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Quantifying Model Risk

Issues and approaches to measure and assess model risk when building quant models

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Executive Summary

With model failures leading to some high-profile financial accidents in the past few years, there has been a renewed emphasis to systematically address model risk in the last few years. Regulatory agencies have issued guidance documents and various organizations including QuantUniversity are offering model review and validation services to assist organizations to comprehensively manage model risk for their quantitative models. With the financial industry heavily relying on quantitative models and with serious repercussions of model failures, it has become essential that organizations prioritize model risk management. Companies are recognizing the need to develop robust processes to address various aspects of risk evolving from the use and deployment of their quantitative models. Though, a lot has been written about model risk management, few discuss practical tools quants could use to measure and assess model risk as a part of the quant development process. In many of the consulting projects we have worked on, model risk management is typically an afterthought usually delegated to the risk organization after quants have completed their development work. This "handoff" increases the possibility of model failures and the consequences could be too acute to remedy. At QuantUniversity, we believe that measurement and assessment of model risk should be an integral part of the quant development process. In this article, we outline some of the tools quants could use to integrate measurement and assessment of model risk as a part of their development process. We start out by orienting quants on model risk and discuss drivers that have brought model risk into the limelight. We then discuss challenges quants have in integrating model risk into the quant development process and introduce practical tools quants can use to quantify model risk, build control measures to manage and prioritize these risks.

Model Risk:

Quantitative models are in the critical path of decision making for various organizations today. In the areas of trading, risk management, credit-rating, asset management quantitative models are in the heart of many processes and any malfunction or failure in models can lead to reputation risk, huge opportunity costs and/or financial losses. As more and more organizations rely on quantitative models for decision making, it is important to ensure that the models perform as per design. The Federal Reserve and Office of the Comptroller of the Currency (OCC) issued a Supervisory Guidance on Model Risk Management [1] for banks to assess model risk. In this note, they define a model as

" A quantitative method, system, or approach that applies statistical, economic, financial, or mathematical theories, techniques, and assumptions to process input data into quantitative estimates."

They note that model risk occurs if the models have fundamental errors and produce inaccurate outputs or if a model is used incorrectly or inappropriately. The note further elaborates what is expected of supervisors and organizations in managing model risk. Recently, we have seen a significant increase in organizations taking up model risk management initiatives. Let's discuss some drivers for this emphasis on model risk.

Drivers to address model risk:

1. Increase in the sophistication and reliance on quantitative models:

Advances in computing technology, faster networks and connectivity and maturing of quantitative technologies have led to a significant increase in using quantitative models in the financial industry. Advances in financial engineering has led to newer and sophisticated financial products that cannot be constructed and used without the help of quantitative models and analytics. As the reliance on these models have increased, risk departments have started to recognize the importance of managing the risk due to the use of quantitative models in organizations. Robust software development practices and security protocols are being established and control mechanisms are being put in place to manage model risk.

2. Regulation:

With the financial crisis of 2008, regulators are sensing an urgent need to address model risk management and there have been many key initiatives towards facilitating this. The Dodd Frank Act, Basel and the Solvency frameworks explicitly address model risk and validation issues that have required banks and insurance companies to institute processes to manage model risk and develop comprehensive model risk management frameworks. As noted earlier, the Federal Reserve and Office of the Comptroller of the Currency (OCC) saw the need to issue Supervisory Guidance on Model Risk Management [1] that discusses model development, implementation, use, validation, governance etc. in significant detail. With stakes so high and with bitter lessons learnt during the financial crisis, there is increasing regulatory oversight to ensure that the stability of the financial system and this oversight is expected to increase in the future. However it should be noted that despite regulatory efforts and guidance, organizations are still facing practical challenges in comprehensively establishing a model risk management framework. For example, FSA's Internal Model Approval Process Thematic review [5] discusses some of the issues and challenges faced by organizations in adopting the Solvency II framework requirements.

