On the treatment of model risk in the internal capital adequacy assessment process

Tilo Bellof, Carsten S. Wehn[1]

Currently, model risk related to risk models is subject of intense discussions between regulators and the banking industry. With regard to increasing requirements on the one hand and yet no standardized approach by banks to handle model risk on the other hand, this article draws the area of conflict by providing a comprehensive definition and delimitation of model risks and the related regulatory requirements. The main focus lies in the systematic treatment of model risk in the context of internal governance and internal capital adequacy, its appropriate assessment or quantification as well as an adequate procedural handling of model risk. The article shows the main different approaches of how to incorporate model risk in the internal risk management and discusses the respective pros and cons.

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[1] *Tilo Bellof is head of the risk-modelling team at DekaBank, Frankfurt. In this role, he is responsible for the development of portfolio models for market, credit, and operational risks.*

Dr Carsten S. Wehn heads the model validation team at DekaBank, Frankfurt, and is responsible for independent validation of risk and valuation models.

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Content

1 Regulatory and economic requirements for model risk

1.1 Current state of the discussion and definition of model risk

There are currently many different definitions of the terms ‘model risk’ and ‘model uncertainty’ in the industry. A uniform standard with regard to the definition and thus the handling of model uncertainties has begun emerging only recently. In the following, model risks are defined and distinguished from other risk types to describe a systematic treatment in terms of assessment, as well as to deal with those uncertainties within the risk management system.

Based on the quite broad understanding of the US OCC [1] and the Federal Reserve [2] (known as SR 11-7), the article at hand comprehensively considers models as quantitative methods, systems, or approaches that use statistical, economic, or mathematical theories, techniques, or assumptions. In a narrow context, the article at hand focusses on different kind of models used for the internal capital adequacy assessment process, i.e. market risk models (VaR models), credit risk models, and economic capital models and alike.

The OCC [1] continues to expand the components of models very generally under this premise as follows:

1. input of data
2. components that process the incoming data under certain assumptions
3. output and reporting of components.

On the basis of this understanding of models and modelling in general, the OCC describes model risk as all possible adverse consequences that can result from correspondingly inadequate or incorrectly implemented models as well as from their outputs and reports. In view of the OCC [1], this concept also includes, in particular, financial damage, bad strategic or business decisions, or even damage to reputation. E.g., the Global Financial Crisis (2007/2008) lead to severe financial and reputational damages for the whole banking sector due to simplifications in pricing models and risk-measuring models like classical Value-at-Risk (VaR). Such risk is, therefore, the result of the model-inherent simplification while trying to represent reality and a statement is to be made about it.

Regarding the current European regulatory framework, the term ‘model risk’ is referred to by the European regulation in Article 85 of [3] in the context of operational risks in the sense of a relevant subcategory. However, no further specification is made in this context. The respective guidelines of the European Banking Authority EBA [4] on the supervisory review and the evaluation process (SREP) published in December 2014 by the European Banking Authority differentiate between the already mentioned model risk (incorrectly implemented or applied model) and the risk of an underestimation of regulatory capital requirements by models subject to supervisory approval. In the following, the aim is to structure the spectrum of possible approaches to deal with model risks that have already been drafted by the above-mentioned heterogeneous supervisory perspectives and to make them available under a systematic and practicable treatment.

