration across risk, accounting, business strategy, pricing strategies. From a regulatory perspective, supervisors assess the extent to which the Management Body and Senior Management understand the limitations and challenge the use of models. The EBA SREP Guidelines define model risk from two perspective depending on the area impacts:

- From a capital perspective, model risk could relate to the underestimation of own funds requirements through the use of regulatory approved models which show deterioration signs

i.e., from this perspective, model risk is addressed through the incorporation of overlays or margin or conservative in the specific risks to capital assessments (exempli gratia (e.g.) the IRB PD and LGD model deficiency are addressed as part of the credit risk assessment);

- From a profit and loss perspective, model risk is related to have poor implementation or improper use of all other models (except the regulatory approved models) deployed by the institution for decision-making purposes (e.g., pricing, evaluation of marketable financial instruments, computation and allocation of economic capital, monitoring of risk limits, etc.). From this perspective the risk is assessed as part of operational risk, hence any deficiencies and limitations should be quantified from the point of view of additional losses that the use of inappropriate models can generate.

In accordance with the above presented guidelines, expectations and regulations, the MRM framework is expected to include at a minimum a complete model inventory that allows the institution to have a holistic view of the risks faced through the use of models as well as the estimate possible impacts due to the shortcomings or misuse of models. Furthermore, it should establish mitigating actions to address the uncertainty and model deficiencies and limitations. This process should be surrounded by a strong governance framework which has clearly defined roles and responsibilities, as well as policies, procedures to formalize the process.

Model risk management and IFRS 9 – through the eyes of stakeholders

The authors have carried out a study on IFRS 9 and model validation consisting of 5 questions on a total sample of 28 participants, of which only 25 answers were provided to the assessment team. The aim of the survey was to understand the implications of the IFRS 9 standard introduction and model risk management as seen through practitioner's eyes.

Overall, 22 of the 25 participants to our study considered that the corporate governance arrangements significantly changed over the last 15 years, with the 2008 financial crisis having the most significant impact. When discussing more in detail the modelling assumptions and expectations around models 3 of them considered worth mentioning that while the 2008 financial crisis could have been predicted (as an end tail event) and considered as part of the unexpected loss estimates, the sanitary crisis noticed in 2020 because of to the coronavirus would have been more difficult to predict. While such events could happen, they were the view that its impact is difficult to be assessed especially from the loss perspective (expected and unexpected), given the significant governmental support observed across the European Union.

Their answers represented the natural transition from appreciating the significant efforts carried by the European Union and the Unites States supervisors to ensure that model governance is adequately implemented to try to avoid the "too little too late" effect noticed in the 2008 crisis.

From the 25 participants 20 consider that the corporate governance arrangements around model validation and model risk should beneficiate from increase focus, the arguments provided being: the increased role of models in order to improve profitability as well as to incorporate the outcome of a risk-based assessment into pricing strategies, loan origination (granting process), resource management (allocation of funds to the most profitable lines of business).

When discussing about the connection/ interconnectivity of the accounting and risk functions in the context of IFRS 9 only 16 of the 25 participants considered that the role and synergies between the different departments of the financial institutions have increased, with 7 participants disagreeing with the statement, in their view – IFRS 9 has additionally introduced complexities to models and poses significant limitations both from a modelling and from a validation point of view. The main challenges mentioned were: the estimation of lifetime losses – significant concerns over the use of limited data and poor modeling capacities, complex methods which increase model error, inconsistencies between the IFRS 9 models and the economic capital models or IRB models used in the estimation of capital needs.

Considering the models used for IRB purposes as the most frequent used models before the implementation of IFRS 9, participants were required to express their view on the existence of

synergies between the IFRS 9 and IRB model. There is a strong agreement (23 participants) that there are significant synergies between the IFRS 9 and IRB models. The following elements have been brought up: the use of the same definition of default, the adjustment of the long run average probability of default to the point in time philosophy, the move from a downturn loss given default estimate to a point in time assessment. In addition, institutions that already had in place a robust stress testing framework the macroeconomic variables forecasted/used in the generation of the stress losses can be adapted to meet the IFRS 9 criteria.

From the current state of the available guidance and legislation the authors wanted to understand if the participants consider that there is need for additional guidance around model risk management. The majority (23 participants) would welcome additional guidance especially around the way the true and fair view of the financial statements could be ensured when significant management overlays need to be applied as the models are not able to capture external events for example the coronavirus impact. Another issue raised was the lack of clear guidance around the incorporation of lifetime macro-variables, namely in the context of volatility and timing of default recognition.

Overall based on the interviews carried out, the authors compiled some suggestions around the way IFRS 9 governance arrangements are expected to be implemented in financial institutions. The suggestions are presented in the next section.

IFRS 9 governance arrangements

In 2012 the Basel Committee for Banking Supervision presented its expectations around governance arrangements in relation to the review and control process i.e., the three lines of model defense:

- the first line of defense - represents should set up controls performed by the business-owner within the business unit primarily responsible for the process;
- the second line of defense is ensured by an independent unit within the institution assessing if the first line's review has been adequately performed in order to identify, followed up and resolve the identified issues;
- the third line of defense usually performed by internal audit ensuring that the processes through which the first and second line operate are appropriately defined, have no material gaps and are adhered to in practice.

