Bank of Israel
Supervisor of Banks

Jerusalem, October 17, 2010
10LM0779
REG10.115.007

To:
Banks and credit-card companies—attn. Chief Executive Officer

Re: Model Validation Guidance

1. In recent years, the banking system has been making increasing use of various models for risk estimation, pricing, fair value estimation, etc.
2. In view of this trend and in accordance with audits performed at banks and the lessons of the global financial crisis, it is found that the practices in using such models need to be strengthened.
3. The attached guidance (hereinafter: the Guidance) concerns the validation of models; it is based mainly on the model validation guidance of the OCC.[1]
4. The Guidance will go into effect in a phased manner, as follows:
   4.1 By March 31, 2011, the bank shall have completed the formulation of its model validation policy and shall have had it approved by the board of directors.
   The policy document to be approved shall be accompanied by full mapping of the models that the bank is currently using and the ranking of each such model in accordance with its importance to the bank, and by a detailed workplan for the implementation of the Guidance, including a detailed schedule for said implementation. The schedule shall be constructed so that validation according to the Guidance of all models rated as of high importance shall be completed by June 30, 2012, and so that the other models used by the bank shall be validated by June 30, 2013.
   4.2 From April 1, 2011, onward, the Guidance shall apply to new models that are placed in service on that day and thereafter.
5. A bank or credit card company that finds the Guidance difficult to apply by the deadlines specified above should apply in writing to Mr. Ido Yad-Shalom, head of the Regulation Unit.

Respectfully,

Rony Hizkiyahu
Supervisor of Banks

[1] Publication OCC 2000-16, *OCC Bulletin,* "Risk Modeling."

Bank of Israel

Supervisor of Banks

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Model Validation Guidance

1. Background

1.1 Computer models are abstract representations of relations among events and values in the real world. Banks use models to estimate risk exposures, analyze business strategies, and estimate the fair value of financial instruments. In the banking industry, the use of models is growing in importance due to the potential of models to enhance management information systems and the steady improvement in computer capabilities. Today, models are used routinely for credit scoring, asset and liability management, trading risk management, and estimation of the value of financial instruments.

1.2 The process used to develop models is complex and prone to errors. The internal logic of most models is usually very abstract and limited; therefore, it takes much judgment and expertise to apply the results of the model outside the narrow context under which they were derived. It is feared that decision-makers will rely on erroneous models, erroneous exposure estimates, or overly broad interpretation of model results—possibly with serious consequences for banks' reputation or profitability. This problem is generally referred to as "model risk."

1.3 Model risk can be reduced by applying a sound process of model building, that includes rigorous validation procedures. Validation is a process that assesses the accuracy of the model estimates and includes oversight and control procedures that assure the maintenance of estimates accuracy. The model validation process not only enhances the reliability of the model but also promotes improvements and better understanding of the strengths and weaknesses of the model among the management and user groups.

1.4 A model has three components: an information (input) component, which provides assumptions and data that are entered into the model; a processing component, that contains the theoretical model, which is responsible for transforming inputs into estimates by means of computer instructions (computer code); and a reporting component, which translates the mathematical estimates into useful business information. If an error occurs in one or more of the components, the information generated by the model may be meaningless or misleading. Accordingly, an effective model validation process must address all three components.

1.5 The purpose of this Guidance is to present guidelines to help banks mitigate potential risks due to reliance on computer based financial models that were not validated or tested appropriately. The Guidance includes principles for

rigorous validation of a model. However, model validation entails not only technical expertise but also considerable subjective business judgment. It is important for decision makers to recognize that this subjectivity elevates the need for sound and comprehensive validation processes.

2. General principles for model validation

2.1 There are three general applicable processes in model validation:
- 2.1.1 independent testing of the logical and conceptual soundness;
- 2.1.2 comparison against other models;
- 2.1.3 comparison of model predictions against real-world results.

2.2 Depending on the circumstances, any or all of these processes should be separately applied to each of the three components of the model. Banks must develop formal procedures to assure the application of all the foregoing principles when circumstances warrant. The depth and scope of validation should be consistent with the materiality and complexity of the risk being managed. If properly planned, formal validation procedures provide staff with the necessary guidance as to the rigor desired by decision-makers and gives decision-makers confidence that the information obtained from the model is reliable and useful in the given business context and provided at reasonable cost.

