

Internal auditing of model risk within banking institutions

R Lingenfelder

Department of Auditing
University of Pretoria

ABSTRACT

Faulty or improper usage of models has contributed significantly to financial and banking institutions' experience of damage to their reputations and profitability. Since the global financial crisis of 2008, regulators have become increasingly concerned about the soundness of decision-making processes underpinned by, and capital requirements derived from models. Additionally, banking institutions have now recognised that flawed models are a source of significant operational risk and reliance on them can have negative consequences. Based on the importance of and increased use of models, internal audit functions should be equipped to provide assurance and auditing services to such areas within financial institutions.

This research study investigates the broadening of the internal audit function's ambit to include robust coverage of model risk within banking institutions. A brief literature review on model risk within banking institutions is followed by an investigation into internal auditing expectations and requirements regarding the coverage of model risk. The quantitative research which was performed is described, and conclusions drawn as to the state of risk management, internal audit's coverage and the skills needed to effectively assess model risk. In addition, the degree to which these have become embedded in these organisations is assessed. The research paper concludes with a set of recommendations on how internal

Key words

Internal audit; model risk; models; model lifecycle; banking institutions; risk management

1 INTRODUCTION

Faulty or improper use of models has contributed significantly to the situation where banking institutions have suffered financial and reputational damage. This was unequivocally highlighted by the global financial crisis, and subsequent high-profile financial incidents which revealed fundamental errors in banking institutions' models (Moore & Brauneis 2008:24; Gerding 2009:129-130; Lumsdaine 2009:46; An, Deng, Rosenblatt & Yao 2012:546). As a consequence of the crisis, banking institutions are facing greater scrutiny by regulators over model risk (Dil 2012; OCC/FED 2011). Regulators have become increasingly concerned about the soundness of decision-making based on, and capital requirements derived from models (Conover 2009; Krishnamurthy 2013:1-2; Petitjean 2013), and have therefore significantly increased their emphasis on model governance (Dil 2012; OCC/FED 2011; Pace 2008:27-28). Notably, regulators have extended their guidance and narrowed their focus relating to risk management and control activities to include model development, implementation and use (OCC/FED 2011; Mays & Sangha 2012:13-18; Krishnamurthy 2014:56-57).

Banking institutions are heavily reliant on models in their financial and risk management activities (OCC/FED 2011:1; Krishnamurthy 2013:1-2). They are becoming more dependent on strategically important, highly sophisticated modelling techniques and analytics to inform their decision-making (Conover 2009:20; OCC/FED 2011:1). Banking institutions

have acknowledged that flawed models are a source of significant operational risk and can have adverse consequences (Wu & Olson 2010:180; Monahan, Meyer, Embersit & Agarwala 2012:26; Xu 2013:12). Banking institutions have therefore recognised the need to improve their model governance and risk management activities. These institutions are adopting various initiatives to comprehensively identify risk throughout the lifecycle of their models (Mays & Sangha 2012:13-18).

Based on the banks' already significant and increasing use of models, internal audit functions should therefore extend their assurance activities beyond mere policy compliance. The research study investigates opportunities for internal audit functions to expand their role in banking institutions' model risk management frameworks by independently verifying whether model risk is being actively managed and controlled.

2 SIGNIFICANCE, PURPOSE AND LIMITATIONS

The global financial crisis, and the significant consequent losses due to faulty or improper use of models has resulted in an expansion of the responsibility for and focus by internal audit on the risks posed by model use (Monahan *et al* 2012:26-27; OCC/FED 2011:19; Protiviti 2013:3-4; PWC 2011:12). Internal audit should therefore ensure that their risk-based audit plan includes coverage of model risk, as it has become a significant risk to banking institutions. As outlined by Head (2009:5-6), internal audit

functions should be able to adapt to changes in the risk landscape and thus focus on model risks and associated areas deemed critical by management.

The primary purpose and focus of this research study is to extend the knowledge of internal audit's responsibilities for the auditing of model risk within banking institutions. It investigates the broadening of internal audit's ambit to include robust coverage of model risk within banking institutions, by analysing internal audit's role within the model governance framework. The study aspires to provide internal audit functions with a greater understanding of their role in and the coverage required over model risk management activities throughout the model's lifecycle.

This research article is structured as follows:

- A review of literature on model risk and associated control activities within the banking industry is reported on. (The review highlights the expectations and requirements banks have of their internal audit functions to include audit coverage of model risk.)
- An analysis of the results of a quantitative research project (the literature study and an examination of secondary data) which draws conclusions on the current state of model risk management and internal audit's coverage thereof.
- A discussion of and presentation on how internal audit functions should enhance their approach to and coverage of model risk.

3 LITERATURE REVIEW

3.1 Model risk within banking institutions

Models are becoming increasingly central to the operation of banking institutions, as they are used in a variety of settings and contexts. However, these models are also becoming a source of increasing risk within the industry (FDIC 2005:1). Faulty or improper usage of models has had significant adverse financial and reputational consequences (Conover 2009:20; OCC/FED 2011:1).

