Searching Guidelines for the Use of Internal Models in Insurance Company's Risk and Capital Management

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Abstract

In this paper, we explore critical aspects related to the use and development of internal models in insurance companies' risk and capital management. Our aim is to find out how crucial the various risk factors of internal models are for successful performance of essential management sub-tasks. The problem is approached hierarchically starting from relevant management sub-tasks, then analyzing the possible causes for the failure of the firm, and finally ending up with an analysis of the most important risk components which have to be taken into account when internal models are used and developed. As source information for causal and risk factors, we use a cause effect model of the European insurance supervisors and an international insurance survey.

The problem is formulated as a multiple criteria decision making task with a hierarchical structure. We use the Analytical Hierarchy Process as a planning tool to analyze management criteria, causal and risk factors. The evaluation is carried out by a panel consisting of senior managers of Finnish insurance companies. As a result, we obtain a list and rank order of the key risk components for the use and development of internal models. The results also illustrate the potential usefulness of decision science tools when making subjective decisions in the context of internal models.

Keywords: Analytic Hierarchy Process, Basel II, Bank and Insurance Supervision, Internal Model, Multiple Criteria Decision Making, Risk Map, Solvency II.

1. Introduction

The solvency regulation in the European Union is under reform. The Solvency II project will introduce a new solvency regulation which better reflects the risks to which an insurer is exposed than the current Solvency I; see, e.g. Sigma (2006). The plan is to implement Solvency II by 2012, but it already has an impact on the behavior of the insurers due to transparent preparation. In the new regulation system insurance companies will have an option to apply internal models for calculating a solvency requirement. An internal model means a risk management system developed by the insurer to analyze the overall risk position, to quantify risks and to determine economic capital required to meet those risks. The goal of this study is twofold. First, we explore management aspects related to internal models. Second, we like to demonstrate the use of operational research tools in the modeling context.

Internal models generally reflect the interplay between assets and liabilities and the resultant risks to income and cash flows; see, e.g. Enterprise Risk Analysis, eds. Brehm et al. (2007). The model may vary from simple standardized calculations to complex econometric or financial mathematics models. The explicit recognition of all of an insurer's operations gives models a power to illustrate the links between strategies and results. On the other hand, the explicit consideration of time delays, alternative outcomes and interrelationships between different aspects of an insurance operation provides internal models with a unique role to help management to identify profit opportunities, avoid negative outcomes and encourage investments in the company.

Insurer's internal models may assist both management and regulators to identify and understand problems, before they grow to the size of crisis. Furthermore, in case the problems emerge, the use of internal models can assist regulators in distinguishing short-term problems that do not warrant intervention from long-term problems that require action. Dynamic financial analysis i.e. the use of internal models for solvency monitoring and other internal management purposes, has a long tradition in actuarial modeling; see e.g. D'Arcy and Gorvett (2004) and Kaufmann et al., (2001).

A working group of supervisors from 15 European countries (so called London Working Group) dissected recent experiences of failed or nearly failed insurance companies, across the life and non-life sectors (Sharma, 2002). By using the cause-effect risk-map as a tool in analyzing the case studies, the group identified the risks that have threatened firms' solvency in the last six years (since 1996) and wished to distinguish the root of a firm's problem.

The London Working Group demonstrated that an insurance company failure is typically the result of a combination of different causes and effects. However, it also demonstrates that the root of most insurance company failures is management, and typically, poor management. Ultimately, to prevent insurance company insolvencies, management and supervisory tools need to be developed which can tackle the full cause-effect chain. The internal issues in the earlier stage of the cause and effect chain are more subjective and open to challenge than issues in the later stage of the chain, e.g. it is easier to recognize that underestimated liabilities caused failure than conclude what caused underestimation.

The London Working Group hoped to create a risk map framework for a more general scholarly discussion of internal models based on findings of group. The aim of this

paper is to study the challenges of the use of internal models in the Solvency II context by applying a risk map approach. In that spirit, we invited an expert panel to evaluate the risks of using internal models. The members of the panel were senior managers of mid and small size insurance companies. Before a joint meeting, each panel member familiarized himself with the results of Bana Skin Survey 2007 and was interviewed individually with an aim to find the most relevant management tasks, causes for failure, and risks in internal models. In a group meeting the influence and importance of various factors and cause-effects were evaluated by using the decision tool by name Analytical Hierarchy Process (AHP) developed by Saaty in the early 70th (see, e.g. Saaty (1980)). The AHP is a mathematical decision making technique that allows consideration of both qualitative and quantitative aspects of decisions (see, Appendix B).

Although the number of the applications of the AHP is numerous, it has not often been applied to financial problems. Among the literature covering business topics relevant to this problem see, e.g. Korhonen and Voutilainen (2006), Korhonen, Koskinen, and Voutilainen (2006a, b), who have studied financial alliance structure alternatives from different perspectives including risk management and supervision. Other applications are published, for example, by Lim et al. Source (1994), Meziani and Rezvani (1988), Steuer and Na (2003), and Urli and Beaudry (1995).

The paper is organized as follows. In Section 2, we discuss the role of internal models. In Section 3, we review the causal chain developed by the London Working Group to explain insurance company failures. Section 4 describes our decision alternatives and criteria. In Section 5, we present the formulation by using the AHP framework and describe the experiment and the results. Finally, in Section 6, we conclude the paper with discussion of the evaluation results.

2. The role of internal models in Solvency II

The Solvency II project strives for a fundamental and wide-ranging review of the current insurance supervisory regime in the light of recent developments in insurance, risk management, finance and financial reporting, for general introduction; see, e.g. Sandström (2006) and for internal models e.g. Ronkainen et al. (2007). A three pillar approach similar to that one implemented for banks in Basel II is also recommended for the insurance sector; c.f. for example European Comission (2008). It is suggested that the first pillar should concern quantitative aspects such as the level of prudence in technical provisions, investment management rules, and regulatory capital requirements. The second pillar concerns mostly qualitative aspects such as internal control and risk management, and also the supervisory review process. The third pillar concerns market discipline and disclosure requirements.