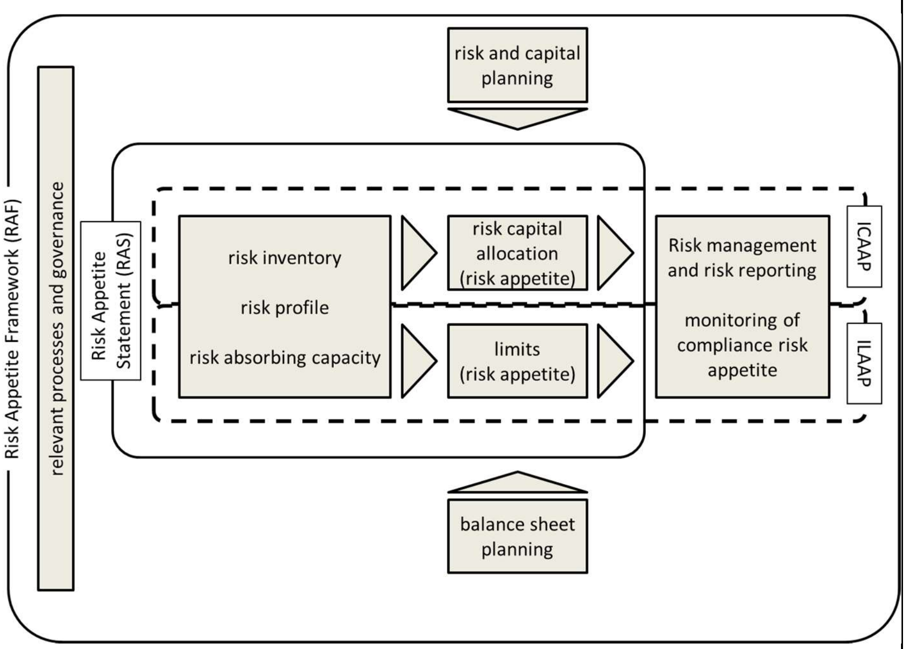
The interpretation of models as corresponding algorithms as sketched above can further be systematized regarding the respective area of application. In a very broad sense (as it is drawn in [1]), model risk considers all kinds of models, e.g. valuation models for pricing functions for financial instruments, especially in the (daily) profit and loss calculation and also models for investment decisions, portfolio optimization, etc. This very general approach, however, creates a complexity that is difficult to control. Hence, we narrow the focus to models used within the context of the internal capital adequacy assessment process, i.e. with the specific objective of identifying an expected or unexpected loss (e.g., value-at-risk or expected shortfall).

1.2 The role of risk models in the ICAAP

Starting with the Basel II accord, the role of internal methods to assure the capital adequacy was established by its pillar 2. This was refined several times by international activities (Basel III and further) and also national or supra-national requirements (see e.g. [4]). Nowadays, the internal capital adequacy assessment process (ICAAP) and the internal liquidity adequacy assessment process (ILAAP) are understood as a multitude of risk management tools, starting with the respective inventory of risks, the understanding of the specific risk profile and the definition of risk absorbing capacity and resulting by the means of adequate risk models in the monitoring of the risk appetite. The ICAAP (and also ILAAP) is embedded in the risk appetite framework that also comprises relevant processes and governance. Figure 1 depicts the different instruments in the ICAAP and ILAAP and its surrounding.

Whereas the ICAAP plays an important role for all institutions within the Euro-zone, in the US only the biggest players were forced to implement a stringent ICAAP. Here, the respective stress tests (like CCAR) are much more prominent. Nevertheless, in our context, many activities concerning model risks are first developed by US regulators, thus heading the discussion around it.

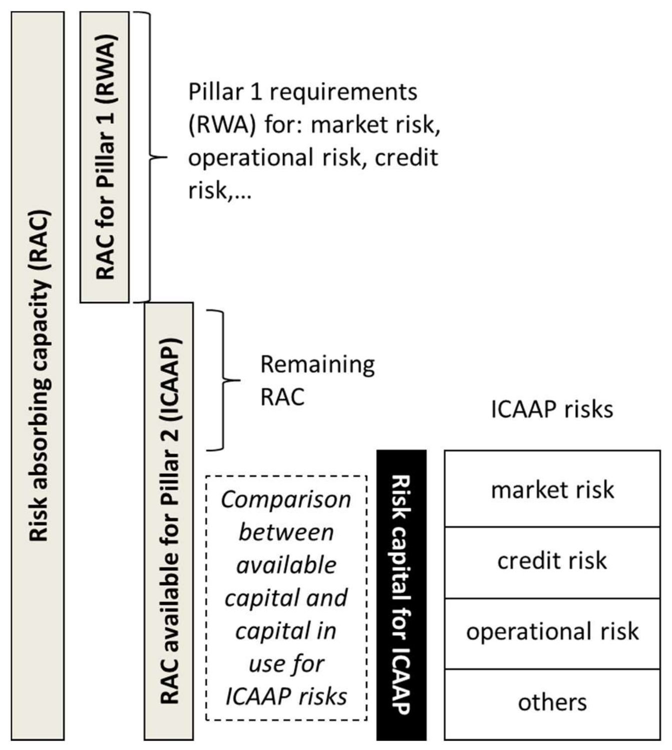
Figure 1: The role of ICAAP and ILAAP in banks



Source: Author's own visualization.