3.1.1 Application of models

Models help financial institutions make strategic and complex business decisions within the context of their uncertain and complex operational environments. The use of mathematical models has also become increasingly important, as they are able to deal with large amounts of complex information efficiently and speedily (OCC/FED 2011:1; Krishnamurthy 2014:56).

Yoost (2013:21) emphasises that reliance on models is growing fast and that their use has expanded into an increasing number of areas, with a simultaneous growth in their importance and influence. The use of models is expanding because technological developments make this possible, and because the availability of data sets is expanding and growing more amenable to sophisticated statistical techniques (Yoost 2013:21; Krishnamurthy 2014:56). Consequently, models are being used on an increasingly broad scale

in financial and risk management activities and in corporate decision-making.

The areas where models are most frequently used include the following (Pace & Robertson 2003:24; Pace 2008:28; KPMG 2012:6-7; Yoost 2013:21):

- Measuring and quantifying risk (e.g. probability of default (PD), loss given default (LGD), exposure at default (EAD), potential future exposures (PFE), value at risk (VaR), duration, convexity, counterparty exposure, annual earnings at risk (AEaR), economic value of equity (EVE), net interest income (NII), and valuation models);
- Initiating or making risk decisions (e.g. scorecards, lending models, risk-reward models, algorithmic trading tools, and financial planning);
- Credit portfolio management;
- Pricing models, profitability models and effective interest rates;
- Calculating impairments consisting of PD and LGD;
- Asset and liability management (e.g. client behaviour models, structural and product hedging, and prepayment models);
- Securitisation (e.g. cash flow and waterfall);
- Liquidity management;
- Operational risk management;
- Stress testing;
- Fraud detection;
- Applied economic forecasting, and
- Estimating regulatory and economic capital.

3.1.2 Models and model risk

Banking institutions predominantly use statistical and mathematical models. Schichl (in Kallrath 2004:28) describes a model as "... a real world objective which is represented by mathematical objects in a formalised mathematical language." These models can range from the use of sophisticated, complex and intricate mathematical, statistical or econometric methods to simple calculations with very few assumptions (CIA, 2008:15-16). Advanced skills from various disciplines are required for the development, interpretation and use of these models (Kancharla 2013:2). Mathematical models are often dependent on computer-based production systems that consist of several interconnected components (PWC 2009:2).

Prior to the guidelines published on 04 April 2011 by the Board of Governors of the Federal Reserve System (FED) and the Office of the Comptroller of the Currency (OCC) (OCC/FED 2011), there was no agreement on a single, standard definition of what constituted a model within the banking industry (Kogler & Vetrano 2007:93; Yoost 2013:22). However, regulatory authorities have now agreed on a universally accepted definition of the term "model",

and a consistent classification of what comprises model risk (KPMG 2013:6).

The regulatory guideline (OCC/FED 2011:3) identifies 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."

Although the release of the regulatory guidelines has provided a high-level definition of a model, banking institutions still find it difficult and challenging to capture model risk under this classification. Conflicting views remain, and there is still debate within the industry and literature on the definition's interpretation and thus on which types of models, calculations, and statistical and econometric methods should be captured within their model inventory (Pace 2008:30; Yoost 2013:22). As a result, material differences exist within the banking industry regarding which criteria and principles should be used when defining a model (Mays & Sangha 2012:15). Additionally, there are concerns that regulatory guidance excludes particular quantitative models (i.e. complex computations not materially underpinned by estimates and assumptions) that are nevertheless often used (KPMG 2013:7). This can create uncertainty and inconsistencies about the types of models that should ultimately fall within banking institutions' model inventory.

Model risk, on the other hand, is defined by regulatory authorities (OCC/FED 2011:3-4) as the "... adverse consequences from decisions based on incorrect or misused model outputs and reports. Model risk can lead to financial loss, poor business and strategic decision making, or damage to a bank's reputation."

Model risk can originate from various sources and throughout the model's lifecycle. These include: flawed model design; incorrect methodology; inadequate testing; incorrect implementation; erroneous calculations, logic or algorithms; faulty estimates; incorrect data; faulty assumptions; imperfect model structure; incorrect or inappropriate use of existing models; lack of understanding by the user; false interpretation or application of results; unauthorised model changes or modifications; rapid deterioration of model performance; negligence by the user, and/or the use of an outdated model (Kogler & Vetrano 2007:90; CIA 2008:17; PWC 2009:2-3; Wu & Olson 2010:180; OCC/FED 2011:3-4; Monahan *et al* 2012: 26-27; Xu 2013:12).

3.1.3 Model risk management and related challenges

Model risk can lead to poor decision-making, introduce operational risk, and result in financial loss and reputational damage (Pace 2008:27; Keyes 2011:7; OCC/FED 2011:3). Model risk management has therefore become vital for reducing exposure to these adverse consequences in banking institutions.

Kancharla (2013:1) states that models have long been an essential component of practically all decision-making, risk management and analysis. However, in recent years models have dramatically

increased in their sophistication and complexity. Mays and Sangha (2012:18) comment that banking institutions are increasingly being challenged to manage model risk as they would any other significant risk. Banking institutions are therefore attempting to understand and better govern their models through enhanced risk management activities. A well-defined and properly implemented model governance and risk management framework can assist financial institutions to better understand their models' strengths, weaknesses and limitations. This governance and risk management framework should ensure that model risk is limited at all phases of its lifecycle - the development, implementation, validation and use phases of the model (Moore & Brauneis 2008:25; Goldberg & Pleune 2008:20-22; Lynas & Mays 2010:44-45).

