The Role of Model Review, Model Risk Management and Continuous Model Monitoring in the Financial Services Industry
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Abstract

In this article we outline our point of view regarding the usage of mathematical models in the financial services industry.

Our fundamental hypothesis is that, despite their perceived role in the recent financial crisis, the use of mathematical models represents a hugely positive benefit to the industry and the stability of the financial system as a whole. However, key to leveraging the power of models is a thorough understanding of their fundamental assumptions and approximations and the limitations these impose on a model’s usage. If such understanding is not in place, then models can be misused with potentially catastrophic consequences.

Our hypothesis leads naturally to the conclusion that model review, model risk management and continuous model monitoring are necessary, not just from the point of view of satisfying regulatory requirements (particularly around the capitalisation of risks via regulatory capital charges), but should be seen as a crucial mechanism for both de-risking the usage of models in the financial services (FS) industry and enhancing risk assessment and understanding. In our view, financial institutions have made significant strides in recent years in understanding their model risks, both at an individual model level and at an aggregate institution-wide level. But we believe that an even more proactive approach around the continuous monitoring of model appropriateness would transform these activities into key business enablers, and not just a regulatory burden to be borne. We believe that the most sophisticated and successful financial institutions will be those that understand and manage their models most effectively.
Increasingly, regulators, politicians and the general public began to demand answers as to what had caused the most severe financial shock and recession (on a near global scale) since the Great Depression of the 1930s. Even the Queen of England was moved to ask a group of distinguished economists: “Why did nobody notice it [the crisis]?” (We believe they are still working on the answer). 1

The debate over the precise causes will rage for many years to come. But among the usual suspects of financiers and video game addicted traders, the use of mathematical models in the FS industry also came under increased scrutiny. The popular media jumped on the bandwagon, labelling the so-called single-factor Gaussian copula model (more of this later) as the ‘formula that killed Wall Street’. 2

There is some merit to the argument that models had a role to play in the crisis. Since the financial crash of October 1987 when portfolio insurance 3 was implicated as a major contributor to the crash, the use and sophistication of mathematical models in the FS industry has grown dramatically. This was driven in part by an increasing need on the part of investors to find yield wherever possible. Global trade imbalances, particularly between the East and the West meant that government bond yields in the Western economies were at very low levels. This provided the catalyst for huge innovation in financial engineering and, in particular, in the credit (debt) markets to develop products that delivered enhanced yield.

As the financial crisis that began in late 2006 in the US mortgage markets unfolded, it spread rapidly from relatively arcane parts of the securitisation markets (particularly the US subprime mortgage market) more generally into the mainstream economy as a banking crisis morphed into an economic crisis.

1 See, for example, http://www.bbc.co.uk/news/uk-20716299
3 Wired, See, for example, http://archive.wired.com/techbiz/it/magazine/17-03/wp_ quant?currentPage=all
5 Possibly an early example of a ‘flash’ crash, but without the ‘flash’, since the portfolio insurance methodology utilised programme trading to implement its (typically daily) dynamic hedging strategy.
The growth of the use of securitisation (and ‘tranching’) fuelled a huge surge in product innovation to deliver yield. The zoology of debt instruments that grew from the fundamental concept of securitisation (which in principle is a simple and sensible example of risk pooling) was at once both staggering and bewildering. The range of acronyms used to describe these instruments were also bewildering: mortgage-backed securities (MBSs), commercial mortgage-backed securities (CMBSs), residential mortgage-backed securities (RMBSs), ABS collateralised debt obligations (CDOs), ABS credit default swaps (CDSs), asset-backed securities (ABSs), cash-flow CDOs, Synthetic CDOs, CDO-squared, CDO-cubed, constant proportion debt obligation (CPDO) CLOs, conduits, structured investment vehicles (SIVs), SIV-Lite’s to name but a few.

