The Model Ajar: Building Rationality Infrastructures within Insurance Organizations

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1. Introduction

The recent adoption of risk-sensitive regulatory approaches, such as the European Solvency II framework (EIOPA, 2009), has led to an expansion in the use of complex quantitative models by insurance organisations, with applications ranging from economic capital calculations to strategic decision making. As models are increasingly embedded in insurers' operations to measure and manage risks, academics, practitioners and regulators call attention to 'model risk', namely the risk of adverse consequences arising from decisions based on incorrect model outputs (Federal Reserve, 2011). In particular, problems arising from epistemic uncertainties due to scarcity of data (e.g. Bignozzi and Tsanakas, 2016); the endogeneity of financial risk (Danielsson and Shin, 2002); and the challenges of governance around models (Cadoni, 2014; Aggarwal et al., 2016) are increasingly scrutinised.

Despite the growing use of models, we still know little about how key stakeholders in organisations deal with models in their daily practice. Some papers have considered the role of formal analysis in organisational decision-making (e.g., Langley 1989; Cabantous and Gond 2010; Cabantous et al. 2011), but there is still a lot to learn about the work of modellers and 'quant' people in organisations; particularly on how their practices facilitate (or not) the embedding and expansion of model use. Here, we aim to make a first step in that direction, by studying the practices of professional modellers, who are key agents in developing and deploying quantitative models in insurance businesses. Specifically, we ask: *How do professional modellers facilitate the expansion of model use?*

We address this question through a qualitative study on the development and use of internal capital models in insurance firms operating in the London Insurance Market. These models – a specific type of simulation-based quantitative models – provide insurance firms with a representation of their portfolio structure, as well as probability distributions for pertinent sources of uncertainty, such as the number and severity of insurance claims, inflation, asset returns, etc.

Our study of the practices by which modellers in the London Market develop such models has two major findings. First, it shows that modellers facilitate the embedding of the model in the organisation by maintaining the model 'ajar', that is, they interact with different types of stakeholders (such as underwriters and board members) around specific areas of the model. In so doing, they produce a model that is neither completely 'closed' – hence enabling stakeholders to have some form of control on the development and deployment of the model –nor fully 'open', which would prevent the model from being useful. We call 'ajarness' this state of partial opening of the model, which modellers enact through their modelling practices.

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Second, we show that modellers enable stakeholders to engage with the model in a way that is consistent with *stakeholders' own* conception of the model and uncertainty. Through their practices, modellers address stakeholders' concerns and uncertainties about the model, and in so doing they enact stakeholders' conceptions of the model. As they engage in this way with various types of stakeholders, modellers create a model that is 'flexible' enough to be consistent with multiple conceptions of the model and of uncertainty, thus facilitating expansion of model use. Such co-existence of alternative conceptions of the model and of uncertainty is consistent with previous discussions on *cultures of model use* (Tsanakas et al., 2016; Tsanakas and Cabantous, 2017), to which our study, while different in its framing, gives an empirical underpinning.

2. Context, data and method

Our study focuses on the development and increasing use of internal capital models in the London Insurance Market. This market, which comprises Lloyd's, is a specialised insurance market for international trading of non-life insurance and reinsurance business, including high-exposure risks, such as those arising from natural catastrophes. While London Market professionals have used complex quantitative models for more than 20 years, e.g. in pricing catastrophe risks (Grossi and Kunreuther, 2005), the use of internal capital models expanded more recently, first with the association between regulatory capital and model outputs under the former UK-wide ICAS regime in 2003, and further with the coming in force of the European Solvency II regulatory regime in 2016.

Insurers use internal capital models in order to compute probability distributions of various quantities of interest, such as a portfolio's net asset value at a given time horizon. Some properties of those distributions, such as means or quantiles, are also outputs that business users incorporate in their decision-making. In particular, under the Solvency II regime, which applies to the London Market, the minimum level of safe assets that an insurance firm must hold is calculated as the 99.5th percentile of firm's position, at a 1-year horizon ('1-in-200 years loss').

To conduct our study, we interviewed 31 practitioners active in the London Market. We targeted in particular professional modellers, typically actuaries, who interact directly with the model, e.g. by running it, analysing and communicating its outputs, and modifying its inputs and specification. Furthermore, we interviewed stakeholders who interact differently with the model, such as board members, underwriters and regulators. Through semi-structured interviews, which lasted from one to two hours, we explored themes such as internal capital models' areas of use and fitness-for-purpose, as well as the impact of the regulatory process and the challenges of dealing with model uncertainty. Interviews were recorded and fully transcribed.