Additionally, the focus on model risk has been heightened as regulators have become increasingly concerned about the soundness of decision-making processes supported by and capital requirements derived from models. Regulators have recognised an urgent need to address model risk management practices within banking institutions and to intervene if necessary (Mays & Sangha 2012:13-18; Ernst & Young 2013a:10; Krishnamurthy 2014:56-57). Regulators have already taken many key initiatives in this regard, including the issuance of new supervisory guidelines and regulations, and shared their insights regarding the institution of more robust model risk management standards and practices.

Regulatory guidance focuses on three areas of managing model risk. These include (OCC/FED 2011; Dil 2012:47):

- Model development, implementation and use;
- Sound model validation processes, and
- Developing, employing and maintaining strong model governance. This includes policies and controls.

In addition to the guidelines provided by regulators, it is critical that banks independently implement model risk management practices that are beyond mere compliance with regulatory requirements, to actively mitigate model risk (Lynas & Mays 2010:45; Krishnamurthy 2013:6). Academics and practitioners alike agree that subsequent to the issuance of the new regulatory guidance, many banks have made positive advances in enhancing their model risk management activities (Mays & Sangha 2012:13-18; Dil 2012:47). Despite the progress, however, there are many banking institutions that continue to face practical challenges and that struggle to implement an effective model risk management framework (Krishnamurthy 2013:2; Krishnamurthy 2014:57). Their challenges include an unclear definition of what constitutes a model; the lack of a globally accepted set of best practices and interpretations of regulations; the absence of company-wide support; underinvestment in model validation functions; the vast number of models to validate; process weaknesses; lack of system and technology infrastructure; difficulty in quantifying materiality of

models' outputs and conflicting consequences, as well as a lack of access to skilled and experienced human resources (KPMG 2012:12; IACPM 2014:8).

Behm, Epperson and Kalra (2013:4) postulate that many banks have failed to implement effective model risk management frameworks due to their generally fragmentary or restrictive approach to the managing of model risk. Lynas and Mays (2010:45) contrastingly recognise that an overly extensive model risk management framework can be injurious to the business (i.e. it adds significant costs, or its governance is too onerous), resulting in senior management avoiding the use of models altogether. Davies (2012:50) raises concerns that model risk management and validation processes can have high demands on scarce resources that are rapidly exhausted. Therefore, some banking institutions do not perform regular validation activities, or avoid them altogether. According to Lumsdaine (2009:47), there is an increasing concern that model management as a discipline is struggling to keep up with the rapidly-changing financial environment and with the pace at which banks operate and take decisions. Consequently, many institutions are not regularly updating of their models, nor assessing the data's relevance and the ongoing validity of the models' assumptions. Additionally, models are usually implemented on an information technology platform which itself severely limits transparency and thus auditability.

3.1.4 Model lifecycle

The model lifecycle reflects the ongoing initiation, development, implementation and use of models within a business process (PWC 2013:3). Since model risk exposure can occur throughout the model's lifecycle, the effectiveness of the model must be evaluated and validated at each stage (Krishnamurthy 2013:4).

3.2 Internal audit

The Chartered Institute of Internal Auditors states that the core role of internal audit is to assist the board and executive management to safeguard the assets, reputation and sustainability of the organisation. This function is performed by evaluating whether all significant risks are identified, controlled and appropriately reported on to executive management and ultimately the board. Internal audit has a responsibility to provide independent and objective assurance on the effectiveness of governance, risk management and internal control activities (CIIA 2013:6; CIIA 2014:1). Internal audit standards require internal audit functions to evaluate the effectiveness of risk management processes and contribute to the improvement of these processes (IIA 2012:11-12; IIA 2013a:1-2).

According to Head (2009:5-6), internal audit functions should be able to adapt to changes in the risk landscape, and focus these adaptations on critical risk areas. Dolan and Moran (2013:43) state that an adequate internal audit function ensures improved effectiveness in the identification of new and emerging risks and an appropriate audit response.

Whalen and Holt (2013:63) emphasise that internal audit must redefine their mandate, moving beyond identifying compliance and financial reporting risks, to focus on risks critical to the organisation as a whole. This process includes identification of key strategic and significant operational risks. According to Murphy (2011:137), the importance of internal audit's role in banking institutions in the identification of risks and the provision of assurance regarding the effectiveness of controls has increased significantly.

Within banking institutions, model risk is classified as a significant risk (Keyes 2011:7) and therefore internal audit must play a major role regarding the provision of assurance activities addressing this risk. Although various research studies and professional publications are available in which model risk management and the requirements of model validation are discussed, there is little discussion on the role of internal audit, nor on the practical coverage required by independent assurance providers.