3. Financial accidents:

In the recent past, we have seen many instances where model risk has led to devastating outcomes for organizations. For instance, S&P disclosed errors in their rating models [2] and has faced severe criticism for their ratings approach during the financial crisis. Knight Capital suffered a $457.5 million loss due to a software error [3] and Goldman Sachs issues erroneous options orders due to a software bug that cost the firm millions of dollars [4]. Note that these are reputed players in the financial industry but still had to face enormous consequences both financially and with their reputation. With high-frequency trading constituting more than 70% of the equity trades in the US, it is practically impossible for humans to intervene and plug damage when millions of trades are executed in a matter of seconds. The magnitude and impact erroneous models can cost has alerted the financial industry to be serious about addressing and instituting processes to manage model risk.

4. Competitive advantage:

Many organizations, especially trading firms use quantitative models as a key competitive advantage in leveraging opportunities in the market. In domains such as algorithmic trading, automated models rely on fast algorithms to quickly take trading decisions capturing opportunities in sub-seconds while competing with other market participants. Speed and efficiency are important and companies spend significant time in optimizing algorithms before they are deployed in production. In certain instances, multiple development and test cycles are involved and algorithms are recompiled into lower level languages or hardware specific languages to take advantage of the execution environment. Models which run on GPU and FPGA architectures are examples of this. These organizations are quickly realizing that model risk needs to be managed throughout the development, testing and execution process to sustain their competitive advantage.

Challenges to integrating model risk assessment into the Quant Development process

Recently, we have seen several organizations embark on developing model risk management programs within their organizations. For many the drivers are purely regulatory, but many organizations have highlighted other drivers we listed before as reasons for developing model risk management programs. In discussions with quant groups, we uncovered multiple challenges quants deal with when assessing and addressing model risk in their quant development process.

1. Organizational Structure:

Many organizations consider model risk management as an initiative driven by the risk group in their organization. But the risk groups typically don't have the granular details of the model design and implementation and typically have to involve the quant groups to help articulate the various risk aspects and to devise methodologies to address model risk issues. In many cases, model risk management is an afterthought and risk departments try to build processes to meet regulatory requirements which don't address the spirit of model risk management. In addition, organizations have multiple groups working on different aspects of the quant development process. A quant research group may be in charge of vetting models and their application. A quant development group may be in charge of developing models. The IT group may be involved in deploying these models and a risk group may be expected to have oversight on all these departments. Identifying and delegating responsibility on who should be responsible for model risk programs requires significant coordination between departments. This is a fairly new process and best practices are still evolving on effective ways of identifying, designing and managing organization-wide model risk management programs.

2. Practical Challenges: How to do it?

There is a lot of research and literature available on what constitutes a robust model risk management framework. Regulatory guidelines, consulting companies and industry organizations like CFA institute and PRMIA have made available recommendations that helps define the key tenets of a model risk management framework. One of the primary challenges quants deal with is practical knowledge on how to incorporate model risk management requirements into their model development process. This includes identifying potential risks in their models, quantifying them, building controls to address these risks and to prioritize model enhancements to address risks. Since model risk management programs are an organization-wide effort, quants are expected to design and implement artifacts that would address the identified model risk aspects. For example, model validation is a key test to be done by insurers as a part of the Solvency II framework [6] and many organizations have had challenges in implementing these requirements. The recommendations may not be easily translatable into actions quants can easily integrate into their quant development process. Typically, the recommendations and guidelines are qualitative and there are few guidelines and tools for practical implementation. In addition, prioritization of the identified model risk, addressing these risks through model changes, assessing the impact of these model changes to address model risk and other consequences (such as speed, performance etc. of a model) is complicated without proper guidelines and metrics. When there are multiple issues to be addressed in a model, quants need to figure out ways to prioritize issues and assess the impact of interactions between issues and any changes they implement to the model.