2.3 Model quality checks may be performed by a function other than the validators, e.g., users. For example, it is customary for users to test a model in the context of the planned acquisition of a supplier's model or to check the suitability of a model developed by the bank. Although such checks do not qualify as validation under this Guidance, the validator may take them into account in the checks that it performs.

3. Sound validation policy

The validation policy should help the bank to make sure that its model validation efforts are consistent with senior management's view of the proper trade off between costs and benefits.

The validation policy should include the following components:

3.1 Independent checking—the validation team should be as independent as possible of the team that constructed the model. Independent checking should be available within the bank and may be complemented by a check performed by an external checker or the internal audit function.

3.2 Clear definition of responsibilities—responsibility for model validation should be specified clearly and formally, just as responsibility for model construction should be specified. The policy should state that the following two conditions must be satisfied before the model is put into production: first, an independent model-validation unit or external checker document the model validation tests and the factors that convinced them that the model is valid; second, the internal audit function makes sure that the model will not be placed in production without a formal approval from the validation unit. The policy shall state explicitly that senior management must formally approve all models that are used for pricing or compliance with risk limits. Management should approve both the conceptual approach and the key assumptions of these models and should verify the existence of reasonable quality control processes.

3.3 Model documentation—the model should be documented in a way that creates a corporate memory in the event of departure of key personnel.

3.3.1 At the bank level, a catalog of models and their applications should be kept.

3.3.2 At the specific model level, appropriate documentation of the model should be kept to allow independent checking, training of new staff, and clear thinking by the model developers.

3.3.3 An especially rigorous policy requires documentation that is sufficiently detailed to allow the model described to be replicated. A less rigorous policy should require, at the very least, a summary overview of the general processes in use and the reasons for the choice of these procedures, description of the applicability and limitations of the model, identification of key team members and milestones dates in model construction, and description of the validation procedures and outcomes.

3.4 Ongoing validation—even after being placed in production, most models undergo frequent changes in response to changes in the environment or to integrate improvements in the model developers' understanding of the model. However, a change in the model may also be helpful in evading risk limits or concealing losses.[1] Best practices for validation policy require the documentation and independent checking of all changes in model processing. It is a useful practice to allow only periodic changes in the model and even then only after independent checking and approval by the appropriate level of decision-makers at the bank. Several copies of the model code should be kept to facilitate disaster recovery and to monitor changes in the model. Models should be subjected to change-control procedures, that allow the modification of code only per approval of the appropriate official.

3.5 Internal audit oversight—the formal policy should hold internal audit responsible for assuring that model validation and model validation units adhere to the formal policy and that model validation is effective.

4. Validation of the input component of the model

4.1 Data checking

4.1.1 Input data may contain major errors while other components of the model are error-free. In this situation, the model results become useless and even a validation process that would be sound in another situation will not necessarily reveal the errors. Therefore, examination of the input data is an essential and separate component of the model validation process and should be included explicitly in the bank's policy.

4.1.2 Data come from both internal and external sources. Where internal data are concerned, a control function should verify that the information fed into the model agrees with the bank's general ledger

[1] For example, modest changes in assumptions about the future interest rate volatility may significantly lower the estimate of interest rate exposure or increase the estimated value of position in interest rate derivatives. Most such changes would be obscure to members of management, but may conceal noncompliance with interest rate limits or trading losses.

data, terms of existing contracts, etc. External data may also be checked intermittently, against multiple sources.

4.1.3 Inexpensive and highly effective error detection procedures include automated filters and checking of input information by an experienced personnel.

4.1.4 In certain cases, especially those involving relatively new models, it is difficult for the responsible business units to make sure that the input data is accurate. If the bank decides that the model provides useful information despite a data problem, its policy should state that audit, risk management, and modeling team are independently responsible for reporting the data problem to senior management. Thus, the decision makers will be aware that the model results may be somewhat unreliable and that there is a need to devote more resources to providing quality data.