The literature review indicates that internal audit functions should play a crucial role in evaluating the model risk framework, and should evaluate whether risk management activities and controls are complete and effective. In particular, internal audit should evaluate the effectiveness and appropriateness of model risk management practices, policies, implementation testing and verification to ensure that model validation is robust and comprehensive (Pace 2008:28; Dil 2012:48, 50). Monahan *et al* (2012:27) point out that an adequate framework should incorporate all three of the following lines of defence. The first line of defence is manned by those responsible for owning, taking and managing the risk; the second line of defence is owned by those responsible for oversight and challenge, and the third line of defence is defended by those responsible for independent assurance (Ernst & Young 2013b:4). Internal audit's responsibilities within this framework should be to provide the independent assessment of the design, robustness and effectiveness of model risk policies and controls provided and maintained by the first two lines of defence (Ernst & Young 2012:2).

From a supervisory point of view, internal audit functions should have an increased role relating to providing assurance regarding risk exposure during the model lifecycle and related processes (OCC/FED 2011:19; PWC 2011:12; Ernst & Young 2013a:12). Regulator guidelines indicate that internal audit functions should have appropriate skills to assist in model risk management activities. Regulators propose that internal audit should assess the overall appropriateness and effectiveness of model risk management activities, including the framework's ability to address faulty or improper usage of models individually and in the aggregate (OCC/FED 2011:19).

Internal audit is required by regulators to verify and confirm that (OCC/FED 2011:19):

- Model risk policies are in place and that these policies are complied with;
- Validations are timely and accurate, and that effective challenge is being applied;

- Records of model use are kept, and if models are subject to controls, that any weaknesses are appropriately identified;
- Model inventory is accurate and complete;
- Processes for determining and monitoring limits and usage are in place;
- Documentation standards, including risk reporting, are met by model owners and control groups;
- Procedures for updating and changing models are clearly documented and complied with; and
- Data used by models are reliable, accurate and complete.

Additionally, regulators recommend that, rather than duplicating model risk management activities for each model, internal audit functions should evaluate the robustness of the collected risk management activities (OCC/FED 2011:19; PWC 2011:12; Dil 2012:50). Conversely, Chambers (2013:16) points out that internal audit functions should develop a sturdy critical approach to each functional discipline and should perform more than just a “reviewing the reviewers” role within institutions.

The level and breadth of skills required for auditing model risk will be highly dependent on the diversity and sophistication of models used within a particular banking institution. Aksoy and Sezer (2012:1284) state that institutions have different internal auditing requirements and needs depending on their nature, size and complexity.

4 RESEARCH METHOD

Due to the increasing use of models and the associated challenges faced by banking institutions as outlined in the literature review, this study focused on internal audit’s responsibility for model risk. The study investigated the broadening of internal audit’s ambit to include robust coverage of model risk within banking institutions.

The first phase of the research investigated the state of model risk management practices (whether they are fully embedded within banking institutions), and the maturity of such practices. The investigation sought to gain an understanding of the current challenges and risks that could affect the practical implementation of a model risk management framework. The aim was to identify which risk aspects internal audit functions should focus on when performing audit activities relating to model risk. In the second phase, an empirical study was carried out to determine the degree to which internal audit functions have already responded to, changed and/or enhanced their assurance activities over model risk in the wake of new regulatory guidelines. Lastly, the research investigated whether the required skills, knowledge and competencies do in fact reside within currently operational internal audit functions.

The data sources comprised the results of three global surveys performed by Deloitte (2014), KPMG (2013) and Protiviti (2013) respectively. The 2014 Deloitte study was based on global model practices and was conducted among 96 different (functionally unrelated) financial institutions worldwide. The survey analysed model validation practices within these financial institutions.

The 2013 KPMG study examined model risk management practices in the financial services industry. More than 60 financial institutions in the United States (US) participated in the study. The respondents were drawn from a diverse cross-section of financial institutions and included international non-US banks, regional US banks and global banking institutions. The study was undertaken to confirm whether model risk management practices had been established for and within the industry.

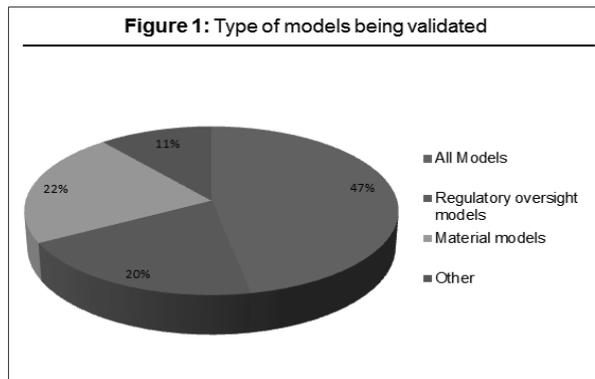
The data for internal audit skills needed to audit model risk were extracted from the 2013 Protiviti internal audit capabilities and needs survey results. Over 100 study participants within the financial services industry were required to assess their level of competence, areas for improvements and industry challenges.