While analysing the interview transcripts, we first focused on modellers' activities in relation to model development and use. In a second step, we examined what modellers achieve through these activities. We realised that these activities enable modellers to interact with three types of stakeholders (modellers, underwriters and board members) in order to open with them areas of the model that are of interest to them. We therefore linked modelling activities to specific areas of the model, and stakeholders. Third, it became clearer that through these activities, modellers attempt to address stakeholders' specific *concerns and uncertainties* about the model and its uses.

3. Model ajarness: opening the model to address stakeholder concerns

3.1 Opening the model

We find that modellers open some aspects of the model to different stakeholders, in the context of specific business processes. By 'open' we mean that a particular aspect of the model is exposed to modification, investigation, or debate, by the modellers themselves or by other stakeholders. But not all aspects of the model are open to all stakeholders; hence some aspects of the model remain 'closed', that is, taken for granted, if they do not resonate with stakeholders' *concerns*. We refer to this process of partial opening as *model ajarness*.

Aspects of the model that modellers open through their activities include the model's *input parameters*, its *design* (with the associated limitations and capabilities), the *relationship between model inputs and outputs*, and the *processes* by which modelling decisions are made. Furthermore, the model itself can be seen as an agglomeration of smaller 'local' sub-models. Hence, what may be opened is an aspect of the model pertaining to the performance of a specific line of business or, alternatively, to the portfolio as a whole.

In Table 1, a non-exhaustive summary of modeller activities, associated concerns, and areas of the model opened is presented. In what follows, we discuss these further and sketch which parts of the model are opened, to which stakeholders, and why.

Table 1: Modeller activities, stakeholder concerns, and areas of the model opened.

Modeller activities	**Concerns addressed by activities**	**Areas of the model opened**
(A1) Choosing and updating the model's parameters (A2) Performing and interpreting validation tests (A3) Changing the way something is modelled	(C1) Technical validity: does the model satisfy technical standards? (C2) Realism: are the model design and properties consistent with modellers' understanding of the business?	Model parameters Model structure and design Input/output interactions (for validation purposes)
(A4) Explaining the model's design and limitations (A5) Generating business recommendations (A6) Responding to challenge and negotiating the model specification (A7) Responding to challenge and negotiating the model's scope of applications	(C3) Operational usefulness: can the model be used to support the specific decisions that users need to take? (C4) Consistency with underwriter judgement: are the recommendations of the model consistent with the judgements and preferences of underwriters?	Model structure and design (focus on capabilities and limitations) Input/output interactions (at the level of line-of-business) Model parameters (at the level of line-of-business) Model scope of application (in relation to specific decisions)
(A8) Presenting model outputs (A9) Running the model to investigate scenarios and opportunities (A10) Evidencing how modelling judgements have been made	(C5) Performance implications of strategic choice: what does the model indicate that the risk / reward trade-offs will be under alternative strategies? (C6) Governance: are modelling judgements carried out by sufficiently qualified staff, using rigorous processes?	Input/output interactions (at the level of the whole portfolio) Model parameters (only those that affect the risk profile of the portfolio as a whole) Modelling process and governance

3.2 Modellers

Our interviews suggest that a persistent concern among modellers revolves around maintaining the model's fitness-for-purpose, involving its *technical validity* (Concern 1 – C1), as evaluated by formal (e.g. statistical tests) and informal (e.g. expert opinion) means. For instance, modellers receive new data every year, because of the new business being planned and underwritten; they "ensure that [the] model is still fit for purpose and if it is, then all the parameters that you use are fit for purpose". In addition, modellers are deeply involved with model validation, as they "need to produce the results for it – also [they] need to be able to then understand the results and maybe justify the results as well." (Capital Modeller). Thus, to address concerns relating to technical validity (C1), modellers engage in *choosing and updating the model's parameters* (Activity 1 – A1), taking into account new data, as well as *performing and interpreting validation tests* (A2).

A distinct set of concerns relates to the issue of whether the representation of the business encoded in the model is *realistic* (C2), that is, whether the model design and properties are consistent with modellers' understanding of the business. A Chief Actuary explains:

> "Last year we completely rebuilt our credit risk model and we buy a lot of reinsurance… Our credit risk modelling wasn't quite … it was, I guess, what you call a standard approach using default rates and everything else, but it wasn't … I think we were expected to be better than that… there are always lots of ways you can think of to improve your modelling, but you strike a balance between what's practical and what's realistic."

Hence, to address the concerns on realism (C2), modellers opened the model's design and *changed the way something is modelled* (A3). In this example, the fact that the company is buying a lot of reinsurance meant that realism of the credit risk model was a concern that was prioritised (credit risk modelling is used to quantify the potential of a reinsurer to default). Hence, we see that concerns about realism (C2) depend on the specifics of a company's portfolio.