Since the field of model risk management is relatively new, organizations rely on experts and consultants to help them formulate and execute a model risk management program. Model review and validation services are typically sought by company to help quant groups implement a model risk management program. Companies (including QuantUniversity) typically work with quant groups to help design and operationalize model risk management practices.

Tools for Quants to integrate model risk assessment into the quant development process

In this section, we discuss an approach we recommend quant groups use to quantify and manage model risk. It builds upon the Aspect-Impact analysis framework advocated in the ISO 14001 standard and also popular in IT, enterprise risk management and computer security risk assessment frameworks [7]. We use this methodology to help quants identify issues in models, quantify the risks and associate model risk controls to help mitigate or manage model risk.

1. Model Risk Assessment Framework

When we work with organizations to help structure a model risk management framework, we recommend organizations form internal model review teams to work with quants in their model risk assessment efforts. The review team typically includes the quant research, development team, subject matter experts or architects who are familiar with the modeling methodology but not part of the implementation group, other stake holders including IT and risk management .The goal for this team is to identify and quantify the key aspects that would lead to model risk, the potential impacts these aspects could have and the model risk controls implemented or to be designed to handle these risks. Fig 1 describes the key terminology used in this approach.

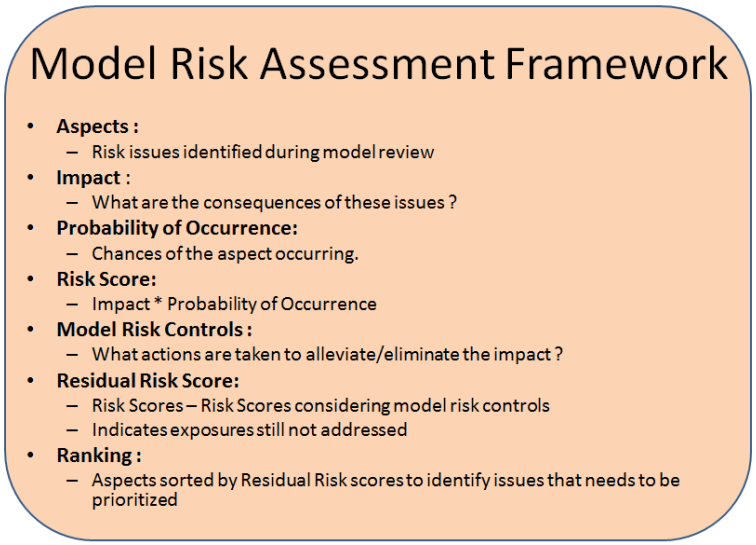

Figure 1: Key terminology in the Model Risk Assessment Framework

The review team reviews every quant model and identifies aspects. Aspects are model issues that lead to potential model risks. Then the team lists the potential impacts the aspects could cause. Impacts are undesired consequences that need to be eliminated or mitigated.

2. Scoring guidelines:

Once the aspects and impacts are identified, the next step is to rate the impacts and estimate the probability of occurrence of these impacts. The goal is to derive risk scores for each aspect which factor the impact scores and the likelihood of occurrence of these impacts as defined in Fig 1. Then the model risk controls implemented to address these aspects are considered and a new impact score and likelihood of occurrence is rated to develop a new risk score. The difference between the old risk scores and the new risk scores indicate the risk exposures that are still to be addressed which could be used to reinforce the model risk controls for the model.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	QuantModel				Risk Scores due to potential impacts				Risk Scores after considering model risk controls				Unaddressed Risk
2	Model	File	Version	Aspects	Impacts	Impact score	Probability of Occurrence	Risk Score	Model Risk Controls	New Impact Score	New Probability of Occurrence	New Risk Score	Residual Risk
3	Stress Model		v1.0										
4	1	ReadData.m		Input < 0	Code Failure								
5	2	ReadData.m		No input checking	Erroneous results								

Fig 2: Scoring guidelines template

Fig 2 shows a sample template to list the aspects, impacts and model risk controls and to calculate risk scores. Column D lists the various aspects pertaining to a model. Column E lists the associated impacts, column F is used to rate the impact scores, column G to note the probability of occurrence and column H is used to derive the risk scores. Column I is used to

list the model risk controls implemented to address the potential impacts and a new risk score is computed in column L. Finally the residual risk exposures are listed on column M.