5 RESULTS

5.1 State of model risk management practices

The results of the surveys performed by KPMG (2013:2) and Deloitte (2014:24) indicate that many banking institutions are enhancing their capabilities and taking a more proactive approach to model risk management. However, inconsistencies remain, and there is significant room for improvement with regard to the application and implementation of model risk management practices. The challenges identified in the surveys included the uncertainty about defining and rationalising the terms model and model inventory, and determining which models to include in the validation process. Figure 1 shows the analysis presented by Deloitte relating to types of models being validated by financial institutions. This shows that around half of financial institutions validate all models, whereas some only validate material models or models subject to regulatory oversight. Furthermore, the analysis shows that approximately two-thirds of financial institutions indicate that model validation should include all models. This is illustrated in Figure 2.

The results of the studies indicate that financial institutions remain uncertain and/or ambiguous in their efforts to assess model risk, adhere to validation cycles, and enforce validation findings. Findings further show that model risk management and validation activities are often decentralised, fragmented, incomplete or unreliable. Additionally, the studies show that model validation functions were under-resourced and that defining roles and responsibilities was challenging.



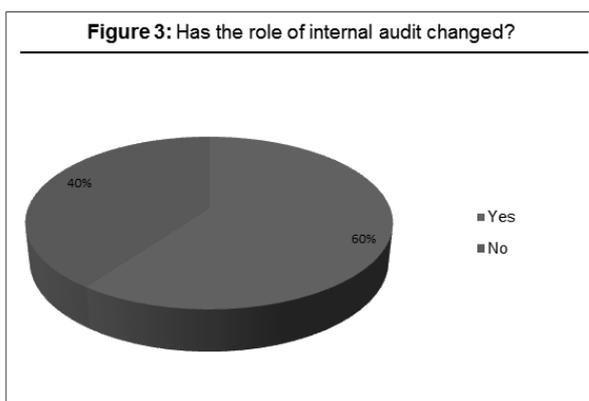
Source: Deloitte (2014: 9)

These results suggest that financial institutions are unclear about the number of models they have in place and uncertain if all models in use remain valid or are being used appropriately.

The results reflect various opportunities for internal audit to standardise and enhance model risk management activities in their institutions by making recommendations on how to streamline and improve model controls.

5.2 Internal audit coverage of model risk

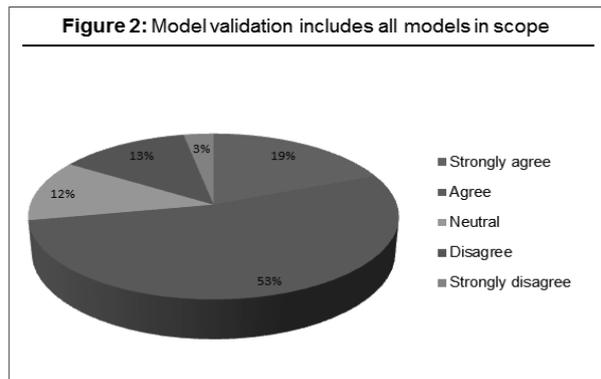
The KPMG (2013:14, 16-17) study's scope included an assessment of internal audit itself. The survey investigated whether internal audit functions had changed their assurance activities to include the then proposed regulatory guidelines. Figure 3 illustrates the perception that internal audit's role in model risk management and model validation had changed positively. The results highlight that approximately 60% of the respondents had made some changes to the coverage provided by their model risk management practices. The changes made included a greater focus (allocation of time and other resources) on the audit of model risk policy, increased



Source: KPMG (2013: 17)

5.3 Internal audit competencies and skills

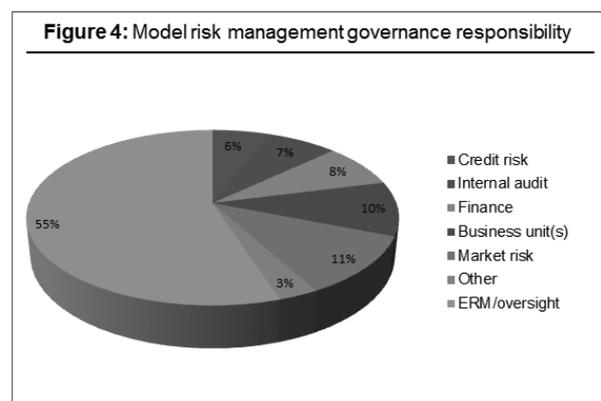
An internal audit capability and needs survey conducted by Protiviti (2013:3-4) during 2013 highlighted that auditing model risk management was ranked as the number one area within financial institutions' internal audit functions that required improvement in competencies and skills. The results



Source: Deloitte (2014: 8)

involvement in the challenge process, closer monitoring of the lines of defence and more emphasis on model-specific audits. However, 40% of the respondents indicated that the internal audit function's role in addressing model risk had not changed. This was most likely due to the inconsistent understanding of the required range and depth of internal audit procedures and approaches appropriate to model risk across institutions.

Figure 4 shows the allocation of responsibilities for model risk management governance (i.e. model risk management function). The results reflect that within the banking industry, the responsibility for model risk management rests with internal audit, business units, credit administration and/or finance. It was cited in the KPMG survey that this was a result of so-called legacy organisational structures. However, based on the three lines of defence model (IIA 2013b:4-6; Mays & Sangha 2012:14), researchers recommend that this responsibility should reside with the second line of defence. Internal audit should provide independent assurance and challenge the various components of the model risk management framework (Dolan & Moran 2013:42).