There are two main perspectives for measuring the internal capital adequacy, namely a going concern and a gone concern approach. Whereas the first assumes the continuation of the banks' activities, the later seeks to prevent banks creditors from losses in the case of liquidation of the institute. Figure 2 shows where the comparison between the available risk absorbing capacity and the risks calculated by respective risk models come in the play for a going concern perspective. Starting with a regulatory definition of the overall risk absorbing capital (mainly own funds and alike), some part of this capital is reserved to ensure that regulatory requirements are still met (for example the respective capital quotas). The remaining risk absorbing capacity then is compared to the risks by the internal definition and calculated by internal means and methods (black drawn box in Figure 2). The gone concern perspective is in principle comparable to the going concern, but there are differences in defining the risk absorbing capacity along internal definitions and by the assumptions to calculate the ICAAP risks.

Figure 2:ICAAP in a going concern perspective



Source: Author’s own visualization.

As already mentioned above, we focus on the risk capital calculated by own methods and respective risk models (ICAAP risks) and the relevant comparison with regard to available risk absorbing capacity.

1.3 Model risk for risk models

In addition to the scope of application of a model, the nature of the error, which can potentially lead to damage, can be differentiated in a complementary manner. If the error lies in the implementation or use of a model, then the reason can be found in technical or human failure and is therefore part of the common definition of operational risks, therefore being already part of the ICAAP risks: According to Article 4 of the Capital Requirements Regulation [5]: ‘operational risk' means the risk of loss resulting from inadequate or failed internal processes, people and systems, or from external events, and includes legal risk.’ In contrast to errors during the implementation or use of models being part of operational risk, we see model risk resulting from consciously made assumptions of a risk model and thus not erroneously.

Here it should be noted that risk models usually require valuation models as a prerequisite insofar that a certain dependency (neglected here) exists, which has been shown not least by the subprime and financial crises. E.g. backtesting value-at-risk demonstrated several short-comings of traditional pre-crisis pricing models for interest rate derivatives like neglecting basis risks among others. Operational risks in connection with misuse or unspecified application of models are collected and assessed in many institutions by means of already established processes (e.g. self-assessments and data collection on damages). The referral to model risks or uncertainties due to assumptions made by the developer, parameterizations, or calibrations is, as already mentioned, not subject to any industry-wide standardization yet. Against this backdrop, a set of possible approaches has been presented below. Again, we focus on the context of risk models.

With regard to the assessment of model risks or model uncertainties, a further distinction is made between possible causes. Starting from the focus on model uncertainties for risk models, three main areas of further investigation that are closely linked to the respective causes can be identified:

1. *Estimation errors or parameter uncertainties:* Algorithmic methods commonly use statistics or estimators for which confidence areas can again be derived and computed within the respective model framework. This is a narrow interpretation of the type of cause, which nevertheless has the advantage that this cause (at least in a univariate sense) is usually relatively easy to quantify.
2. *Variation of individual model assumptions:* In this case, decisive assumptions within the algorithm (e.g., certain distributional assumptions) are targeted and then these assumptions are varied. This somewhat broader interpretation of the causal categories presents considerable requirements for quantification and their interpretation as long as such a possibility is still reliable (for example, how much more likely is a certain empirical distribution compared with to a parametric distribution?).
3. *Use of challenger models:* The complete model is replaced by a plausible alternative model, which, in turn, is used with other assumptions and algorithms. In this case, an interpretation of the resulting differences regarding the possible model uncertainty is very demanding.

Depending on the focus of model uncertainties, there are implications with regard to the management and framework of the internal capital adequacy process (see below). While concentrating on estimation errors or parameter uncertainties, the accessibility and hence the derivation of confidence areas is easier than while using challenger models, hence a probabilistic access is more feasible. In contrast, the scope of model risk is much broader by comparing also results of alternative model assumptions or even challenger models. We will get more in detail about this in the next section.

2 Integration into the risk management processes

As mentioned before, no uniform standard has yet been established for either quantifying or dealing with model risks in risk management. Hence, the implementation of these processes into a bank's already existing risk management processes requires a careful approach to avoid redundancies or even inconsistencies in the reporting process and the resulting control impulses. The question of an appropriate integration of the processes involved in model uncertainty now is divided into three parts, each of which is discussed in the following sections:

- How do we adequately assess model risks in risk models?
- What are the processes and bodies that require a reflection of model-based uncertainties?
- What are the options for consideration with respect to the internal capital adequacy process?