The capital requirements will consist of two solvency control levels. The higher one is a risk-based solvency capital requirement, and the lower one is a minimum capital requirement. It is suggested that the new system should allow insurance companies to use their own internal models for calculating the solvency capital requirement. This should, however, be conditional upon the internal model having been validated and approved by the supervisory authority. It should be noted that internal models are not nowadays yet used for other regulatory purposes, but they are commonly used for risk management purposes, e.g. under the second pillar risk management process.

The main reasons for giving European insurance companies an option to apply internal models for calculating the main solvency requirement within the Solvency II framework is to enhance better risk management in firms and to give them a chance to derive a more accurate risk-oriented capital requirement than the standard Solvency Capital Requirement would be able to provide. The possibility to use internal models within pillar one basically means freedom to calculate the solvency requirement using some other formulae and even principles than those given by a standard formula.

According to CEIOPS (2008) the main objectives and potential benefits of using internal models for regulatory purposes include better, more risk-sensitive and innovative risk management, efficiencies in terms of capital and costs, and more effective discussion between insurers and their supervisors as well as with shareholders, analysts and rating agencies.

The revised Basel II regime (BIS 2008) for banking supervision is one of the major references for Solvency II together with other international developments for instance the International Actuarial Association (IAA, 2004). In the banking regulations internal models have already been recognized, although in a rather narrow sense, covering only market risk in the trading books of banks. On the other hand, in the insurance sector, both in the EU and internationally, the current regulatory developments are based on a so-called total balance sheet approach; see IAA (2004). Therefore CEIOPS states that while the goals and principles for the regulatory approval of internal models are similar in banking and insurance, there are significant differences between these sectors. The nature of some risks and thus the risk profiles differ between the two sectors.

The regulatory recognition of internal models is a core instrument that allows keeping regulation in line with rapid development of financial markets. Given that both use and supervision of internal models are relative costly, the deal between supervisors and companies is lower regulatory capital in exchange for better information.

3. The causal chain of insurance company failure

The London Working Group considered the complete population of life and non-life insurer failures and near failures from 1996 to 2001, identifying the main cause for each. From the total population 270, 21 cases were selected to represent of the whole population and covering the main risks.

Analysis of the case studies revealed that the failure or near failure of each insurance company was the result of different, but often interrelated risks. It also revealed that it is possible to construct a standard template of an insurance company failure to explain these relationships. Figure 1 describes the basic cause-effect chain that was identified by the London Working Group (Sharma, 2002).

The failure or near failure of each insurance company was typically precipitated by some sort of an external trigger event. Being the most immediate cause, this ‘trigger event’ is often the easiest to identify; however it provides only a partial explanation for a particular effect, as it is merely the final link in a chain of causes. Only when combined with underlying and intermediate causes does the ‘trigger event’ become a problem for solvency.

When analyzing the case studies, the members of the London Working Group often mentioned another firm that had faced the same or similar trigger event, but had not got into serious difficulties. Comparing these firms it was found that the significant difference was that the insurance company that got into serious difficulties had some underlying weaknesses. The observation is supported by the cause-effect work of authors like Blockley (1996) who have also suggested that firms can exhibit a 'proneness to failure'.

Management or governance issues were at the root of every case, even in two cases where at the first sight there were no management problems. Indeed one of these cases was selected specifically to illustrate a failure where management was not a fault, but under scrutiny underlying management weaknesses were identified. A pattern of four forms of management problems emerged:

- incompetence, straying outside their field of expertise or uncritically following herd instinct;
- excessive risk appetite or objectives that are at odds with prudent management of the business;
- lack of integrity;
- lack of autonomy and inappropriate pressure.

The significance of management in insurance company failures has implications for the governance of firms as well as for regulators.

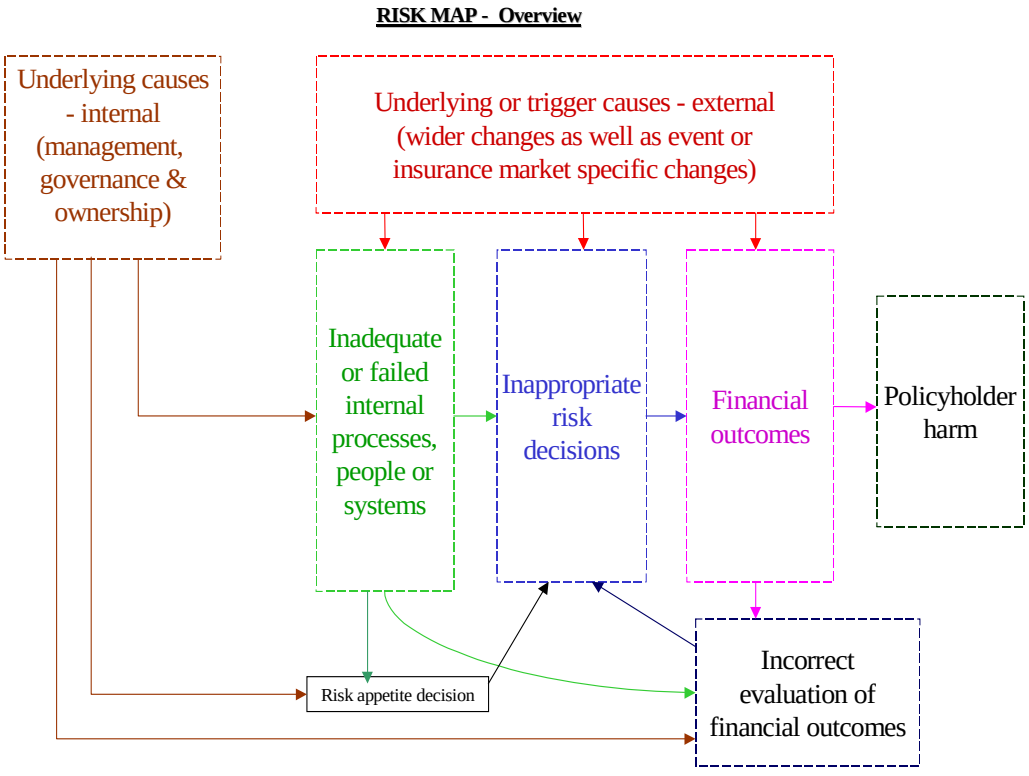

FIGURE 1. Risk map of causes chains (Sharma, 2002).