The IFRS 9 standard does not prescribe requirements for the validation of the models used in the expected loss calculation, hence the institutions must rely on the more specific guidance issued by Basel Committee on Banking Supervision (BCBS), 2006 and EBA, 2007 for the validation of the models used in the Basel requirements capital calculations. Furthermore, specific guidance for the IFRS 9 standard has been issued by the EBA in the Guidelines on credit institutions' credit risk management practices and accounting for expected credit losses.

The following suggestions and recommendations with regard to the governance arrangements and parameter refinement are proposed in line with the guidance and comments received from the participants to our survey.

In order to ensure an adequate computation of the ECL the financial institutions must set in place adequate governance arrangements where data and model governance, including sound development, validation and back-testing process are the building blocks of an appropriate ECL framework.

Where possible, financial institutions have leveraged on existing process i.e., forecasting, stress testing and regulatory capital functions.

The ECL process should ensure an appropriate segregation of duties i.e., model development and model validation should be independent functions, furthermore internal audit should be reviewing the process.

The risk function is expected to be in charge of the quantitative models used for estimation of the probability of default (PD), Loss given default (LGD), Exposure at default (EAD) and ensures they are

continually refreshed in order to comply with the point in time criteria by incorporating the adequate forward-looking information and forecasts and most recent available information.

Following the development or refresh of a model, a thorough validation process should be carried by the validation department (independent to the model development team). After obtaining reasonable assurance the chief risk officer should be providing the sign-off of the ECL.

After the modelling process is complete, the accounting department is expected to assure that the output is in compliant with the accounting principles and required financial disclosures. Once these requirements are ensured, the chief risk officer should provide it is sign off. Following this process, the ECL estimates should be further discussed at board level as well as by the credit, risk and audit committees. Another option for the latter governance structure is the development of joint credit, risk and audit committee sessions to discuss and oversee impairment (ECL) results.

Following the assessment of the board committees, the management can propose overlays to address specific shortcoming and are based on objective assumptions, given the use of point in time estimated leads to pro-cyclicality, hence management's actions would try to reduce the pro-cyclicality of the models by proposing overlays.

Hence the financial institutions should ensure the finance and risk functions work together to understand the need of such overlays and try to integrate them within the models.

At least on a quarterly basis the accounting and risk functions should analyze and assess if there have been any significant changes that should be considered in the models e.g., the macroeconomic environment shows signs of distress, the structure and profile/riskiness of the portfolio changed. More frequent reviews are expected in case there are significant changes in the macroeconomic conditions or in the profile of the institution.

Furthermore, back-testing as well as sensitivity analysis should be considered in the refresh model of the models on individual parameters as well as the ECL output. During this process is expected that institutions refresh at least:

- the unconditional PDs to incorporate new obligor-specific information;
- the LGD parameters to factor new closed recovery cases and re-assess the outcome of the incomplete population;
- the macroeconomic explanatory variables required used in the computation of conditional PDs, LGDs and EADs;
- compute the 12 months and lifetime ECL based on the updated parameters.

Conclusions

The paper presents the evolution of the credit risk modelling practices and supervisory expectations starting with the Basel Accords (Basel I, Basel II and Basel II) and moves to the more recent IFRS 9 standard and Basel III completing post crisis reforms as well as the importance of model risk and model risk management.

IFRS 9 has seen as significant improvement in the accounting world as it changed how prospective losses are recognized to address the shortcomings witnessed in the last financial crisis i.e., a move from the incurred loss model as previously depicted by IAS 39 to an expected loss model factoring all available information at the point of the assessment (including forward looking data) under IFRS 9. The use of forecasted information and expected lifetime losses should overcome the weaknesses of IAS 39 and prevent the "too little too late" recognition of impairment which led to the beginning of the 2008 financial crisis.

The journey started with the introduction of the Basel I Accord and the emergence of the risk compliance function. The risk function and its ramifications (model development, validation) started playing a critical role with the introduction of the Basel II requirements as the normative capital requirements started informing pricing and business decisions.

Another milestone was the introduction of IFRS 9 which intended to ensure the impairment models forward looking and risk sensitive by linking the finance data to the risk information.

The IFRS9 standard intends to align the practices within the financial institutions and create synergies between the computation of the expected credit losses, unexpected losses i.e., the Basel Pillar 1 (normative capital) and Pillar 2 (economic capital) stress testing and recovery planning.

As the introduction of IFRS 9 has led to increased emphasis on the reliance of Credit Risk Models for loan loss provision estimation and required increased cross functional collaboration institutions must focuses on obtaining model risk management to ensure model deficiencies are identified and clearly understood within the organization.

References

Adrian, T. and Shin, H.S., 2008. Liquidity, Monetary Policy and Financial Cycles. *Current Issues in Economics and Finance*, 14(1), pp.1-7.

Basel Committee on Banking Supervision, 1988. *International Convergence of Capital Measurement and Capital Standards*, [online] Available at: <http://www.bis.org/publ/bcbs04a.htm> [Accessed 15 January 2021].