2.1 Assessment of model risk for risk models

The assessment of model risk is very much dependent on the respective assumptions or uncertainties in the model. As already shown, a categorization makes quantifying the effects of uncertainties and (probabilistic) interpretation regarding individual estimators or parameters much easier than with the use of challenger models. See also the discourse by Quell & Meyer in [6], where the authors treat the problem of defining a (risk) measure, which reflects the respective model risk as a kind of meta-risk.

In the following, it is attempted to systematize approaches to the assessment of model uncertainties. The three categories of cause that were already mentioned are supplemented by an additional perspective in particular for risk models (like value-at-risk- or expected shortfall-models used in ICAAP):

1. *Estimation errors or parameter uncertainties:* The statistical errors resulting from the selection of a basic data period (in the sense of confidence intervals) can be examined by suitable sensitivity analysis. In doing so, the estimators or even relevant parameters are individually deflected appropriately and the effects on the risk figures are quantified. I.e., the effects of shorter or longer calibration periods or different estimation procedures on regular and stressed value-at-risk-figures and confidence intervals might give an impression of estimation errors or parameter uncertainties which can be reported and analysed as part of the validation process.

2. *Local variation of the model components:* The influence of the respective assumption can also be quantified by the (local) exchange of relevant model assumptions (such as parametric vs. non-parametric distribution) and subsequent calculation of the risk figure. In addition, a numerical method (e.g. Monte Carlo simulation) which may be used in the context of aggregation can also be investigated. This especially focuses on the output layer of the model. For example, if using a parametric assumption by Monte-Carlo simulation, this assumption might be replaced by using a historical simulation, i.e., since one can include historical realizations of risk factors into Monte-Carlo simulation value-at-risk models or use a full-blown Monte-Carlo simulation for generating VaR-figures across different desks for aggregating risks on a regular basis, we obtain an impression of the influence of model assumptions on our risk figures and, hence, on their inherent model risks. Because this will usually need an increased effort in terms of processes, model modifications and computational time, it is most likely to include this into the yearly validation process of the model as well. Another local variation might be the comparison between approximated valuation function like by sensitivities to a full revaluation value-at-risk.

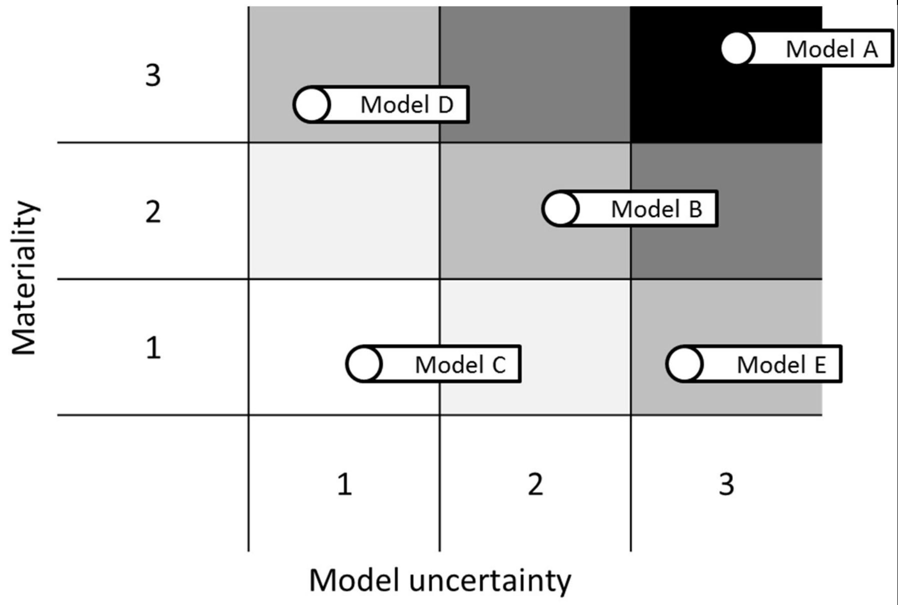
3. *Analysis of challenger models:* In this method, fundamentally different but plausible models are used to compare the output value. This process is relatively complex, since a parallel