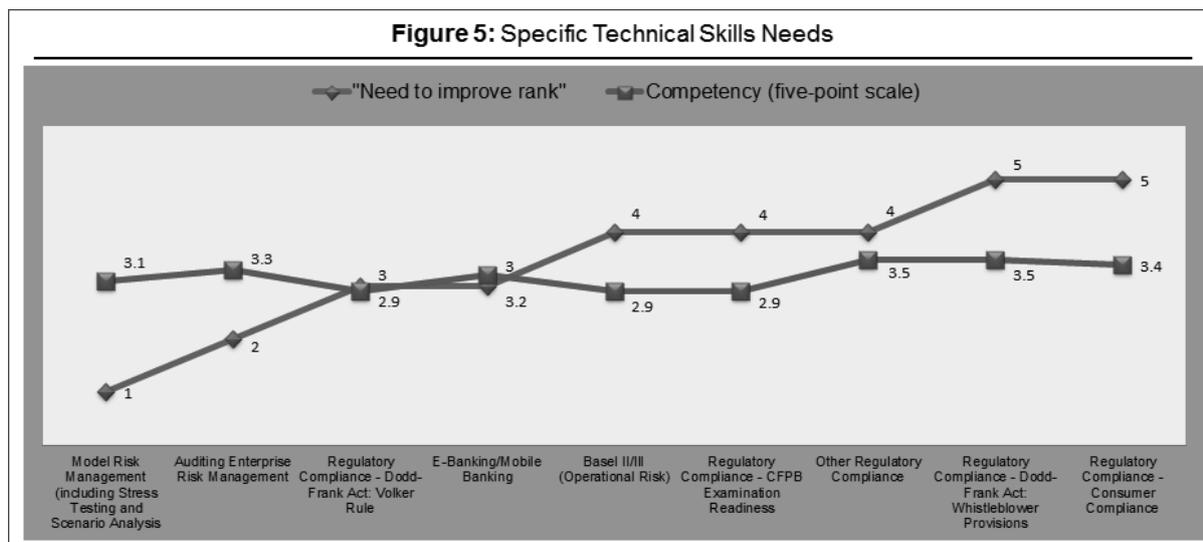


Source: KPMG (2013: 14)

of the survey and study are highlighted in Figure 5. The reason for this specialised skill being cited as a challenge for internal audit is that the auditing of models requires high levels of quantitative and mathematical skills which are often scarce resources. This view is supported by Le Rice (2014:22), who recommends that internal audit functions in the financial sector should be required to employ

mathematicians and data scientists. Furthermore, as highlighted by Bartolucci and Chambers (2008:66), the internal audit profession accepts that a lack of

specialised skills, capabilities and capacity is collectively one of the primary challenges to their achieving their mandate.



Source: Protiviti (2013: 3)

6 DISCUSSION

There continues to be inconsistency in the wide range of practices implemented by financial institutions relating to model risk. In particular, internal audit functions face challenges relating to coverage of model risk arising from their current audit procedures and approaches. Some of these factors can be attributed to the complexity, nature and size of the financial institutions. Additional factors include the absence of clear guidelines to the profession regarding the audit of model risk. Although regulatory guidelines have been made available for internal audit, uncertainty about their practical application persists, and the interpretation of these guidelines remains vague. Additionally, it has been established that internal audit functions lack specific skills and knowledge, resulting in their inability to appropriately cover model risk. The qualifications and skill sets required for auditing model risk is not discussed in detail in this research paper, and is proposed as a topic for further research.

In order for internal audit to have an impact on the coverage of model risk, it is proposed that they formally incorporate appropriate coverage of this risk in their audit plan. Given the sheer volume and complexity of available models, not all of them can be subjected to independent oversight by internal audit in a single audit cycle. Therefore, internal audit will be required to prioritise the coverage of specific models and model risk management activities. This should be performed based on the model's materiality (risk and use) and on the significance of the model's output to

the entity. Internal audit should therefore vary their coverage and should utilise different approaches and types of audit review when assessing this risk.

Based on practical experience, focus group interviews and a literature review, a recommended audit approach for the coverage of model risk was developed. The proposed approach is illustrated in Table 2.

6.1 Model risk governance audit reviews

The aim of model risk governance audit reviews is to check that the board and executive management have set the tone and that a robust framework for their model risk assessments is in place. During these reviews, internal audit should verify that the institution has adequately developed the roles and responsibilities of the board, executive management, model developers, model owners and control groups in respect of model risk management activities. Internal audit should ensure that appropriate oversight is performed, and that segregation of duties, effective challenging and model performance reporting (model limits and restrictions) processes are in place. Internal audit should check that model approval processes have been established and are being followed for initial model approval and for ongoing use. Additionally, internal audit should verify that processes are in place to ensure the regular updating of model inventory. The institution must have formalised these activities and controls within its policies and procedures manuals. Table 3 outlines key issues that audit should verify are in place in these policies.