3.3 Underwriters

The model is typically used as a decision support tool for underwriters, in the context of processes such as business planning, for instance to determine the optimal amount of exposure in particular lines of business or to evaluate the portfolio performance under alternative reinsurance configurations. Through such applications of the model, modellers interact extensively with underwriters:

> "As soon as you start mentioning limitations… frequently this is used as an excuse by people to ignore the model. The question then becomes: "well how granular do we want the model to be"? And that's now becoming a challenge because as the appetite increases and senior management becomes more educated in this… they get more interested and they want more out of this tool… it means the model needs to give more but in order to give more you need to have more granularity." (Capital Modeller).

A main concern among underwriters is whether the model can be used to support the specific decisions that they need to take, that is, they are concerned with the model's *operational usefulness* (C3). Limitations in the extent of bottom-up detail of the portfolio captured ('granularity') imply that the model cannot be used to answer all questions underwriters may have. Therefore, modellers need to *explain the model's design and limitations* (A4) to underwriters. This interaction may lead modellers to enhance the model usefulness by changing the model design (A3), such as its

granularity. Whether these changes are implemented depends heavily on the balance of perceived benefits and resource constraints.

Since modellers also use the model to *generate business recommendations* (A5), they open to underwriters the modelled relations between inputs (e.g. the expected profitability and the amount of premium to be written for a particular line of business) and output (e.g. portfolio performance). As a result, the values of model parameters for the line of business considered are sometimes discussed, even when underwriters do not have a specific concern with technical validity, as explained by a senior actuary:

> "You'll always see [challenge of model assumptions] from the underwriting side because it's affecting their business plan. If we turn round and say "we think this account's poor and isn't going to make you a good return", then that may affect how much of that income they can write next year. So underwriters will challenge that… and we will challenge ourselves to say "well are we right on this?""

The use of the model, while supporting underwriters' decision-making, also restricts underwriters' freedom in acting according to their own judgements e.g. as to how much business they should be writing. Therefore, a concern arises for underwriters as to whether recommendations derived from the model are *consistent with their judgement* (C4). When underwriters sense such inconsistency, they may choose to dispute the validity of the model, including that of key statistical input parameters affecting the modelled profile of their line of business. Modellers subsequently need to *respond to challenge and negotiate the model specification* (A6) with underwriters. The model specification therefore is also the result of a negotiation, to which modellers' efforts to satisfy their own concerns around technical validity (C1) and realism (C2) form a baseline rather than the last word.

The concern for consistency with underwriters' judgements (C4) motivates debate not only of the model specification, but, more broadly, of its appropriate scope of applications. In one example, a CRO explained how modellers generated a recommendation for an underwriter to reduce the amount of reinsurance bought. The underwriter resisted the recommendation for reasons not to do with the model's perceived validity but because of commercial reasons, arguing (as reported by the CRO) that he has to "continue that relationship" with a reinsurer, because this reinsurer "helped [him] out" at one point when the underwriter "had a very bad time". Consequently, modellers need to *respond to challenge and negotiate the model's scope of applications* (A7). Other respondents described similar debates with underwriters and senior management about whether recommendations generated with the model should be followed in particular areas and situations.

3.4 Board

Boards have less opportunity and reason to interact directly with the model. They typically get information on the model when modellers *present model outputs* (A8) either via periodic reports on important management information, such as their firm's regulatory and economic capital, or in the context of exploring strategic opportunities. For example, a board member outlined how the model has been used to evaluate the possibility of expanding the business to a new territory.

> "Somebody may say "well I'd like to recruit this chap here, he's got a particular specialty in an area that we don't cover, this is what we think his business model could look like, what he's likely to do". It's then taken and run through the model and we say, "well no that's not going to be worthwhile"."

Here, the board's concern revolves around *performance implications of a strategic choice* (C5) – when the proposal is "run through the model", the risk and return of the portfolio under the proposed strategy is calculated. Risk in those cases typically represents concrete costs in terms of capital requirements. Thus, the activity through which modellers address the board's concern is *running the model to investigate scenarios and opportunities* (A9). Through this activity, some input/output interactions in the model are opened up to the board – these interactions usually relate to the portfolio as a whole, rather than a specific line of business, as is the case when modellers open the model to underwriters.