development has to be ultimately conducted from the ground up. Moreover, in case of such an alternative modelling, the meaningfulness with respect to the difference in the output figures is quite demanding. I.e., if using a historical simulation as value-at-risk model, we could compare the results with an analytical delta-gamma approach. In a credit risk context, one could even think of replacing a credit metrics like approach by another model like e.g. credit risk+. Once interpreting also regulatory methods as means to derive risk figures in terms of risk weighted assets, another challenger model could be the regulatory approach, e.g. the comparison of an economic capital model for credit risk to the internal ratings based approach in Basel II (interpreted as a one-factor Vasiczek model). It should be noted, that by construction, different models will lead to different risk figures: As the aim is not to have a maximal convergence between results, the analysis of differences gives rather a qualitative impression of structural differences between alternative approaches.

The *actual forecast quality* of the model serves as a decisive additional support to monitor the model adequacy as far as possible: In this case, the basic model quality is examined by means of backtesting. This method assesses the model and its output as a whole and does not focus on individual components. In this case effects due to different assumptions might be compensating one another. Backtesting is particularly suitable for high-frequency observations—for example, in the context of market risks.

The scope and intensity of the procedures that are used should consider a preliminary assessment of the uncertainty and materiality of the risk for which the respective risk model is applied. Here a visualization using a prioritization matrix with dimensions of materiality and uncertainty can help. Figure 3 illustrates this concept for models with different levels of materiality and uncertainty. In order to assess the materiality of the respective model, a metric can be derived, for example, based on the results of the risk inventory or the area of use (for example whether risk weighted assets are derived by the model or not). Also measures not directly linked to the model (like sensitivities for market risk or exposures for credit risk) can give an impression of the materiality of the risk category. For the classification of the uncertainty of the model, assignment rules like an adequate scoring have also to be defined that are consistent to the internal governance and understanding in the respective institution as there are a large set of potential approaches available. In practice, we would break down the model in its components and give a certain score by qualitative or expert-based assessments in particular. The results from validation analysis should then also enter the score for uncertainty as well as results from analysis performed under the angle of the three points above (especially parameter uncertainties and local variation). For risk management purposes, the following principle applies: A higher uncertainty of the model and a higher materiality corresponds to more intense treatment with regard to the model uncertainties involved (in Figure 3, for example, Model A).

Figure 3: Prioritization matrix for different models



Source: Author's own visualization.

In practice, the consideration of uncertainties in the context of internal risk management processes is not trivial — for example, the probabilistic interpretation of the use of a completely alternative model approach that might be necessary for a direct interpretation in the ICAAP is not obvious. Against this backdrop, the definition and ultimate treatment in the risk management process is the responsibility of a suitable management body; it represents not only the development and validation of the model, but also the use of the model. This issue is addressed in the next section.

2.2 Roles, processes, and committees

Integration into risk management processes can only be conducted with a clear view on the scope of coverage — i.e. the exact scope of coverage (in the preceding case, for example, risk models). Such a written inventory with clearly defined content (e.g. elaboration of core functionalities, limitations and strengths/weaknesses of the model, and the potential model-inherent causes for model uncertainties) thus forms the basis of the risk management process (cf. also, e.g., the studies and white papers by Ernst & Young [7] or KPMG [8]). A model inventory hence should draft the main purpose and use of the model, all relevant assumptions and components of the respective model, a history of model changes, results of the modelling and validation processes and alike, see e.g. [1].

The model risk function which has to be part of the independent control function should cover the following responsibilities (cf. [6] or [9]):

- Development and maintenance of a model risk assessment framework
- Maintain the model inventory
- Definition and observation of materiality limits for models
- Standardization with a view to validation
- Ensure validation
- Reporting of validation results and other conclusions

If the scope of application is limited to risk models, then linking the inventory with the annual risk inventory is advisable. Basically, with more comprehensive models involved, the establishment of a separate regular process for collection for the maintenance of the model inventory is more likely. The organizational anchoring of responsibility for the guidelines and coordination of the model inventory should be based on it.

During the actual inventory of the relevant models, all essential information of a model is collected on the basis of a standardized template and structure. This includes, for example, a brief description, scope of application, responsibilities, and model history. This process also corresponds to the expectations of the OCC [1]: ‘Model inventory: Banks should maintain a comprehensive set of information for models implemented for use, under development for implementation, or recently retired.’