Many causes are interrelated, as are many causes and effects. For example, bad management can lead directly to inadequate internal processes and systems that may, in turn, result in inappropriate risk decisions.

Dealing with the early links in the cause-effect chain is desirable but problematic. Focusing on technical outcomes and their evaluation (the later links in the cause-effect chain) is generally easier than dealing with the earlier stages, as the later stages tend to be more tangible and easier to benchmark and assess objectively. For instance, setting and monitoring limits for certain asset types is generally easier than assessing investment strategy or the competence of the investment manager. It is, however, well worth focusing on the earlier links in the causal chain as it may be possible to 'nip problems in the bud'. The benefits of this are as follows; see, McDonnell et al., (2002):

- firms will be less likely to fail or to face serious threats to their solvency or market standing that are a major drain on senior management resources;
- supervisors are more likely to achieve regulatory objectives and save the effort involved in taking more severe enforcement action at a later stage or coping with a failing firm; and
- consumers and other market participants will benefit from reduced risk of loss and inconvenience and market disturbance that can arise when a firm is in trouble.

4. Senior manager's view on risks of the internal models

In this section, our aim is to find out how crucial the various risk factors of internal models are for successful performance of essential management tasks. Our approach is based on the subjective evaluation of a panel consisting of senior managers of life and non-life insurance (mutual and incorporated) companies. The evaluation process consisted of two phases: 1) individual interview and 2) group evaluation. Before the individual interview, the Insurance Banana Skin Survey (CSFI, 2007) was given the experts as background information. Each expert was asked to name relevant management sub-tasks and risk factors in internal models which they believed to have essential influence on successful management.

Based on the information received from the interviews, we constructed the hierarchical multiple criteria evaluation model (Fig. 2). To the top level, we placed six most relevant management criteria. To construct the intermediate level, we used the risk map of London Working Group (Sharma, 2002), from which we extracted three cause components (see, Fig. 1). Those cause components play an important role in the early observation of the path may leading to the failure of a firm. At the lower level, we have risk factors in internal modeling most relevant for each cause. The risk factors were introduced from those ones the managers highlighted.

Using the hierarchical multiple criteria evaluation model, our purpose is to find out how significant various risk factors in internal models are for successful management sub-tasks. We do not analyze these relationships directly, but instead we use as an intermediate link the underlying external and early internal causes for failure (Sharma, 2002). As a decision support method, we use the Analytic Hierarchy Process (AHP) (see, the description in Appendix B). The evaluation was carried out by an expert

panel. First, the panel evaluated the mutual importance of the management criteria, then, it compared how important role various causes played for successful management sub-tasks, and finally how strong influence various risk factors in internal models had on the causes. As a final result, we obtained in a numerical form how significant various risk factors in internal models are for successful management.

4.1 Underlying causes - management criteria

The Centre for the Study of Financial Innovation (CSFI) has recently completed its inaugural Insurance Banana Skin survey 2007 (see Appendix A) of leading members of the insurance industry to find out their concerns about the soundness of the financial markets. The survey puts together a league table identifying potential sources of risks to the insurance industry and ranks them by severity. The survey is based on 139 responses in 21 countries.

The managers were initially asked to name the most important management sub-tasks using the Insurance Banana Skin Survey (CSFI, 2007) as background information. Based on the interviews, we prepared a list of most relevant management sub-tasks (called management criteria) for a group meeting.

Before the evaluation started, the group had a preliminary discussion about the semantics of the criteria to ensure a common perception. The interpretation of certain criteria was adjusted.

The viewpoint was that of senior management where the main task is to avoid bankruptcies. This is the general point of view not only related to internal models. The introduced management criteria with brief interpretation are as follows (see, Fig. 2):

M1. *Investments Management* (Capability to manage investments)
The related risk in the Banana skin Survey is "*Investment Performance*". This includes all management operations that are directly related to investments.

M2. *Cycle Management* (Capability to manage the cycle)
This includes both national economic and insurance underwriting cycles. Emphasis is on the right reaction to changes. Investment performance is excluded.

M3. *Risk Management* (Capability to utilize risk management)
This criterion includes risk management processes, systems and techniques and also their control mechanism and management.

M4. *Actuarial Assumptions* (Capability to choose right actuarial assumptions)
This criterion has a wide interpretation: the related risks in Banana Skin Survey are actuarial and longetivity assumptions. These assumptions are based on past experience.

M5. *Distribution Channels* (Capability to control distribution channels)
The criterion includes both distribution channels and underwriting operation from an average company's point of view.

M6. *Pricing new risks* (Capability to price new risks)
Contrary to criterion 4, in this case there is no historic data available.

It is good to know that most of the threats listed in Banana Skin Survey were external factors (like natural catastrophes) that were not easy transform into management criterion.

4.2 Early and external fauses for failure

Next we focused on the early and external causes for failure in the causal chain proposed by the London Working Group (see Figure 1). Hence forward we refer to these causes by using the expression "causes for failure". These are

C1. *Inadequate or Failed Internal Processes, People or Systems,*

C2. *Inappropriate Risk Decisions, and*

C3. *External Underlying or Trigger Causes*

Those causes appear in the report by Sharma (2002) as risk process components. According to Sharma (2002), the underlying internal causes are management, governance, ownership. The errors in those causes may leads to Inadequate or Failed Internal Processes, People or Systems which further may lead to Inappropriate Risk Decisions. These are early causes for failure. Various external underlying causes such natural catastrophe, radical market disturbances etc. may trig the process leading to failure. A late sign for an unsuccessful management process are bad financial outcomes.