While the financial innovation continued relentlessly, it is fair to say that the sophistication of the mathematical modelling applied to these products did not. A common requirement in modelling securitisation products is the need to capture the correlated behaviour of the assets in the underlying securitisation. If someone defaults on their mortgage, what is the joint probability of someone else also defaulting on their mortgage and what is the causal relationship between the two events? Such questions are relevant in determining the cumulative losses over time in a securitisation. However, they are also extremely difficult questions to answer. But the actuarial industry has decades of experience (and crucially empirical data) of asking similar questions about, for example, single and joint mortality rates and correlations.

The use of copula models (which characterise the joint behaviour of a correlated pool of assets) is well-established in the actuarial industry. It was introduced into the FS industry (initially by Li) in the context of portfolio credit derivatives – default baskets and synthetic CDOs as a means of characterising the joint default risk in a pool of corporate counterparties. With a few simplifying assumptions to make the model usable (particularly given the lack of relevant data to parameterise the model fully) the model quickly became the market standard approach.

It is worth noting that although the single-factor Gaussian copula model has implicit modelling limitations, one of the fundamental reasons for its apparent failure is the use of inappropriate data to parameterise it. In the actuarial industry there is a large amount of relevant, empirical data that has been collected over the course of many decades. This data can be used to robustly parameterise the model. In the derivatives industry, such data is typically not available.

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6 However, it is worth noting that the concept of securitisation is not a new one, having been formulated many decades previously
9 The assets that were securitised were also wide and varied; home loans (prime and subprime), credit card receivables, auto loans, student loans, credit default swaps, commercial loans to name some of the most common. Basically, anything with a future stream of cash flows was considered fair game
10 Available, for example, from http://papers.ssrn.com/so3/papers.cfm?abstract_id=187289
11 Namely reducing the full co-dependence matrix down to a single scalar value, assuming a single source of systemic risk and assuming that the shocks are normally distributed
about the types of assets underlying complex securitisations. In the end even a good model, if it is parameterised incorrectly, can lead to erroneous results and conclusions.

Given the model’s relative ease of implementation and apparent sophistication, it was seized upon in particular by those seeking to trade greater and greater volumes of these instruments, as the model allowed them to quantify and price risk (or so it was believed)\(^\text{12}\). It should be noted also that many institutions adopted even simpler, cashflow based models (particularly for cash-flow CDOs and other cash-flow-based securitisations) that neglected some of the most fundamental features of these complex instruments.\(^\text{13}\) These models captured the mechanics of the cash flows in the securitisation and coupled these with assumptions about, for example, future delinquency rates to come up with an estimate for an instruments value. However, this approach fails to capture the co-dependence of events. This is a crucial element to capture since co-dependence drives the tail risk that is so important when trying to analyse potentially extreme scenarios.

As the crisis evolved through the course of 2007 and 2008, the losses and write-downs incurred by securitisation products grew ever larger. Small and medium-sized hedge funds went bust, SIV’s went pop, money market funds ‘broke the buck’ and investment banks began to rack up losses stretching into the billions of dollars.\(^\text{14}\)

As the crisis evolved through the course of 2007 and 2008, the losses and write-downs incurred by securitisation products grew ever larger. Small and medium-sized hedge funds went bust, SIVs went pop, money market funds ‘broke the buck’ and investment banks began to rack up losses stretching into the billions of dollars. Eventually these losses and the associated impact on confidence in the viability of financial institutions believed to have large exposures to these instruments, led to an almost existential crisis for the entire financial system around the time leading up to, and after, the Lehman collapse in September 2008. Huge amounts of taxpayers’ money and unconventional monetary policy (ultra-loose fiscal policy, asset purchase schemes, quantitative easing, etc.) were eventually required to provide some stability to the financial system. We note that this is by no means a problem that is solved, merely kicked down the road.

It is also worth pointing out that some of the biggest shocks to the financial system did not stem directly from the securitisation market. The first run on a bank in the UK in 100 years – Northern Rock in 2007 – was more a result of a business strategy that worked when money markets were operating normally – and funds could be accessed easily, but came under severe pressure when the markets dried up. In the end, liquidity, not Brownian motion is what moves markets. Poor acquisition strategies also accounted for other large banking failures totally unrelated to the use of sophisticated mathematical models.