Table 2: Audit coverage of model risk

Audit Type	Examples of audit/audit focus areas
Model risk governance audit reviews	<ul style="list-style-type: none"> • Policies and standards • Senior management reporting • Model inventory management • Coverage plan and independent model validation • Documentation standards • Model approval
Business unit reviews covering models	<ul style="list-style-type: none"> • Model development and documentation • Review and approval of the use of the model • Data accuracy and completeness (historical data/model input data) • Correctness of model inventory • Implementation testing • Systems and accuracy of implementation • Post-implementation reviews • Model monitoring • Model validation • Change control over model code
Model-specific audit reviews	<ul style="list-style-type: none"> • Model code review • Mathematics review • Model methodology review • Re-perform validation tests • Model is in compliance with regulatory requirements
Regulatory audit reviews	<ul style="list-style-type: none"> • Risk-weighted assets calculation • Use test • Senior management awareness • Implementation of regulatory models • Self-assessments for regulators
Business monitoring	<ul style="list-style-type: none"> • Attend technical and monitoring committees • Management meetings/interviews • Audit issue follow-up • Review ongoing model performance monitoring reports, validation results and coverage • Tracking of model projects and control issues

Source: OCC/FED (2011); Davies (2012); KPMG (2012); Ernst & Young (2012); Ernst & Young (2013a); Board of Governors of the Federal Reserve System (2013)

Table 3: Auditing of model risk management policies and procedures

Audit focus areas	Auditing model risk requirement
Policies and procedures	<p>Model risk management policies should be reviewed annually and updated on an ongoing basis. The policies should include the following aspects:</p> <ul style="list-style-type: none"> • Model and model risk definitions • Acceptable and clearly assigned roles and responsibilities for the model owner, model developer, primary and secondary users, independent validation, control groups • Control requirements over model development, implementation, and use • Mandatory requirements for ongoing model validation activities, including validation framework and policies • Model classification and materiality (based on use and complexity) • Model inventory management • Appropriate oversight by the board and executive management • Procedures and approval authorities for the review and approval of new, changed and recalibrated models • Model documentation standards • Model reporting standards • Segregation of duties • Data quality framework and standards • Audit oversight.

Source: Kogler and Vetrano (2007: 90–93); Pace (2008: 28); OCC/FED (2011)

6.2 Business unit reviews covering models

The purpose of business unit review audits is to confirm that appropriately defined processes, methodologies and controls exist for model development, implementation and use at this level of the organisation. The extent of audit coverage and scope during these audits should be based on the materiality, complexity and extent of use of the model,

as well as on the stage of the model in the model's lifecycle.

These audits must verify that data accuracy checks, model validation and model testing occur at each of the stages of the model lifecycle. Internal audit should ensure that model validation and model testing activities are rigorous assessments that facilitate credible challenges that identify model weaknesses

and limitations. These validations should verify the stability and accuracy of the model and establish whether the model is performing in accordance with its design and intended business use. Appropriate

action plans should address model weaknesses, and redevelopment plans should be in place for models performing sub-optimally. Table 4 outlines the audit testing of model validation.

Table 4: Auditing of model validation, monitoring and testing

Audit focus areas	Auditing model risk requirement
Model validation	<ul style="list-style-type: none"> • Validation was scheduled on the coverage plan and takes place as scheduled • Validation verifies that there is sufficient documentation and paper trail of the model's design • Verify that validation evaluates the conceptual soundness by assessing the quality of the model's design and construction. The validation should include the following analysis or sanity checks: <ul style="list-style-type: none"> ◦ Efficiency/discriminatory power, accuracy/back testing, stability and convergence ◦ Benchmarking or replication ◦ Stress testing or boundary tests ◦ Sensitivity analysis ◦ Computational testing • Limits and triggers have been defined for the appropriate metrics, were consistently applied and the commentary provided was in line with the monitoring results • Validation includes the review of data integrity and data controls (missing data, input data validation; up to date data and frequent information refresh) • Judgment exercised in model development was reviewed for accuracy and appropriateness • Confirm effective challenge in the model validation process and that it was performed by an experienced and competent independent reviewer • Validation reviewed for any material model changes (model agrees to the approved model) • Validation identifies and communicates limitations of the model • Validation was reviewed and signed off by the model owner, business owner and control groups • Actions arising from the validation are logged, tracked and remediated in a timely manner

Source: Lynas and Mays (2010: 45 – 46); OCC/FED (2011); Davies (2012)

Additionally, audit should verify the completeness of the model inventory, correctness of the assigned model materiality, adherence to model documentation standards, existence of model change controls and appropriate storage of model data (input and output).

6.2.1 Model development

During the development phase of the model lifecycle, internal audit should assess the soundness and effectiveness of the model development procedures. Internal audit should check that model documentation produced by the model developer is sufficiently detailed to enable independent re-creation of the model. Model documentation should include the criteria set out in Table 5. In addition, the audit coverage should confirm that data quality, relevance and initial model validation have all been tested. The coverage should verify that new models, model changes or model recalibrations have all been

appropriately approved prior to implementation and use.

6.2.2 Model Implementation

During the implementation phase of the model lifecycle, internal audit should verify that user acceptance testing, training, and implementation testing have been conducted and documented. Audit coverage of implementation testing should verify that data quality reviews have been performed and that the code has been tested. The nature of these tests and results should be documented, assessed and approved by the model and business owners prior to the model being implemented. Internal audit should check that the models have been applied in a controlled system environment with appropriate access restrictions and change controls. Additionally, internal audit should check that additional testing was completed after model results had been produced.