Our purpose is to study which causes are most relevant in different risk management tasks M1 – M6. We analyze the relevance of those causes for each management task.

4.3 Relevant risk factors of internal models

Our ultimate goal is to analyze which risk factors in internal models are most significant from management perspective when an aim is to avoid the process leading to failure. The analysis is carried out through the causes of failure C1 – C3, because in the spirit of Sharma's report we wanted to first focus on the evaluation of the impact of risk factors on causes for failure instead of asking the managers to evaluate direct impacts on management tasks.

Together with the panel members, for each cause for failure we introduced specific risk factors based on their relevance:

Inadequate or Failed Internal Processes, People or Systems

1. Data risk. The risk that insufficient, inadequate or incorrect data is held, collected or aggregated for internal model;
2. Technology risk. The risk of inadequate or inappropriate use of information technology or failure to understand the consequence of advance in information technology;
3. Model management risk. The risk that a staff or managers lack the skills to enable them to use internal models adequately and successfully. It includes the risk of over-reliance on model; and

4. Operational risk. Other risks of inadequate or failed internal processes, people and systems, including outsourced processes.

Inappropriate Risk Decisions

1. Model expense risk. The risk that an inappropriate expense management strategy is adopted or that the chosen strategy is inadequately implemented on model building and maintaining;
2. Dependence assumption risk. The risk of failed dependence assumptions (i.e. correlations) and a crude risk aggregation; and
3. Model risk. The risk that model is miss-specified (dependence assumption excluded).

External Underlying or Trigger Causes

1. Systemic risk. The risk of ”domino” effect that arises when the regulators render internal models too homogeneous;
2. Supervision risk. The risk that the supervisors controls the use of models and interferes with business decisions when they are based on internal models; and
3. Competition distortion risk. The risk that the rules are not fair for all types of companies and between countries i.e. there will be no level playing field.

Model management, dependence assumptions and model risk are specific internal risk factors for internal models. The other internal risk factors also existed in the London Working Group rapport but in a more general context. The introduced external risk factors for internal models are related to regulation and supervision.

The choice of the internal model specific risk factors can be easily motivated. Internal models are complex and they require high level expertise. Development of internal models is relatively costly, especially for smaller companies. All internal models are based on assumptions about certain risk factors and the related data. Modeling dependencies is fundamental to internal modeling. Without a realistic model of dependencies, the partial models may be realistic, but the whole model is unrealistic. Thus, dependence assumptions are crucial. The importance of regulation risk matches the result of Banana Skin Survey where too much regulation is the top risk. Inappropriate risk decisions are directly related to models.

Our final problem hierarchy is presented in Fig. 2.

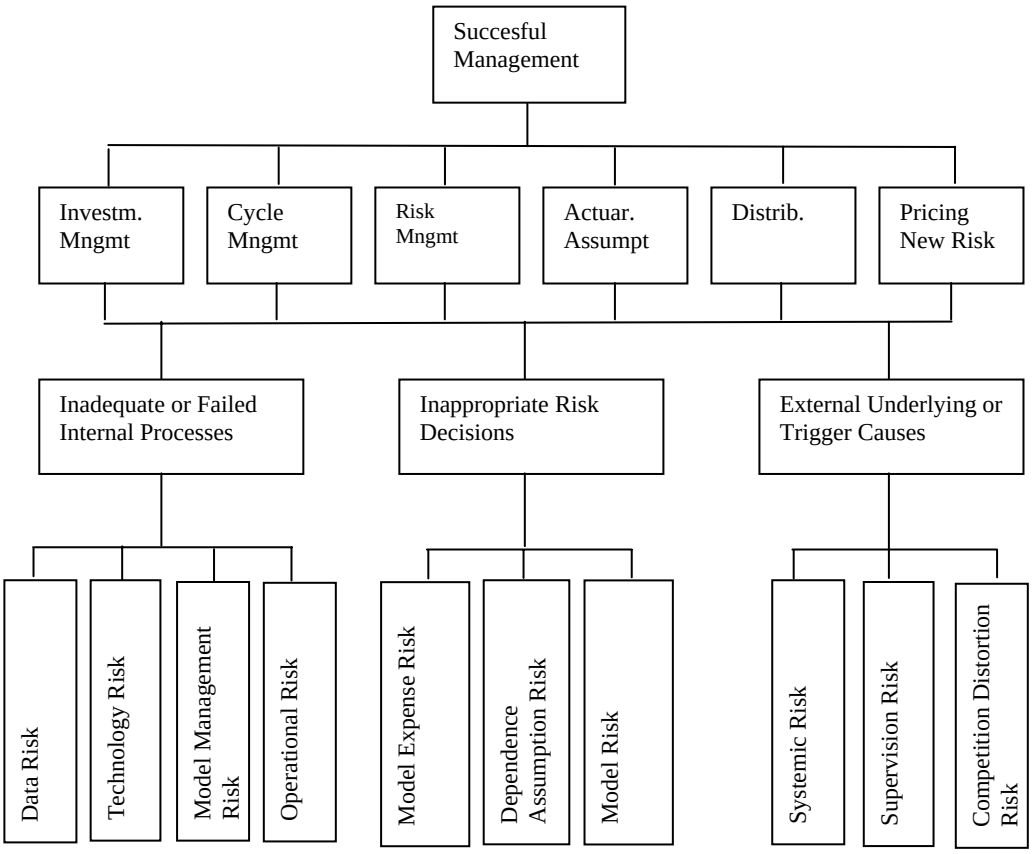

FIGURE 2. Criteria Hierarchy

4.4 Evaluation of the criteria and risk factors

The AHP provides us with a simple tool first to evaluate the relative importance of criteria, then to compare the significance of the alternative risk factors, and finally synthesize the impact of various risk factors on successful management. The panel started the evaluation process by comparing pairwise the relative importance of the criteria. In this context, the importance was interpreted as a strength of focus. In principle, the joint opinion can be found by applying as a majority rule or a consensus. The panel decided to negotiate until the consensus was reached.