It is probably more accurate to think of the problems in the securitisation market as being a symptom of a whole host of other problems that had been building up in the wider economy. Excessive debt and leverage – personal, corporate, banking and sovereign – where everyone was living beyond their means (‘spending the house’ via equity release mortgages for example) meant that once banks turned off the spigot of easy credit, everything collapsed. Once the genie was out of the bottle there was no putting it back in.

To examine the role of models more carefully, and to arrive at our basic hypothesis that mathematical models are a positive benefit to the FS industry, we will first deconstruct the anatomy of a model to examine what it is, what good practice in model building looks like, why they fail and importantly why it is so hard to build good models in the FS industry.

This analysis will lead to our additional conclusion that the only way in which to use models safely in the FS industry\(^\text{14}\) is through constant review, challenge and monitoring.
Anatomy of a model

What is a model?

The Fed OCC SR11-7 SR\textsuperscript{15} definition of a model is a ‘quantitative method, system or approach that applies statistical, economic, financial or mathematical theories, techniques and assumptions to process input data into quantitative estimates’. All well and good, but it misses the point completely. More accurately, and in line with a simpler, scientific definition of a model, SR11-7 goes on to say: ‘Models are simplified representations of real-world relationships among observed characteristics, values and events’. The key phrase here is ‘simplified representations’. A model is only an approximation of reality. Understanding this is the key to understanding how to safely leverage the power of models.

Models are, of course, ubiquitous in virtually all aspects of life. We have a model describing the behaviour of subatomic particles as they are smashed together at near the speed of light in a particle collider in Switzerland (leaving elusive Higgs bosons predicted by the so-called standard model of electroweak interactions in their wake). We have a model characterising the airflow over a Formula 1 cars rear-wing as it goes around Parabolica at 200kph (a computational fluid dynamics problem essentially solving the Navier–Stokes equation on a complex geometry). We have a model capturing the joint default behaviour of corporate counterparties modelled, using a single-factor Gaussian copula and packaged up into a synthetic CDO and used to value a tranche of the latest CDX series index (CDX is a standardised index composed of CDSs written on North American investment grade counterparties).

All of these models have one defining characteristic in common: they all make assumptions and approximations about the representation of the problem. Assumptions and approximations are necessary to make the models tractable and therefore useful in the real world. It is often the case, particularly in the natural sciences, that the problem we really want to solve is simply too complex to comprehend fully. Therefore, we need to work backwards stripping out the complexity and reducing the problem to a simplified representation that we can understand and solve, and which at the same time can provide additional insight. Once this point is reached, we can then begin to move forwards again, adding incremental layers of complexity back into the problem to approach a solution to the real thing of interest.

\textsuperscript{15} See: http://www.federalreserve.gov/financialreform/letter/sr1107.htm
What constitutes a good modelling approach?

In the natural sciences models are typically built using the principle of Occam’s razor; a model should be as complex as it needs to be and no more. In addition to this, a good model should also be able to reproduce the experimentally observed data, or at least reproduce the expected phenomenology (directional movements) of the data. Finally, the model’s assumptions should be tested against the experimental data to see where these assumptions break down, thereby determining the limits of applicability of the model – the operating envelope (or regimes) of the model.

A very important principle in model development is that the model should fit the (experimental) facts – and not the other way round. If the model, irrespective of how mathematically rigorous, elegant or clever it is, does not fit the facts it should be improved or ultimately discarded. This is a fundamental principle in the natural sciences where there are precedents of new theories replacing almost overnight centuries of accepted wisdom (for example the theory of special relativity subsumed within it almost three hundred years of development of Newtonian mechanics as a limiting case at speeds much less than the speed of light).

A good modelling approach therefore should be as simple as possible, but at the same time capturing the essential characteristics of the problem being solved. Once a simple model has been constructed, which captures the experimental facts, at least approximately, additional refinements to the modelling can be added incrementally. We also observe that models have inherent operational envelopes (or regimes) within which the assumptions and limitations of the model remain valid. While within this envelope, a model can be safely used for the purpose it was intended. Operating outside of this envelope represents a model usage risk. To mitigate this risk, we will argue that a process of continuous model monitoring must be embedded within the overall governance specifying a model’s usage.