On the basis of the model inventory, a model-specific assessment of model uncertainty is carried out. It is recommended that this step be considered as a continuation of the regular, usually annual, validation process. This approach is not only a matter of efficient use of resources, but also ensures the greatest possible consistency of results (cf. also the aforementioned arguments in section 2.1). Furthermore, the following applies: The analysis and knowledge of the validation of individual model components can and should be used for a qualitative assessment of model uncertainty (for example, for the above-mentioned matrix) and the quantification of model uncertainties. For example, the results of alternative modelling approaches can find immediate inputs in the quantification of model uncertainty.

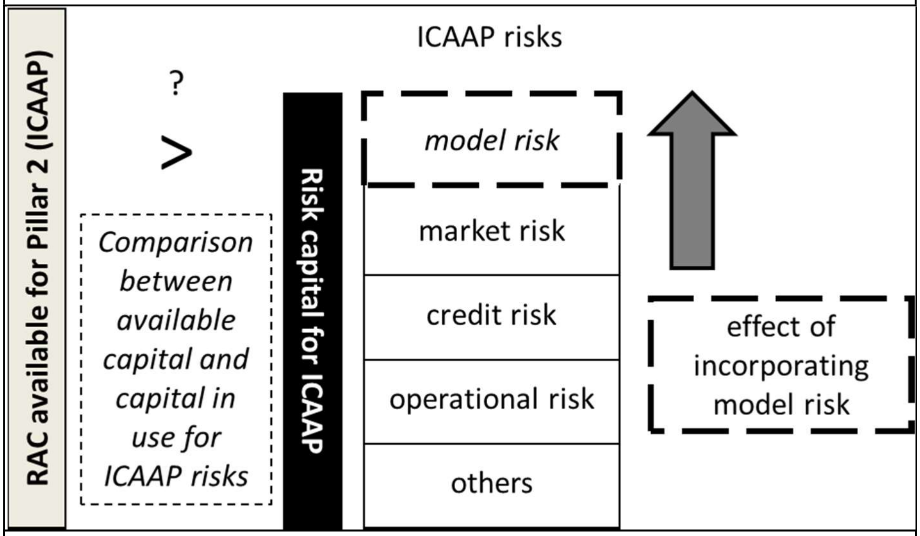
The consideration of model uncertainties at different hierarchical levels is an essential prerequisite for effective handling of model risks. Against this backdrop, it is necessary that the results of the evaluation of model uncertainties are presented, discussed, and finally confirmed in suitable committees. It is advisable to involve the heads of business units responsible for the model, the heads of business units that use the models, and, in a suitable form, the management board or a committee commissioned by it. In addition to an approval of the model inventory and the confirmation of the assessment of model uncertainty, the committee should make a clear recommendation regarding the consideration in the control system. With regard to the integration into the risk management processes of the bank, specific governance and controls should be made in the absence of specific regulatory requirements. While model uncertainties from valuation models in the form of model reserves are directly included in the calculation of profits and losses, model risks or model uncertainties associated with risk models pose the question of a suitable consideration in existing management processes.

2.3 Integration in the internal capital adequacy assessment process

If the institution has decided to take model risk explicitly into account for its internal capital adequacy assessment process aside from a qualitative treatment then weighing the alternative forms of integration is important. The fundamental question is whether the assessed uncertainty of the model should be understood as a component of the risk side or as a capital (reducing) component. The advantages and disadvantages of various options are discussed in the following.

Alternative 1: Treatment of model uncertainty as a separate risk type, i.e. model risk