The panel evaluated the relative importance of the risky management components by using a verbal description such as "*essential or strong importance*" as explained in Appendix B. Those evaluated are presented as quantitative numbers corresponding to verbal descriptions. The results are given in Table 1. On the last column, the weights (priorities/value scores) calculated by the AHP are given. The management components are afterwards ranked according to their importance.

Table 1: The pairwise comparisons of the management criteria

Management Criteria	M1	M2	M3	M4	M5	M6	Weights
M1 Investments Management	1	5	5	9	7	9	0.494
M2 Cycle Management	1/5	1	2	7	5	7	0.212
M3 Risk Management	1/5	½	1	5	7	6	0.160
M4 Actuarial Assumptions	1/9	1/7	1/5	1	7	3	0.073
M5 Distribution Channels	1/7	1/5	1/7	1/7	1	3	0.036

Saaty (1980) has proposed the use of a so-called consistency ratio (C.R.) to measure the consistency of the evaluation. The consistency ratio in this case was 0.17, which is not very good, but is acceptable (< 0.20).

It is not surprising that the criterion "*Investment Management*" is the most important one, but the importance of "*Risk Management*" is not at all obvious. The reason for the significance of risk management criterion may be that in many applications it is not possible to find a unique model and price, which leads to more complex and subjective modeling techniques and assumptions, and further complex risk management processes. The weights are displayed a histograms in Fig. 3.

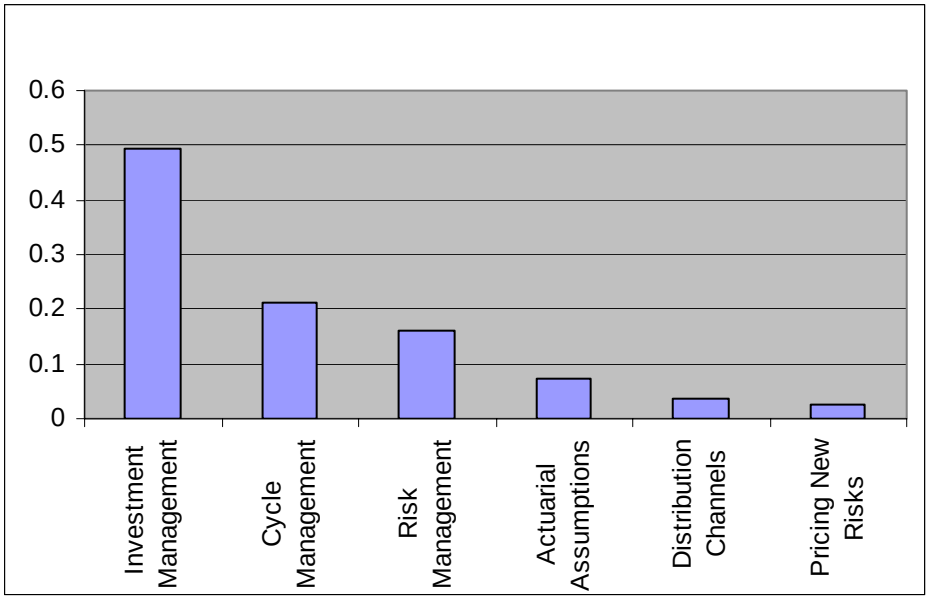

FIGURE 3. The mutual importance of management components.

Next the panel evaluated the relative importance of failure cause components for each risky management components. The evaluation results are illustrated in Fig. 4 and the detailed results are given in Appendix C. In each case, the consistency ratio was acceptable. It is not a big surprise that "*External Causes*" are experienced as the most important risk class for the capability to manage investments. "*Inappropriate Risks Decisions*" is the most important for the capability to manage the cycle, to utilize risk management, and to control distribution channels. On the other hand, risk class "*Inadequate or Failed Processes*" is most important for the capability to choose right

actuarial assumptions and price new risks. It is also interesting to observe that one cause component clearly dominates in the case of management components.