Why do models fail?

We have outlined what good practice in building a model looks like. However, even the best models can fail. It is reasonable to ask therefore why this is the case. We argue that models can fail for a variety of reasons:

- Misuse, for example using a vanilla interest rate model to price an exotic derivative, or using a model outside of the operational envelope (regime) in which it is designed to be used safely (this raises the important point that models will have clearly defined ranges of applicability where their underlying assumptions are valid)
- Misspecification (incorrect modelling assumptions or implementation)
- Mis-parameterisation (using inappropriate or simply erroneous model inputs)
- Operational error

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16 The quotation “If you are out to describe the truth, leave elegance to the tailor” is attributed to Einstein
17 Although, in mitigation, Newton himself was aware of some of the limitations of his own theories
18 For example, Newtonian mechanics applies to objects moving at speeds much less than the speed of light. However, once the speed of light is approached then Newtonian mechanics must be replaced with relativistic mechanics
19 For example, the Challenger space shuttle disaster in 1986 was a result of the O-rings used in the solid rocket boosters being used outside of their safe operating temperatures. This limitation in the behaviour was known to Morton Thiokol – who built the O-rings – and NASA management at the time. Interestingly, the stock market worked out within approximately 30 minutes of the disaster who was responsible (the stock of Morton Thiokol was marked down significantly compared to other stakeholders in the construction of the shuttle). It took a congressional committee including the Nobel Prize winning theoretical physicist – and bongo player – Richard Feynman, months to reach similar conclusions (James Surowiecki, The Wisdom of Crowds, Why the Many Are Smarter Than the Few, Abacus (2005))
Fundamentally, it is the assumptions and approximations utilised when building a model that leads to model limitations; using models in regimes where these limitations become apparent is a major source of model failure. We conclude that, technically speaking, models do not fail; they are misused.

**Why is it so hard to build good models in economics and finance?**

We have outlined a number of characteristics of good model development, such as reproducing the experimental evidence and incrementally building the complexity of the model to refine it further and further (building on a solid foundation of established knowledge).

This is an approach that works spectacularly well in the natural sciences (stretching all the way back to ancient Greece – think Archimedes). Why doesn’t it work in economics and FS? The problem we believe is that model building in the natural sciences is fundamentally easier than in economics or FS.

Yes, modern theories of the universe such as the standard model in particle physics or cosmological theories of the formation of the universe require tremendous amounts of intellectual ability to understand and develop; but at the heart of these models is an assumption that the laws of physics are unchanging over time. New discoveries, such as the aforementioned Higgs boson, are only really new discoveries of phenomena that had been there all the time, just waiting for our experimental sophistication to catch up with our imagination and theoretical models.

In economics and FS, the foundations on which we build our models are constantly shifting. A Value-at-Risk (VaR) model that correctly captures the behaviour of the interest rate market today (evidenced via good backtesting performance) may not do so in the future. This is not necessarily because our understanding of the interest rate markets improves (and we develop a better model), or new experimental evidence comes to light, but simply because the nature of the market...
These factors all taken together lead to the conclusion that model building in the economics and FS industries is a difficult task. This leads to the next question: why build models at all?

**Why do we need models in financial services at all?**

We have argued that models are difficult to build in the FS industry. So why bother using them at all? There are two arguments in favour of using models. The first is a pragmatic argument. Regulators require certain risks to be quantified and therefore capitalised with regulatory charges. In order to avoid punitive capital charges based on very simplified modelling assumptions (imposed by the regulators), there is a strong incentive to reduce these charges as much as possible by building better models.

Secondly, despite their inherent limitations arising from the assumptions and approximations made, a model can, if well-built and used appropriately, provide valuable insight into the risks faced by an institution. Whether these are the risks associated with an individual exotic derivative position, the counterparty credit risk associated with multiple trades executed with a risky counterparty, or the risk of a retail portfolio of hundreds of thousands of small loans, a model of these risks can help to describe, quantify and ultimately assist in controlling the risk. Models can provide insight into complex problems by synthesising large amounts of information into a more readily interpretable fashion.