Figure 4: Alternative 1: Treatment of model uncertainty as a separate risk type

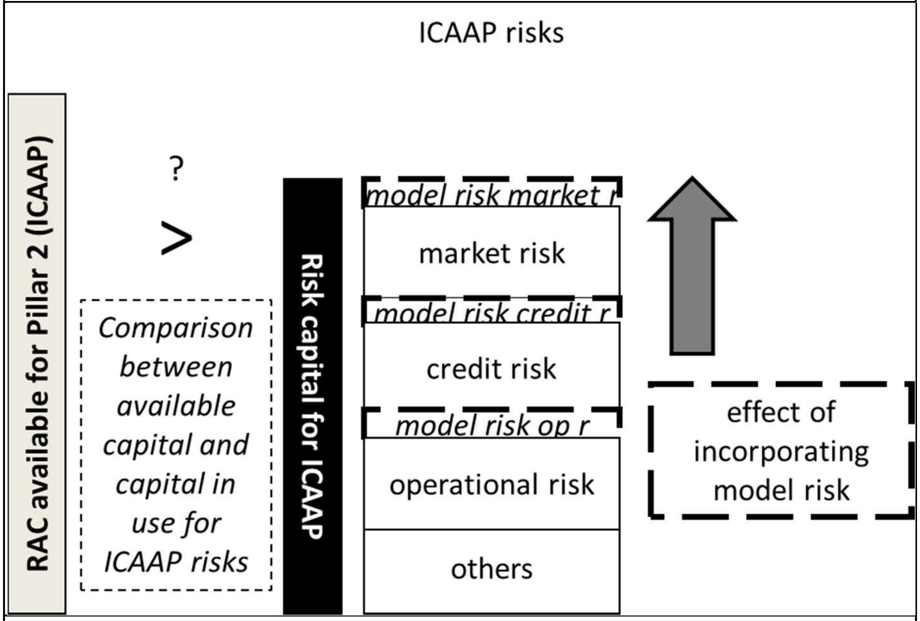


Source: Authors' own visualization.

The identification of model risk as a separate type of risk, as outlined in Figure 4 as an excerpt of the ICAAP drawn in Figure 2, is an intuitive treatment, because the frequently used term 'model risk' can also be understood to mean a separate risk category. This concept applies if the focus of model risk is on the above-mentioned parameter and estimation errors for all relevant risk types, as in this case a probabilistic interpretation of deviations is conceivable. Regarding the risk management process, the advantage of a separate reflection is essentially the fact that a targeted sensitization of report recipients can take place. Given that the 'original' risks and uncertainties associated with their modelling are shown separately, no mixing of figures takes place, and the control impulses to be derived from the reporting can be differentiated and thus targeted. A detail that should be noted, however, is that with the basic understanding of a separate risk type depending on the materiality, specific regulatory requirements with regard to major risk types can follow (for example, risk strategy or frequency of valuation). In addition, it should be kept in mind that uncertainties of the model are never isolated, but occur only in connection with the risk models that are used. In particular, the aggregation of model risks across different risk categories to a single risk figure for all model risks can also be a complex task. In fact, these single model risk figure afterwards has to be attributed to the different risk categories at least on a reporting level for different business units and desks again to allow a certain risk management. Here, also the question arises whether there are diversification effects linked to model risk.

Alternative 2: Treatment of model risk as part of existing risk types

Figure 5: Alternative 2: Treatment of model risk as part of existing risk types

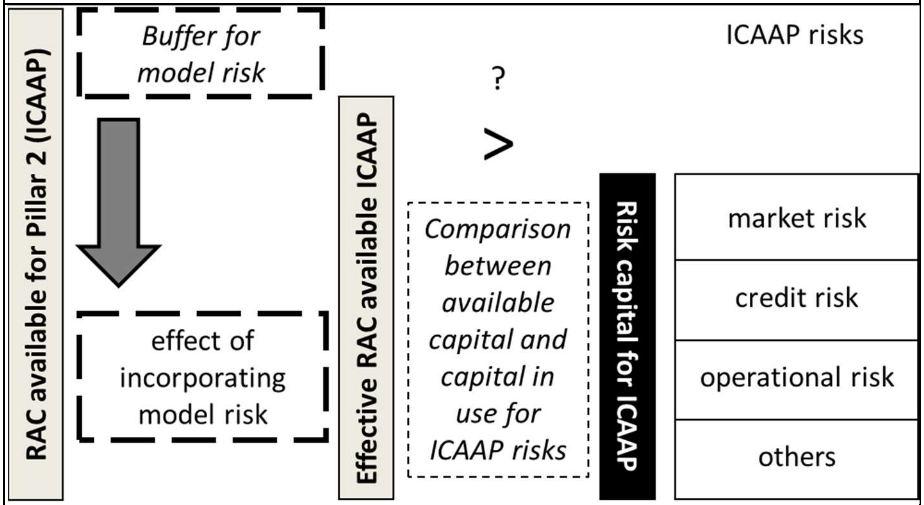


Source: Authors' own visualization.