The risk scores help in implementing or validating if the model risk controls are sufficient to handle the risks posed by various aspects. For example, in Fig 3, we illustrate the possibilities of risk scores for an impact score ranging from 1-5 and a likelihood rating of 1-5.

		Risk Scores				
Impact	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
		Likelihood of occurrence				

	Red	High Risk
	Yellow	Moderate Risk
	Green	Low Risk

Fig 3: Sample Risk grading considering impact and likelihood of occurrence

A quant group may categorize four kinds of aspects to determine priority and actions for model risk control measures. For example:

- ***High Impact- High likelihood of occurrence :*** Needs adequate model risk control measures to mitigate risk
- ***High Impact – Low likelihood of occurrence:*** Address through model risk control measures and contingency plans
- ***Low Impact – High likelihood of occurrence :*** Lower priority model risk control measures
- ***Low Impact – Low likelihood of occurrence:*** Least priority model risk control measures

Based on the scores, the quant group may classify aspects and designate red, yellow and green colors to indicate categories of high risk, moderate risk and low risk respectively. The group may then decide that models with red category aspects cannot be deployed till there are sufficient model controls in place. This method also helps prioritize the aspects and controls that need to be implemented to address model risk. In addition, this approach helps invoke discussions within the quant group and in the model internal review team to ensure there is agreement on the risk perception, risk appetite and to ensure that risk controls implemented are vetted thoroughly. Owners can be designated to address these risks and timelines noted to ensure that the risk exposures are mitigated in a timely manner. A key advantage of using this framework is that the structured and team-based approach enhances transparency in the quant group and other stakeholders while alleviating the risk of unforeseen events. This structured approach also helps identify training opportunities and to evolve best practices for the development process in the quant group to continually improve the model development process.

Note that this process isn't a one-time activity and periodic reviews need to be done. The triggers could be new model issues, changes to existing models and model enhancements that introduce material changes to quant models. We have

designed tools and dashboards to track changes and provide a "current-view" of the existing state of model risk in the group and update the state when changes are introduced. This facilitates various stakeholders in the organizations to know and review progress and plan to address gaps. It also helps in recordkeeping and communicating the current state of model risk management to external parties including consultants and regulators. Though this framework doesn't cover all aspects of model risk management, it provides quant groups a practical and easy way to assess model risk and helps build the foundation to integrate other aspects of model risk management into the quant development process.

In Summary:

Model risk management is becoming a key function for quantitatively driven financial organizations. In this article, we briefly introduced model risk and discussed the drivers and reasons to address model risk. We also discussed some of the challenges quant groups have when integrating model risk assessment into the quant development process. We then discussed the model risk assessment tool to help identify issues in models, quantify the risks and associate model risk controls to help mitigate or manage these risks. We illustrated, through templates, tools quants can use to have a structured approach to model risk assessment and discussed some of the advantages of this approach. By integrating model risk assessment in the quant development process, quants can build robust models and ensure that model risk is effectively managed within their organizations.

References:

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About:

QuantUniversity offers quantitative modeling and consulting services to financial institutions. QuantUniversity offers training and custom consulting packages for model risk management.

Sri Krishnamurthy, CFA, CAP is the founder of QuantUniversity.com, a data and quantitative analysis company. Sri has significant experience in designing quantitative finance applications for some of the world's largest asset management and financial companies. He teaches quantitative methods and analytics for MBA students at Babson College and is the author of the forthcoming book published by Wiley titled "Financial Application Development: A case study approach".

For a copy of sample templates quants can use for model risk management, contact Sri at sri@quantuniversity.com