We make the important caveat to the second point. Models can be beneficial, but only if their behaviour and limitations are understood completely and the models are used correctly. If this caveat can be mitigated, then there is no logical reason why models cannot be employed successfully within the FS industry – just as they employed in a multitude of other industries – to provide insight and understanding into the nature of risk. If all the participants in the market apply the same level of diligence in understanding their models, then the overall financial system will ultimately be more secure.

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22 One could argue that a new modelling paradigm based more on analogies of financial markets with evolutionary, complex biological systems may be a more appropriate methodology

23 For example, estimating the probability of default (PD) for a corporate counterparty implies that there is some data on the corporate available. But what if the corporate hasn’t defaulted before? How do you estimate the PD? Do you use a proxy? How is it chosen, is a suitable proxy even available?

24 Specifically, models to capture VaR, stressed VaR, incremental risk charge (IRC), all price risk measure (APR), credit valuation adjustment (CVA) and stressed CVA

25 The current trend for data mining leveraging the vast quantities of data that are being generated on a 24/7 basis – in the form of data analytics – is a good example of where models can be utilised to make sense of, and provide insight into, vast quantities of data.
The role of model review, model risk management and continuous model monitoring

Having described the characteristics of models, why they are of fundamental benefit to the FS industry and the problems that can arise from their use,26 we now go on to describe what can be done to de-risk the use of models. Central to our argument is the role of continuous model review, model challenge and monitoring of models, all within a model risk management framework.

We now describe each of these activities.

Robust, transparent, independent model review

Model review is a crucial part of the model development life cycle and forms one of the defences against model misuse. The purpose of model review is to assess a proposed model against a number of criteria:

• Is the proposed model appropriate for the application it is being used for (for example, a short time-horizon market risk VaR model would not be appropriate for quantifying counterparty credit risk over a longer time horizon)?

• What are the fundamental modelling assumptions that the proposed model is making, i.e. to what extent is the model a simplified representation of the real problem we are trying to describe. This is potentially a very difficult task to assess since it requires a full understanding of the actual problem.27 The model reviewer must have sufficient expertise and knowledge to identify what a ‘perfect’ model should incorporate and to understand where approximations can be safely made (e.g. neglecting basis risks because they are a second-order contributor to risk). The skill, expertise and experience necessary to make such judgements should not be underestimated.

26 These issues are by no means specific to the FS industry
27 For example, a model calculating the regulatory capital charge of a flow CDS book may identify default risk as the primary risk factor and neglect all other factors. However, other factors such as recovery uncertainty and basis risks may actually be significant contributors to the overall risk, which should not, in fact, be neglected, i.e. the model is misspecified because it is too simplified.
• What are the consequences of the model’s fundamental assumptions? That is, what are the consequences of approximations made (for example approximating the calculation of an integral expression numerically)? What are the modelling limitations imposed by the assumptions (for example, can the model deal with trades with multi-currency, early exercise or path-dependent features)?

• Is the numerical implementation of the proposed model actually correct (and where does the model break down numerically)?

• Are there alternative models that should also be considered (and if so, what is the rationale for the actual model chosen)?

• What are the limitations of the proposed model? For example, under what conditions will the model fail to calibrate to observed data (and is appropriate data available)? What are appropriate stressed model inputs to test the model’s safe operational envelope?

In answering these questions the model reviewer can build up a picture of the model’s behaviour, where the model will perform strongly and under what conditions it will not perform well. In addition to this the model’s relative complexity and materiality to the institution should also be characterised. We define this knowledge as the operational envelope of the model, which determines the range of applicability (regimes) of the model.

In practical terms we see model review as being a two-stage process. In Stage I we perform basic sanity checks to assess the proposed model’s behaviour. Is the model fit for purpose with reasonable assumptions, do limiting cases behave intuitively, what are the fundamental assumptions, etc.? Stage I is designed to provide a basic level of comfort around the proposed model.