Through the writing of reports or in the context of discussions with board members, modellers once again open input/output interactions, for instance through the presentation of analyses of change and waterfall charts. But this opening is selective, as only the most important changes and inputs are discussed in detail with the board. Furthermore, highly technical detail on the model inputs is typically not discussed:

> "Suppose we'd moved a few degrees of freedom in a t-copula[1]… I mean, I try not to use those words to start with. I don't know. What do we do in similar situations? If it's judgement, we say it's judgement. This is whose judgement it is. These are the people who have discussed it. These are the reasons why on balance they plumped for that." (Chief Risk Officer)

Instead, board members, seem concerned with the *process* by which modelling judgements have been made, which reflects a board concern around *governance* (C6): as board members do not have the time and expertise to provide a detailed review of technical decisions, they need to make sure that modelling judgements are carried out by sufficiently qualified staff, using rigorous processes. Modellers address this concern by *evidencing how modelling judgements have been made* (A10).

4. Creating a 'flexible' model that supports alternative conceptions

Our analysis also shows that modellers facilitate the expansion of model use by creating a model that is *flexible*. Despite the fact that all stakeholders deal with the *same* model, we found that they have different modes of engagement with it: they each engage with the model in a way that is consistent with *their own* conception of the model and concerns (or uncertainties) about it. As each stakeholder does so, multiple (in our case: three) conceptions of the model and uncertainty are enacted, as presented in Table 2 and elaborated on below.

First, through their activities, modellers enact the model as a *representation of the world*. This conception of the model is directly linked to modellers' concerns with technical validity (C1) and realism (C2), which point to a view of the model in technical terms, as a mathematical/statistical representation of the business and its external environment, encoded within specialised software. This conception of the model also reflects a specific view of uncertainty. Since for modellers the model is a representation, uncertainty, for them, refers to the observation that there are multiple such representations that pass modellers' validity and realism checks. Furthermore, alternative

[1] *Degrees of freedom* are important parameters of *t-copulas*, statistical functions that enable the modelling of joint occurrence of extreme losses. Changes in those parameters has typically a substantial impact on outputs such as regulatory capital – at the same time they are hard to estimate from available data and are usually set by expert judgement.

model specifications can lead to substantially different outputs. As a senior actuary tasked with estimating key parameters said:

> "But for certain key assumptions, we'll have alternate views. We'll sort of say "look, the correct assumption could be anywhere between here and here. We've picked one because we have to pick one". And when we're doing our capital modelling we will make sure that we're looking at "well what's the impact if we go at the lower end, what's the impact if we're at the higher end?" So we can judge how material this assumption is."

An assessment of the impact of uncertainty thus conceived goes through sensitivity analysis: investigating the implications for the model output of using alternative assumptions.

Table 2: Concerns and conceptions of models and uncertainty of different stakeholder groups

Concerns	**Conception of the model**	**Conception of uncertainty**	**Stakeholder group**
(C1) Technical validity (C2) Realism	Representation of the world	Multiplicity of technically plausible representations	Modellers
(C3) Operational usefulness (C4) Consistency with underwriter judgement	Instrument of control	Practices affected by an instrument that is not fully understood, in ways outside users' control	Underwriters
(C5) Performance implications of strategic choice (C6) Governance	Calculative engine	Model gives outputs with adverse strategic implications Inherent limitations of quantitative modelling	Board

Second, our analysis suggests that modellers' activities enact the model as an *instrument of control*. This conception mostly emerges from the activities that aim at dealing with underwriters' concerns – in particular operational usefulness (C1) and consistency with underwriter judgement (C2) – and which suggest that underwriters primarily see the model in terms of its disciplinary and controlling power, sometimes fearing that it may, to some extent, supplant them:

> "So it's changed the way the businesses are run, they tend to be more run by finance and risk management people, and they lack the experience. […] Now the problem is, underwriters are busy out underwriting and marketing. So while they've been busy, or you could even say sceptical about all of this, there's been a whole bunch of things done and life's moved on without them. There's a danger that it [the model] is used in a certain way which brings a company down or, makes it a weaker entity."

The expanding uses of models produce new constraints and incentives for underwriting decisions, which can feel undesirable to underwriters, reflecting their concern for consistency with underwriting judgements (C4), and ultimately their uncertainties both about what the tool does (and can do) and their future role in the organisation. Moreover, a model seen as threatening to undermine underwriters' autonomy can also be perceived as opaque or of limited practical use (C3). These concerns therefore point to a specific view of uncertainty, as lack of understanding of the new work situation, where underwriters' working practices are affected by an instrument they do not understand fully, and in ways that are partly outside their control.

Modeller activities aim at assuaging those concerns through negotiation and accepting challenge (A6, A7), working towards a convergence of underwriters' views and the model's representation of the business. A Chief Actuary describes disagreements between modellers and underwriters in the context of business planning.