Basel Committee on Banking Supervision, 2005a. *International Convergence of Capital Measurement and Capital Standards: A Revised Framework, BIS, Updated November 2005,* [online] Available at: <http://www.bis.org/publ/bcbs107.htm> [Accessed 26 January 2021].

Basel Committee on Banking Supervision, 2005b. *Validation, Newsletter No. 4,* [online] Available at: <http://www.bis-org/publ/bcbs_nl4.htm> [Accessed 13 February 2021].

Basel Committee on Banking Supervision, 2015. *Guidance on credit risk and accounting for expected credit losses*. [pdf] Available at: <https://www.bis.org/bcbs/publ/d350.pdf> [Accessed 28 February 2021].

Basel Committee on Banking Supervision, 2017. *Basel III: Finalising post-crisis reforms*, [online] Available at: <https://www.bis.org/bcbs/publ/d424.htm> [Accessed 9 March 2021].

Black, F. and Scholes, M., 1973. The University of Chicago Press. *The Journal of Political Economy*, 81(3), pp.637-654.

Board of Governors of the Federal Reserve System, 2011. Office of the Comptroller of the Currency, Guidance on model risk management, *SR Letter,* 11(7), pp.1-21.

Derman, E., 1996. *Model Risk. Technical Report*. Goldman Sachs New York. [pdf] Available at: <http://pricing.online.fr/docs/model_risk.pdf> [Accessed 10 February 2021].

European Banking Authority, 2017. *Guidelines on credit institutions' credit risk management practices and accounting for expected credit losses*. [pdf] Available at: <https://www.eba.europa.eu/sites/default/documents/files/documents/10180/1842525/d769d006-d992-4202-8838-711a034e80a2/Final%20Guidelines%20on%20Accounting%20for%20Expected%20Credit%20Losses%20%28EBA-GL-2017-06%29.pdf> [Accessed 12 February 2021].

European Banking Authority, 2017. *Guidelines on PD estimation, LGD estimation and the treatment of defaulted exposures.* [pdf] Available at: <https://www.eba.europa.eu/sites/default/documents/files/documents/10180/2033363/6b062012-

45d6-4655-af04-801d26493ed0/Guidelines%20on%20PD%20and%20LGD%20estimation%20%28EBA-GL-2017-16%29.pdf?retry=1> [Accessed 17 January 2021].

European Banking Authority, 2016. *Guidelines on the application of the definition of default under Article 178 of Regulation (EU) No 575/2013*. [pdf] Available at: <https://www.eba.europa.eu/sites/default/documents/files/documents/10180/1721448/052c260f-da9a-4c86-8f0a-09a1d8ae56e7/Guidelines%20on%20default%20definition%20%28EBA-GL-2016-07%29_EN.pdf?retry=1> [Accessed 9 February 2021].

European Banking Authority, 2018. *Guidelines on the revised common procedures and methodologies for the supervisory review and evaluation process (SREP) and supervisory stress testing*. [pdf] Available at: <https://www.eba.europa.eu/sites/default/documents/files/documents/10180/935249/4b842c7e-3294-4947-94cd-ad7f94405d66/EBA-GL-2014-13%20%28Guidelines%20on%20SREP%20methodologies%20and%20processes%29.pdf?retry=1> [Accessed 15 February 2021].

European Central Bank, 2017. *Guidance to banks on non-performing loans*. [pdf] Available at: < https://www.bankingsupervision.europa.eu/ecb/pub/pdf/guidance_on_npl.en.pdf > [Accessed 4 March 2021].

European Commission, 2013. *Regulation (EU) No 575/2013 of the European Parliament and of the Council of 26 June 2013 on prudential requirements for credit institutions and investment firms and amending Regulation (EU)* No 648/2012, [online] Available at: <https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:32013R0575> [Accessed 17 February 2021].

European Commission, 2013. *Directive 2013/36/EU of the European Parliament and of the Council of 26 June 2013 on access to the activity of credit institutions and the prudential supervision of credit institutions and investment firms, amending Directive 2002/87/EC and repealing Directives 2006/48/EC and 2006/49/EC*, [online] Available at: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32013L0036> [Accessed 12 April 2021].

International accounting standards Board, 2014. *International Financial reporting standard 9 Financial Instruments*. [pdf] Available at: <https://www.iasplus.com/en/standards/ifrs/ifrs9> [Accessed 3 March 2021].

Kato, T. and Yoshida, T.,2000. Model Risk and its Control. *Monetary and Economic Studies*, pp.129-151.

Le Lesle, V. and Avramova, S., 2012. Revisiting Risk-Weighted Assets. *IMF Working Paper*, 12(90), pp.4-36.

Morini M., 2011. *Understanding and managing model risk: a practical guide for quants, traders and validators*. Chichester: Wiley.

Rebonato, R., 2003. Theory and Practice of Model Risk Management. *Quantitative Research Centre (QUARC) of the Royal Bank of Scotland Oxford Financial Research Centre – Oxford University*, pp.1-11.