In Stage II we extend the analysis of Stage I to perform a more robust challenge of the proposed model. This will include a more detailed assessment of the choice of model, analysis of the model’s limitations and the consequences of these limitations, independent price verification (IPV) performance, etc. We may also implement independent versions of the model or other alternative model’s to assess the choice of model made. Stage II is more appropriate to cases such as, for example, internal model method (IMM) waiver application support, where it has to be demonstrated that a thorough model challenge process has been undertaken.
An important element of both stages I and II is thorough, clear and accurate documentation of the analysis undertaken. This is especially important when considering the through life behaviour and evolution of a model. It is our view that financial institutions do not document thoroughly enough the analysis of models undertaken.

We summarise Model Review and Challenge in Figure 1. In this figure we also enumerate in more detail the sorts of activities we see as being part of the two stages of model review.

At the end of stages I and II the model reviewer should have formed a complete understanding of the model’s characteristics and its operational envelope. This operational envelope is crucial in leveraging the model review to de-risk model use as we will now discuss.

**Figure 1: The two-stage model review process. Stage I is a basic ‘kicking of the tyres’ assessment, Stage II is a more detailed assessment of the model choice and its associated limitations. Stage II builds incrementally on the foundation provided by Stage I.**

**Typical Stage II Activities**
- Identify market standard modelling methodology
- Conduct a literature review to identify standard and alternatives, and provide evidence supporting or not, proposed model choice
- Independent model implementation
- Alternative model implementation and comparison
- If appropriate, implement an alternative model to mitigate model risk
- Detailed analysis of model assumptions and limitations
- Quantify the impact of model assumptions
- Model performance – stress testing and scenario analysis
- Model performance – back-testing and P&L attribution
- Identify reserves and reserving methodology
- Analysis of parameterisation methodology
- Review proposed data sources (availability, reliability, consistency across asset class), data preprocessing, calculation of model parameters
- Price and calibration stability analysis
- Run the model over a period of time to quantify the stability of calibration parameters and PV

**Typical Stage I Activities**
- Review model/product and trade economics
- Review the underlying mathematical model
- Review and enumerate underlying model assumptions
- Basic sanity checks and limiting cases, e.g. schedule generations
- Basic implementation checks
- Convergence checks for numerical methods
- Parameter sensitivity analysis (including calibration failure envelope)
- Quantify the model’s behaviour as parameters are varied over their full permissible range, noting where the model breaks down
- Define range of model product and usage scope
- List the types of trade the model is applicable for use with
- List acceptable parameter range validity
Robust, transparent, independent continuous model monitoring

The initial model review provides a snapshot of the model’s behaviour at the beginning of its useful life. However, the market conditions under which the model was originally developed and the assumptions made may not be relevant several years down the line. It is therefore necessary to monitor the model’s performance during the course of its operational lifetime.

It is our experience that financial institutions have become much better in the last decade at the model review piece of the puzzle. This has been driven by a combination of regulatory pressure (for example, the Fed OCC SR11-7 SR guidance providing a very comprehensive benchmark against which institutions should assess model development) and also the realisation that model misuse and modelling errors can in fact lead to catastrophic losses.

It is also our experience that financial institutions typically monitor a model’s performance on a relatively ad hoc basis. Annual reviews of model approvals are often a box-ticking exercise with limited information collected about the model’s performance against the evolving market conditions. It is not often the case that a full model rereview will be instigated, unless something very, very significant has happened. This process therefore tends to be a reactive approach to model risk management, only kicking in once model limitations have been exposed by the evolving market conditions.

It is our assertion that institutions should adopt a much more proactive approach to model risk management. We believe that the operational envelope of a model described earlier should form the basis for a process of continuous monitoring of a model’s performance. In particular, we argue that a dedicated team of suitably qualified individuals are necessary to perform the task of continuous model monitoring. We envisage the process as follows:

- For a particular product/model combination an initial model review is undertaken (as described previously).
- The model review should define the operational envelope of a model. This should be used to specify the model diagnostics to be tracked as part of the ongoing model monitoring.
- As part of the definition of the model’s operational envelope, we will also naturally identify what are suitable stressed model inputs. Stressed scenarios should also be part of the diagnostics run as part of the continuous model monitoring process.
- The continuous model monitoring team implement these diagnostics.
- The continuous model monitoring team run these diagnostics on a continuous basis (via regression testing) and produce model Management Information (MI).
- The model MI should be presented to the relevant governance committee as part of the overall model governance framework to identify potential model failures. Senior management should become accustomed to, and comfortable with, model metrics as a means of understanding their business.
- The continuous model monitoring acts as a feedback mechanism providing constant internal regulation of the model’s continued usage. In addition to this the process of continuous monitoring acts as a feedback mechanism for the business and their usage of models.