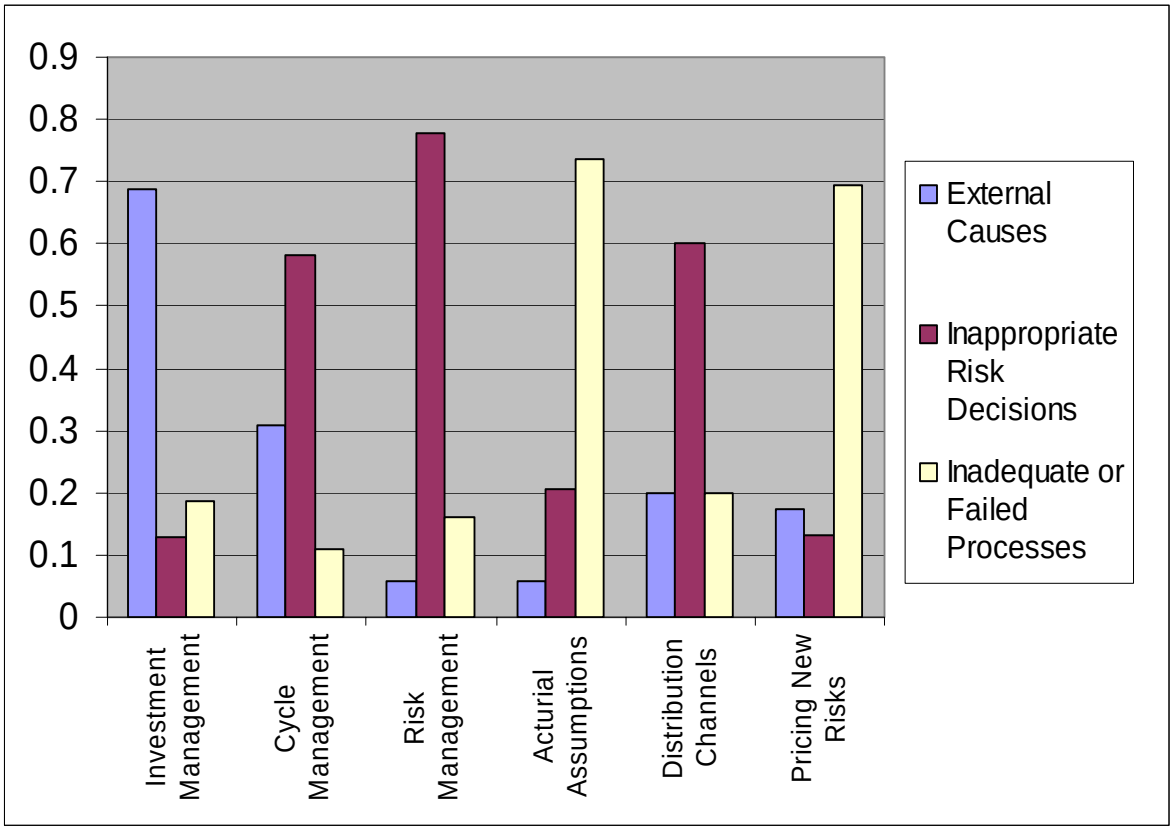

FIGURE 4. The importance of the causal factors in the management components.

The final step was to evaluate the relative importance of the various risk factors related to internal models to the cause component for failure, and finally aggregate this information up to risky management components. Different risk factors are significant for different cause components for failure. Thus the idea is to first study which risk factors in internal models most likely will trig a certain cause to lead a "failure path", and then to aggregate this information to risky management components.

The evaluation is carried out such that using the AHP, we will find the relative weights for the risk factors most significant for each failure cause components and then we use the importance weights we found for those components to aggregate the significance of the risk factors up to risky management components. This information helps managers to evaluate a relative importance of various risk factors from the perspective of management. The summary information is given in Fig. 5 and detailed calculations are given in Appendix D.

From Fig. 5, we will see that "*Systemic Risk*" appears to be the most important one and another regulation related to risk factor "*Model Control Risk*" but the "*Competition Distortion*" was considerably less important. Other high level risk factors were "*Model Risk*" and "*Dependence Assumption Risk*".

The overall picture from the evaluation is that the management should pay attention to practical issues such as the modeling expertise, suitable software and data sources.

Then there should not be so much troubles with model risk, dependence assumptions, model management. Instead the regulators should try to avoid the increase of systemic risk and take care of model regulation and competition aspects.

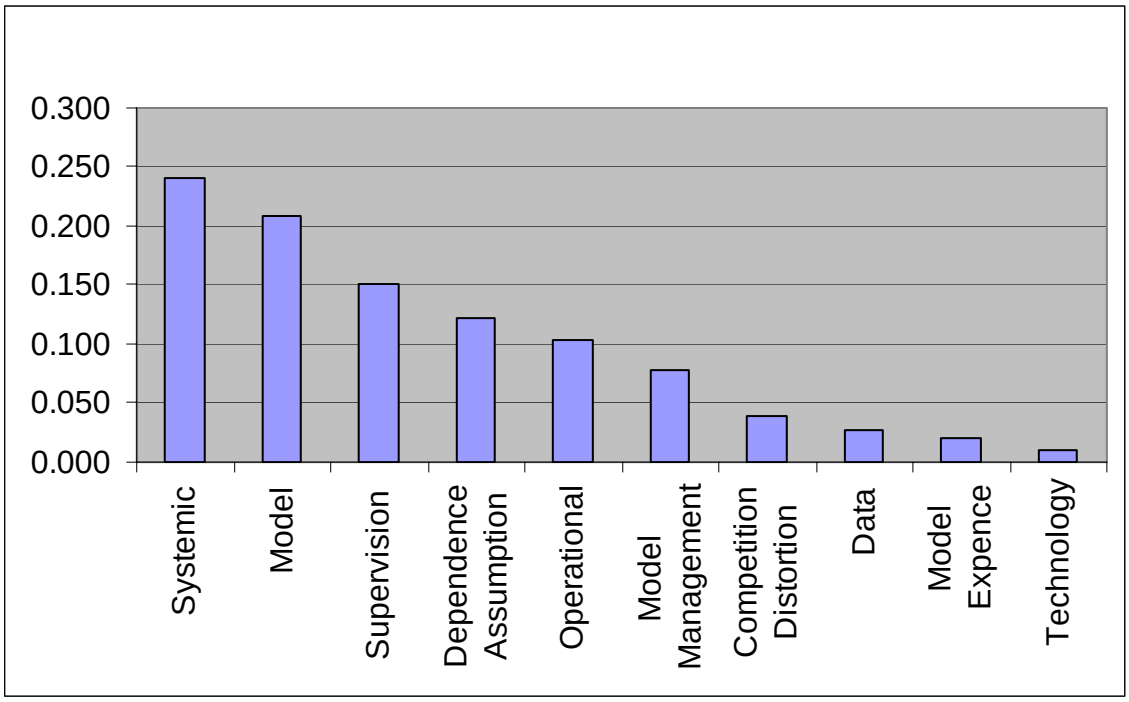

FIGURE 5. The Relative Importance of Risk Factors for Internal Models

5. Discussion of the results

Even if the panel results are not statistically representative, we believe that the results are quite common for medium and mid size insurance companies in the EU. We discuss the implications of the results for internal model users, developers and supervisors and the potential usefulness of decision science tools in the modeling work.

Regulation risks

The panel's concern is that the regulatory system may create potential for new sources of systemic risk. Using similar internal models and data sets insurers may pursue similar strategies to mitigate the adverse effects of crisis. In such cases, individual actions do not cancel each out but may reinforce each other with the consequence of destabilizing rather than stabilizing the financial system.