> "For this year, actually, we've agreed that for planning purposes, we're going to use the internal model, the actuarial numbers. But what's happened is that, we've converged with the underwriters. And I think we've converged for a number of reasons, one is they've moved closer to us and actually, we might have moved a bit to them as well. We've reached a compromise."

Such convergence however, is not always complete. The remaining disagreements are often managed by granting underwriters the discretion to not pursue model-based recommendations, as a CRO explains:

> "We view the models as providing a consistent framework. A starting point for the underwriting judgement if you like. But the underwriter is at liberty to charge what they like and what the market will let them."

Third, modellers enact the model as a *calculative engine*, especially through their activities related to boards' concerns. Our analysis suggests that, for boards, models are above all formulas that generate performance and risk metrics under current and alternative strategies. Modellers sometimes find that boards can be less interested in discussing the broader meaning of model outputs than in drawing precise conclusions from them:

> "I think I wanted the [risk] tolerance stuff to spark a debate, but management and risk people, they like red, amber, green charts – they like clear, defined lines." (Chief Actuary)

Satisfying the board's concern about performance implications of a strategic choice (C5) requires unambiguously interpreted outputs. Boards' governance concerns (C6) are intricately related to such a perception of the model, revolving mostly around the correctness of such model outputs. This view is rather distinct from modellers' concerns of the model's validity as representation. Boards' focus is not on the model as an abstraction but as an (albeit complicated) formula for generating numbers that are useful in their decision-making. Their narrower focus frames what they mean by the model's 'correctness': that sufficient checks have been performed by qualified professionals.

Correspondingly, boards' uncertainty revolves around the possibility that the model-as-calculative-engine produces numbers that have adverse strategic implications, such as an excessively large level of regulatory capital. Modellers, through running the model to investigate scenarios and opportunities (A9) enable boards to prepare for (and avoid) such eventualities. In that context, uncertainty around the multitude of technically plausible models, as experienced by modellers, is not a major concern for boards. Given that their governance constraints have been addressed, e.g. that sufficient validation has been performed and evidenced (A10), boards do not spend time agonising over alternative plausible models – instead they take the model for granted. As one board member told us:

> "I suppose that my view [about whether] the internal model could give us a very different result would be no, I don't think it probably could. You might use slightly different techniques on this or slightly different techniques on that. A different actuary might well say, no, I want to simulate this slightly differently. I can't feel that we would actually come up with an answer which is dramatically different to that which we had."

Such a view does not mean that boards are impervious to uncertainty or unfamiliar with models' limitations. Their view of uncertainty refers not to specific shortcomings of their own model, but to broader *limitations of quantitative modelling as such*, particularly in relation to capturing novel and extreme risk scenarios.

> "It's very reasonable to think, "Okay what is the next asbestos?" Or, "Is something going to come out of cell phones that nobody knew about?" There is going to be some disease later on; I think it's very difficult. You can only reasonably model for what has gone before and the exposures you see on your books, that's all you can do. […] You've got to keep going as if, you've got to keep going as if…"

Boards themselves seem to manage such uncertainty by accepting that the model should inform decisions, but form only one of several inputs into the decision process. This is consistent with a view of the model as valid, but intrinsically limited.

5. Conclusion

We studied how modellers facilitate the embedding and expansion in the use of internal capital models by their London Market organisations. Our notions of 'ajarness' and 'flexibility' summarise modellers' key achievement: producing a model that is partially open, while accommodating stakeholders' alternative conceptions of it.

The co-existence of alternative conceptions of models and uncertainty forces compromises. Modellers witness their notion of uncertainty being transformed, as it journeys through the organisation: from a technical idea relating to alternative statistical assumptions, to a deeply political notion relating to the role of models in the workplace, to a concern about the implications of the model-as-calculative-engine. Uncertainty sometimes is an enabler: for example, without an acknowledgement of the plausibility of multiple model specifications, there would be less scope for negotiation between modellers and underwriters.

At the same time, enabling stakeholders to engage with the model in their own way, limits the extent to which modellers can enact their own conception of the model. For example, modellers sometimes find that boards have limited appetite for understanding the extent of model uncertainty, as seen by modellers, as such a technical conception of uncertainty is not directly related to the board's concerns. According to our analysis this is understandable and even necessary for the embedding of the model. However, a new concern arises: whether through the effort to embed the model and expand its uses, crucial information about its technical limitations gets lost within the organisation. We see this as a key issue for governance in an industry where complex quantitative models have an increasingly dominant role.

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