28 The frequency with which the diagnostics are run will be to some extent (product, model) dependent, but we envisage the process should be run weekly as a minimum.

29 For example, if their model parameterisation is too aggressive then this will be identified as part of the stress testing diagnostics.
The objective of the continuous model monitoring is to constantly track the model’s performance. Ideally, this process should act as a detective control, providing forward guidance as to when market conditions are moving a model towards an area where its performance can no longer be guaranteed.30

We acknowledge that continuous model monitoring may be a difficult task to achieve in practice, and that it may seem like an expensive luxury. However, we believe strongly that such a process would have a significant positive benefit to an institution that implements it effectively. It would allow models to be managed dynamically in a proactive rather than reactive manner and would assist greatly in de-risking the use of models. Given that it is almost inevitable that models are used in the FS industry, we should at the very least do the utmost to ensure that they are used as safely as possible.

Robust, transparent, independent model risk management

Finally, Figure 2 shows how we envisage the model development life-cycle looks. It forms part of a comprehensive model risk management framework. The model risk management framework should consider additional metrics with which to characterise and classify models including:

- model complexity
- product complexity
- product materiality
- model risk tiering

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30 For example, in late 2007 the standard model for synthetic CDOs became incapable of calibrating to the market observed prices, particularly for tranches very high up the capital structure. This was due to a systematic repricing of risk in the market as the consequences of the financial crisis began to be understood. It eventually required an extension of the standard model to incorporate stochastic recovery to fix the problem, but at significant cost to institutions (measured in billions of dollars) as the positions were remarked using the new model. A formalised model monitoring process would not have prevented the problem, but could have identified it far earlier, allowing more rapid preventive action to be taken at much lower cost.
The left-hand side of Figure 2 shows the initial model development process (a business need is identified, a model proposed to meet this need and a prototype implemented). The initial model development and testing (the first line of defence) will usually be undertaken by the desk and front-office quant team. Part of the model development framework must also be a clear articulation of model implementation (and coding) standards, model acceptance criteria and model validation standards.

Once this initial development has been completed, the initial (pre-implementation) model review and challenge is undertaken (the second line of defence). When this has been successfully completed the model goes into production. Once in production the model is continuously monitored against the operational envelope defined by the model review. It is important to note that it is not just breaches of the operational envelope that are flagged, but the model’s dynamic evolution (to detect potential problems as they start to become apparent).

Ideally, it should be apparent from the model MI what the direction of travel of the model is, to enable proactive decisions to be made regarding a model’s continued suitably. When problems are identified, the feedback mechanism alerts the model owners (typically, front-office quants), who can then take remedial action. The remedial action may or may not trigger a rereview of the model, and the whole process continues again. This continuous process of build–review–monitor in principle de-risks the ongoing usage of models in the FS industry.

31 We acknowledge that, in practice, model review is often done post a limited trade approval is granted by, for example, the desks risk managers.
Conclusions – The role of models within the financial services industry

In this article we have argued that, despite recent negative publicity, the use of mathematical models in the financial services industry is a positive benefit. Models, when properly used, allow institutions to quantify and ultimately control their risk. However, the key caveat is that models must be properly used. In order to achieve this, robust review, challenge and monitoring of models must be incorporated into the model development life cycle, not as afterthoughts, but as key components in the overall model governance process. Only by recognition that models have inherent limitations and instituting constant monitoring of the models’ performance against these limitations can models be safely deployed in any environment, not just the financial services industry.
If you would like to discuss any of the issues raised in this report in more detail, please speak with your usual PwC contacts or anyone listed below.

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