Model supervisory control may also increase homogeneity in the risk management practices. Of special concern is how the proposed regulations could induce the harmonization of key management actions like investment decisions. This could severely harm the decision making with an internal model according to the panel.

Hence, allowing a wide flexibility in the data and the structure of the internal model, and also in the way of using the model may beneficial. However, this flexibility counteracts the objective of generating a level playing field and a compromise is needed between these targets.

Management actions

The output of internal models greatly depends on how the management decisions are taken into account and directly affects a company's capital requirement. Hence it is essential to link the decision making to an internal model. But in making decisions, managers must incorporate the opinions as well as the complex institutional constraints and the opportunities that influence the decision making process. This makes the linking of decision making to an internal model a very demanding task.

The findings of the panel study help to focus on certain topics since the panel stresses the importance of proper modeling of management actions that are related to "*Investment Management*", "*Cycle Management*" and "*Risk Management*". In particular it highlights that "*External Causes*" are the most important causal factor class for "*Investment Management*". On the other hand, early internal causes are most critical factors for two important classes "*Cycle Management*" and "*Risk Management*".

Decision theory provides formal tools for formulating and evaluating multiple criteria. The problems can be divided into two categories: discrete alternative problems and optimization problems. The senior managers meet both kinds of problems when using internal models in decision making. Wallenius et al. (2008) have recently reviewed the multiple criteria decision analysis literature.

Model use risks

The model risk arises in a situation where the results and decisions emerging from an analysis are sensitive to the choice of model and the there is uncertainty of the suitable model. A possible remedy for model risk is a Bayesian approach which provides a coherent framework to make inferences in the presence of model uncertainty. For instance, Bayesian model averaging (see e.g. Hoeting et al., 1999) provides plausible and statistically well-founded techniques for accounting this model uncertainty. In this technique each considered model is weighted by its posterior probability. In face of model risk, rather than to base decisions on a single selected "best" model, a modeler can base his inference on entire set of models by using model averaging. A bit unexpectedly the data risk was not found especially important. Perhaps, the subject is more important for the modeling team than for senior management.

Alexander (2005) states that all models are subjective and all data are incomplete for the purpose of forecasting risk. Further, she presumes, like the panel that particularly crude assumptions are made between categories of risk. The reason for this is that the dependences are not easily quantified. An insurer's own data are rarely adequate. Inevitably, a good deal of professional judgment will be required. Typically this is done by defining a correlation or a joint distribution in terms of marginal and conditional distributions for model's random variables.

Human limitations of memory and information processing capabilities often lead to subjective probabilities that are poorly calibrated or internally inconsistent; see, e.g., Kahneman et al. (1982). However, decision analysis provides tools for better assessment. For instance, Clemen and Reilly (1999) describe how correlations and copulas can be assessed by experts subjective judgment and Winkler and Clemen (2004) show how adding experts and adding methods can both improve accuracy in assessing correlations.

6. Conclusions

In this paper we explored several critical aspects of risk and capital management of an insurance company – e.g. management criteria, model error, data problem - and provided examples that illustrated the potential importance of management science tools for internal model users and developers.

As source information for the causes of failure and internal model related risk factors, we used the cause effect model of the European insurance supervisors and insurance Banana Skin Survey (2007). The problem was formulated as a multiple criteria decision making task with a hierarchical structure. We used Analytical Hierarchy Process developed by Saaty (1977) as a planning tool to analyze management criteria, causal and risk factors. The evaluation was carried out by a panel consisting of senior managers of Finnish insurance companies. The AHP turned out to be an excellent tool for structuring and focusing discussions.

"*Investment Management*" was found to be the most important management criterion. Other important criteria were "*Cycle Management*" and "*Risk Management*". As a final result, we obtained a list and rank order of the key risk components of internal modeling. Panel's main concern was that the new regulatory regime may create a potential for new sources of systemic risk and supervisory over-control of the internal models. Model related important risk factors are (pure) model risk and dependence assumptions.

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APPENDIX A INSURANCE BANANA SKIN SURVEY 2007

CSFI and PriceWaterHouseCoopers

1 Too much regulation
2 Natural catastrophes
3 Management quality
4 Climate change
5 Managing the cycle
6 Distribution channels
7 Long tail liabilities
8 Actuarial assumptions
9 Longevity assumptions
10 New types of competitors
11 Investment performance
12 Managing technology
13 Equity markets
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15 Back office
16 Political shocks and pressures
17 Pricing new risks
18 Terrorism
19 Complex instruments
20 Retail sales practices
21 Pollution
22 Interest rates
23 Corporate governance
24 Demographic trends
25 Contract wording
26 Capital availability
27 Security of reinsurance
28 Availability of reinsurance
29 Business continuation
30 Fraud
31 Merger mania
32 Too little regulation
33 Asbestos

Appendix B Analytic Hierarchy Process

To find the relevant criteria is an important task and crucial for the success of the decision making. Keeney and Raiffa [1976, p. 50], present the following desirable properties of the set of criteria:

- complete, it covers all the important aspects of the problem,
- operational, it can be meaningfully used in the analysis,
- decomposable, all aspects of the evaluation process can be simplified by breaking it down into parts,
- non redundant, so that the double counting of impacts can be avoided, and

minimal, so that the problem dimension is kept as small as possible

The basic assumption in the Analytic Hierarchy Process (AHP) is that a human being makes comparisons between objects on a ratio scale (see, e.g. Saaty [1980]). For instance, the expression: A is "twice better" than B means that the utility (value) v(A) of A is two times higher than the utility (value) v(B) of B. Even a "softer" expression like A is "much better" than B is interpreted in the AHP to mean that v(A) = kv(B), where k >>1. The concept "better" can be replaced e.g. by the concept "more important". Then function v describes the intensity of focus. A is more important than B means that we have to pay more attention to A than B. In the AHP, the objects to be compared can be concrete or abstract.