4.2 Use of model assumptions

4.2.1 In addition to data, computer models entail the use of a set of assumptions. The assumptions may be derived from a separate model that itself must be validated under this Guidance.[2] Many assumptions are available in general from available public sources at relatively low cost.[3] Conversely, a bank may think it better to derive assumptions from study of its customer base than by using general information about a national or regional population. Similarly, a bank may think it has a special insight about market behavior and that its assumptions about the markets are superior to publicly available information. Model developers should be able to provide a clear rationale for their choice between assumptions derived from public information and assumptions derived from internal-private information.

4.2.2 Whether the assumptions are derived from public information or from the bank's own research, important behavioral assumptions should be routinely compared with actual portfolio behavior.[4] As a best practice, banks should consider including a comparison of assumptions with actual behavior in their reports to senior management.

5. Validation of the processing component of the model

Model processing includes computer code and the theoretical models that the code implements. Theories are simplified representations of a given reality and

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[2] Main examples include prepayment functions for loan valuation models, market implied interest rate volatility for derivatives pricing models, and assumptions on the withdrawal of core deposits for asset and liability management models. These types of assumptions are generally determined by the use of a separate model that itself has inputs, processing, and outputs that must be validated using the principles set forth in the Guidance.

[3] For example, many banks use data from various vendors about market implied volatility and mortgage prepayments.

[4] For example, prepayment assumptions predict a rate of prepayment for all possible changes in interest rates. These assumptions should be compared, on a monthly basis, to the actual prepayment that the bank experiences in its residential mortgage loans and its security portfolio. When the interest rate changes, so will the bank's actual rate of prepayment. If the actual changes are significantly larger and more consistent than those predicted over a period of several months, then the prepayment function is systematically optimistic, and vice versa.

judgment is applied in order to decide which simplifications to accept. Apart from the choice of theory, validation procedures for model processing should make sure that the mathematical calculations and the computer code are error-free.

5.1 Code and mathematics—several processes are used for the testing of code. Most models, such as those that operate on spreadsheets, have relatively simple code and equations that can be checked at relatively low cost by constructing an identical independent model. If the results of the two models agree precisely, it is highly unreasonable that both, independently constructed, would contain exactly the same error. For more complex models, the construction of an identical independent model may be quite costly. This situation requires alternative practices such as the following:

5.1.1 Assignment of modeling experts to check the code line by line. This practice may reveal most errors but is not immune to errors.

5.1.2 If possible, comparing the results of the model with the results of a benchmark model. This practice is highly useful if the validator can ensure that the inputs and theory of the other model are identical to those of the first model, at least during a trial period. In most cases, however, the inputs and theories of the two models will be different, at least somewhat, meaning that there will be at least slight discrepancies between the models' outputs. Unless the discrepancies are conspicuous, the validator will have to render a subjective judgment to determine whether the differences in outcomes were caused by differences in inputs or by processing errors in the model constructed.

5.1.3 Leveraging of existing processes at the bank, e.g., by running a bank algorithm on a different dataset or using the dataset in an independently developed algorithm.

5.2 Theory

5.2.1 To implement a computer model, the developer of the model usually has to solve several questions in statistical and economic theory. The answers to the theoretical questions are usually a matter of judgment, although the theoretical implementation is also susceptible to conceptual and logical errors. One way to avoid errors of this kind is to make sure that the developer of the model has requisite skill and experience to do the job. One of the main sources of model errors is the use of theoretical tools, usually statistical methods, by unskilled model developers.

5.2.2 Another important element in model validation is independent checking of the theory that the bank employs. Under many circumstances, internal checks are quite effective. Under other circumstances, effective internal checking is difficult to accomplish. In these cases, senior management should expect model developers to provide a clear description, in nontechnical terms, of the underlying theory of the models and to show that the underlying theory of the model has received recognition and support from professional journals or other forums.

5.2.3 Comparison with other models is generally a useful technique for the detection of errors. Other models include prior models or similar models already in use at the bank, market prices (which represent the

"true model"), and publicly available results of a model. When a new model is developed, comparison of the outcomes with other sources of information will confirm the expectations of the developers of the model, reveal errors in the model, or lead to an enhanced understanding of the phenomenon being tested.