The integration of model risk in the model of the respective risk type within the framework of the internal capital adequacy calculation offers a solution for the two last mentioned points. In principle, the sensitization of report recipients is also ensured here. If, however, the inclusion takes place only in the form of a surplus, then a risk of dilution of the risk management processes exists depending on the materiality of the model risk, since there is no distinction between the original risk (controlled by the first line of defense, i.e., the business units) and the modelling of connected uncertainty (controlled by the second line of defense, i.e., the modelling and validation unit). A corresponding design of the reporting (for example, visualization in the form of uncertainty bars) can be remedied. Regardless of this situation, the challenge is to allocate the calculated buffer for model uncertainty to the business segments or legal units, in accordance with the institute-specific capital adequacy statement, because not only risk types, but also business units or legal units are limited. A simple pro-rata allocation is not necessarily adequate. For example, once having a value-at-risk model using sensitivities, this approach might be adequate on an overall basis but business units with large derivative exposures exhibit a quite more substantial model risk (due to simplification of the risk profile) than business units with only a linear exposure. Thus, the methods for determining the uncertainty of the model may have to be refined in order to be able to make business-specific statements and decisions.

Alternative 3: Consideration as capital buffer

Figure 6: Alternative 3: Treatment as capital buffer



Source: Author's own visualization

A complementary approach is to consider the calculated buffer on the capital side by means of a corresponding reduction in the risk-covering capital, i.e. the risk absorbing capacity. This view is appropriate when the focus of model uncertainty is on variations of model assumptions and the use of challenger models, since the results are difficult to identify as a risk, that is, especially under a probabilistic view. The issue described in alternative 2 (business unit-specific statements with regard to the uncertainty of the model) does not arise here because the calculated buffer can be considered in sum. As a result, lower capital to cover risks is available to the business units and as a consequence, the institutions risk appetite is lowered. This approach facilitates the targeted management of the original risks associated with business activities. This form of representation of the buffers for model uncertainties is not explicitly stated. Thus, the danger of a limited sensitization of report recipients regarding the subject matter exists. However, this disadvantage can be compensated by a correspondingly intensive discussion about the uncertainties associated with the modelling.

The question of an appropriate integration in the internal capital adequacy assessment process should be answered in each case in line with the institutions specific requirements. At present, there are neither clear industry standards nor explicit requirements on behalf of the regulatory or supervisory authorities. Therefore, considering the institution-specific approach to the internal capital adequacy calculation, the decision should be carefully balanced between the effort involved in the approach of the solution (for example, the adjustment of reports or systems) and the intended use of the management of model uncertainties. As explained, the question of the evaluation methods used also plays an important role. Last but not least, it should be considered whether the governance for model risk is sustainable and resilient with respect to regulatory requirements and in the eyes of internal and external auditors.

3 Conclusion and outlook

In summary, the following central findings can be maintained with regard to the systematic handling of model risk in the context of internal capital adequacy: The definition of central concepts (models, model risks, model uncertainties) specific to the institution is indispensable in the face of neither a clearly established market standard nor any given uniform regulatory guidance or requirements. In order to avoid redundant assessments, a clear distinction must be made between the aspects that have already been taken into account elsewhere (such as, for example, in an operational risk context). Concerning the definition of the scope of coverage, the focus on selected models can be a sensible entry to gain experience and to be able to improve the selected approaches in a timely manner. For the actual assessment of the uncertainties of the model, various methods are available (assessment of estimation errors, local variations of the model components, use of challenger models), which consider the different causes of uncertainties in the model. When considering the form in which the results of the assessment can be integrated in the internal control processes, in addition to the scope of the models considered, existing risk management processes and committees should be considered. If model uncertainties are quantified, then the internal capital adequacy must be weighed against whether the identified model uncertainties are to be understood as risk premiums or capital deductions.

Recently, US regulators asked banks even about the potential interconnectedness between different models, see [10]. This urges banks again to widen the scope of application and also to create new approaches to assess model risk by e.g. neural network theory and alike.

Finally, against the backdrop of missing standards so far, simple and practicable solutions are preferable, which can potentially be refined with increasing experience throughout time. Regardless of the chosen form of implementation, the treatment of the strengths and weaknesses of the respective models and then their uncertainties should have an established place on the risk agenda of the organization. Only in this way the goal regarding model governance can be achieved, which is the rise of awareness with regard to the uncertainties associated with the models that are used.

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