Table 5: Auditing of model documentation

Audit focus areas	Auditing model risk requirement
Model documentation	<p>Model overview</p> <ul style="list-style-type: none"> • Statement of purpose, overview of the approved use and nature of the decision the model will support • Description of the modelling approach • Model materiality • Roles and responsibilities (model developer, model owner, users) • Model history <p>Model theory and approach</p> <ul style="list-style-type: none"> • Detailed description of the methodology, model design, theory, logic, estimation techniques and key assumptions used • Known model weaknesses and limitations <p>Data utilised</p> <ul style="list-style-type: none"> • Model development data used including details of the data source, field definitions, allowable values and ranges, filtering rules, data cleaning and segmentation • Treatment of missing values and a justification for the approach chosen • Treatment of conservatism and how it is sufficient to account for data integrity and quality • Analysis of the accuracy, completeness and relevance of the data utilised <p>Model testing</p> <ul style="list-style-type: none"> • Detailed documentation on model testing including back testing, benchmarking (comparison of model predictions), stress testing, statistical measures, out-of-time and out-of-sample testing <p>Monitoring, limits and triggers</p> <ul style="list-style-type: none"> • Details of the proposed monitoring plan going forward • Details of the limits and trigger measures to be used to assess model performance <p>Governance and control</p> <ul style="list-style-type: none"> • Details of the testing and implementation plan, how changes to the model process are managed, data quality requirements and the treatment of model overrides

Source: PricewaterhouseCoopers (2013: 3 – 6); OCC/FED (2011)

6.2.3 Model use

During the use phase of the model lifecycle, internal audit should verify that appropriate controls are in place to ascertain whether the model is functioning effectively and being used appropriately, and that it is performing correctly over an extended period of time. Internal audit should check that model monitoring is carried out regularly and that independent validation is performed annually. Additionally, internal audit should verify that data accuracy and completeness controls are in place, and that overrides as well as post-model adjustments are being monitored.

6.3 Model-specific audit reviews

Model-specific audit reviews should be performed only on models with outputs that are material to the institution. Internal audit should verify for such a model that the model's methodology, conceptual soundness, approach and code are adequate and appropriate for its business purpose. The aim of these audits is to perform re-performance testing of the model's computer code or mathematical formulas to identify any potential flaws or weaknesses. The internal audit plan should include an analysis of the extraction rules applied by performing a line-by-line review of the code used, and should check that the code of the model corresponds to the approved and documented model method. During these audits, internal audit should challenge the model methodology used, and if the method underlying the model is uncommon, non-standard or unique, determine whether it is supported by professional journals or best practice guidelines.

Additionally, model-specific audit reviews should include performance testing of model monitoring and model validation controls. This includes the re-performance testing of model performance measurement calculations, triggers and metrics. The aim of these audit tests is to verify the quality of validation testing and the accuracy of validation results by verifying that internal audit obtains the same results as these control groups.

6.4 Regulatory audit reviews

Regulatory audit reviews of models should be risk-based, and follow a systematic approach to assessing that models comply with regulations. Internal audit should perform independent verification of the accuracy of financial information and other information derived from model use, which is reported to regulators. Some of the audits should include the review of risk-weighted assets, the use test, senior management awareness and model self-assessments requested by regulators.

6.5 Business monitoring

Business monitoring of model risk requires that internal audit performs an ongoing evaluation of the need for audit coverage of model risk and to timeously update the annual audit plan. The intention of business monitoring is to keep internal audit up to date on the ever-changing model risk environment within the banking institution, so that it may better understand emerging (unknown) or known model risks. Business monitoring of model risk should form part of internal audit's risk assessment processes that informs adjustments to the audit plan, the audit

universe, internal audit reporting and periodic audit summaries as they occur.

7 CONCLUSION

Models have become central to the operation of banking institutions; however, they have been identified as sources of significant operational and reputational risk to these institutions. Banking institutions have therefore begun enhancing their model governance frameworks, enabling them to better manage and understand the risks posed by their use of models. Internal audit is identified as a critical component of this framework. Internal audit's responsibilities entail the independent evaluation of the effectiveness of the controls maintained by the first two lines of defence, thus requiring internal audit to prioritise model risk in their coverage and to enhance their associated assurance activities.

Conversely, internal audit should be practical about its coverage and assurance activities, given the high

number and often extreme complexity of these models. To have an impact on the coverage of model risk, internal audit should employ an appropriate risk-based approach based on the complexity, materiality and extent of the models used. Employing the audit approach recommended in this research paper would allow for structured and practical coverage of specific models and model risk management activities. Through such regular internal audit reviews and effective challenge, internal audit would be able to enhance governance and risk management activities in respect of this significant risk.

Additionally, internal audit functions should enhance their capabilities and skills in order to provide audit assurance on the conceptual soundness, performance and use of models. However, this type of audit coverage will require experience and skills of a level significantly higher than those that are currently generally employed in the internal audit environment.

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