5.3 Vendor's model—a bank that uses a vendor's model also needs to be sure that the model is defensible and works as promised. Vendor s' models confront banks with a dilemma of convenience vs. transparency. Under the constraint that the vendor will not reveal proprietary information, users of a vendor's model should demand that the vendor provide information about how the model was constructed and validated. As professional model developers, vendors should themselves use appropriate validation practices and prove to their banking customers that they have done so. A common misapprehension about vendors' models is that their processing component does not need validation because they have "met the market test". In fact, banks that subject vendors' models to good validation practices often detect material processing errors. This experience proves that the validation principles should be applied whether the model was purchased from a vendor or developed in-house. When banks assess vendors' models, they should take account of the ease with which processing or software errors, once identified, may be corrected.

6. Model reports (management information systems)

Once the data are processed, the model generates a price, an exposure estimate, or decision indices that decision makers will use. The model validation process should assess the validity of these estimates. It is no less important, however, that the reports generated from the model outcomes be clear and that decision makers understand the context in which they were produced.

6.1 Validation of model outcomes

6.1.1 Many procedures used to validate the input and processing components of a model are also useful in validating the outcomes of the model.

6.1.2 Once the model begins to generate outcomes, its developers and validators should compare the outcomes against similar models, market prices, or other available benchmarks.

6.1.3 As the model is being used, its estimates should be compared with actual results in a process known as "back testing."

6.1.4 Many models, assets and liabilities models in particular, generate projections that are conditional upon the economic environment that actually materializes. Over time, such conditional projections may also be validated against actual outcomes.

6.2 Validation of report contents

6.2.1 The business decision maker and the model developer usually have different backgrounds. Even when pricing and risk reports seem clear, the model developer and the decision maker may interpret the information differently. For example, decision makers generally misinterpret the outcomes of a model-generated risk estimate as a "worst-case scenario" even though there are inevitably plausible scenarios and assumptions under which the bank may lose more than estimated.

6.2.2 A bank's model documentation policy should include the requirement of an executive summary that is made available to senior management. Since the questions that the model answers are always rather narrow in logical terms, an explicit statement about the purpose of the model helps senior decision makers to understand the limitations of the model. The executive summary should include the main assumptions in order to give the limitations of the model special emphasis.

6.2.3 An independent check of the underlying theory of the model should relate to reports that convey information from model developers to decision makers. An essential element of designing a model's reports is ensuring that the outcomes are presented clearly and accessibly.

6.2.4 Model reports based on best practice include a sensitivity or scenario analysis. Such an analysis generates alternative estimates on the basis of reasonable alternatives to the main assumptions. A scenario analysis not only offers a range of estimates but also to communicate to decision makers the robustness or gragility of the model results.

7. Conclusion

Model validation may be expensive, especially for small banks. However, the use of unvalidated models for risk management is an unsound and unsafe practice. Even when the risk is not particularly material, reliance on an unvalidated model is not a good business practice.

Estimation of the costs and advantages of model validation is a subjective and context-dependent task for which senior management is responsible. The bank's formal policy should ensure that the following goals are met:

7.1 Decision makers understand the meaning and limitations of the model outcomes. When the models are too abstract that non-experts cannot understand their underlying theory, the bank should have a model reportage system that transforms the model outcomes into information of use to decision makers, without concealing the inevitable limitations of the model.

7.2 The outcomes of the model are tested against actual outcomes, especially when the model has been used for a reasonable period of time.

7.3 The information fed into the model is subject to control. Input information errors are treated within a reasonable period of time.

7.4 The seniority of the management personnel who oversees the model process is commiserated with the materiality of the risk from the relevant line of business.

7.5 Model validation is independent of model development.

7.6 Responsibilities for the various components of the model validation process are clearly defined.

7.7 The model software is subject to change-control procedures that allow neither developers nor users to modify the code without checking and approval by an independent third party.

Banking is making growing use of computer models for the estimation of risk exposure, the analysis of business strategies, and the estimation of fair value of financial instruments. Given the increasingly important role of models in decision making processes, it is crucial for bank management to mitigate the risk of error in or misinterpretation of model outcomes. The best defense against model risk of

this kind is the application of a sound model validation framework that includes a robust validation policy and appropriate independent checks.