A central element in the AHP is a full set of n(n - 1)/2 pairwise comparisons, where n is the number of objects. Because it is difficult for a person to distinguish simultaneously more than 7-9 different levels of preference, Saaty (see, e.g. Saaty [1980, p. 54]) has proposed the use of the following verbal descriptions and the corresponding scores in making comparison:

Table a: Verbal descriptions and the corresponding original numerical scores

Score	Description	Explanation
1	equal importance	Two activities contribute equally to the objective
3	moderate importance of one over another	Experience and judgment slightly favor one activity over another
5	essential or strong importance	Experience and judgment strongly favor one activity over another
7	demonstrated importance	An activity is favored very strongly over another; its dominance is demonstrated in practice
9	extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation.
2,4,6,8	Intermediate values between adjacent values	When compromise is needed

If object i has one of the above nonzero numbers assigned to it, when compared with object j, then j has the reciprocal value when compared with i. Intermediate scores of 2, 4, 6, and 8 are used, if a person thinks that for example object i is at least moderately better than object j, but (s)he is not comfortable with saying that i is strongly better than j. Then his or her view might be represented by the score 4. If object j is at least moderately but not necessarily strongly better than object i, then the score 1/4 would be assigned to the comparison of i with j.

Having recorded the quantified comparisons on pairs i and j as numerical entries in the matrix A, the problem now is to find numerical value scores w_i, i = 1, 2, …, n, for objects such that $a_{ij} \approx w_i/w_j$. However, in practice, it is unrealistic to expect this relation to be exact. Part of the deviation is caused by the score used for a_{ij}, but the main part of the deviation is caused by the inability of a human being to be precisely knowledgeable and consistent. For example, if one prefers object 1 to object 2 by 2:1, and object 2 to object 3 by 3:1, consistency means that

one should prefer object 1 to object 3 by 6:1, otherwise the comparison is inconsistent. Saaty [1994] provides some measures for evaluating the degree of inconsistency.

When the objects i and j are compared in a pairwise manner, one hopes that the final values derived from the paired comparisons of the objects are better than those obtained by direct assignment of numbers to all objects at once. How good the estimates are for value scores depends on the scale used to interpret verbal descriptions referring to the ratios of the value scores.

To estimate the value scores w_i, i = 1, 2, …, n, on the basis of the pairwise comparison matrix, Saaty [1980, pp. 49-53] proposed the use of the eigenvalue method. As discussed in Saaty and Vargas [1984], other estimation criteria, such as least squares or logarithmic least squares, are also proposed in the literature.

An ultimate goal in the AHP, is to estimate a vector $w = (w_1, w_2, \dots, w_n)$, $w_i > 0$, i = 1,2, …, n, which usually is scaled so that $\Sigma_i\, w_i = 1$ whereby w_i represents the relative value score of object i. The positivity condition $w_i > 0$ on the components of the vector w require that the objects be comparable on a ratio scale.

The objects to be compared may be for instance forces, actors, criteria (objectives) or alternatives (scenarios). In the AHP, the evaluation problem is presented in a hierarchy. At each hierarchy level, we have the objects of the same type. For instance, at the criterion level, we compare the criteria. At the lower level in the hierarchy, we may have the alternatives which are compared on each criterion.

Appendix C Importance of Causes for Management Criteria

Table C1. Investments Management

C.R. = 0.090	Inadequate or Failed Internal Processes	Inappropriate Risk Decisions	External Underlying or Trigger Causes	Weights
Inadequate or Failed Internal Processes	1	2	1/5	0.186
Inappropriate Risk Decisions	1/2	1	1/4	0.127
External Underlying or Trigger Causes	5	4	1	0.687

Table C2. Cycle Management

C.R. = 0.004	Inadequate or Failed Internal Processes	Inappropriate Risk Decisions	External Underlying or Trigger Causes	Weights
Inadequate or Failed Internal Processes	1	1/5	1/3	0.109
Inappropriate Risk Decisions	5	1	2	0.582
External Underlying or Trigger Causes	3	1/2	1	0.309

Table C3. Risk Management

C.R. = 0.139	Inadequate or Failed Internal Processes	Inappropriate Risk Decisions	External Underlying or Trigger Causes	Weights
Inadequate or Failed Internal Processes	1	1/7	4	0.162
Inappropriate Risk Decisions	7	1	9	0.778
External Underlying or Trigger Causes	1/4	1/9	1	0.059

Table C4. Actuarial Assumptions

C.R. = 0.113	Inadequate or Failed Internal Processes	Inappropriate Risk Decisions	External Underlying or Trigger Causes	Weights
Inadequate or Failed Internal Processes	1	5	9	0.735
Inappropriate Risk Decisions	1/5	1	5	0.207
External Underlying or Trigger Causes	1/9	1/5	1	0.058

Table C5. Distribution Channels

C.R. = 0.000	Inadequate or Failed Internal Processes	Inappropriate Risk Decisions	External Underlying or Trigger Causes	Weights
Inadequate or Failed Internal Processes	1	1/3	1	0.2
Inappropriate Risk Decisions	3	1	3	0.6
External Underlying or Trigger Causes	1	1/3	1	0.2

Table C6. Pricing New Risks

C.R. = 0.077	Inadequate or Failed Internal Processes	Inappropriate Risk Decisions	External Underlying or Trigger Causes	Weights
Inadequate or Failed Internal Processes	1	7	3	0.694
Inappropriate Risk Decisions	1/7	1	1	0.132
External Underlying or Trigger Causes	1/3	1	1	0.174

Table C7. Synthesis of the Importance of Causes for Management

Weights:	0.494	0.212	0.160	0.073	0.036	0.024	
	Invest. Mngmt	Manag. Cycles	Risk Mngmt.	Actuarial Assumpt.	Distrib. Channels	Pricing New Risks	Weights
Inadequate or Failed Internal Processes	0.186	0.109	0.162	0.735	0.2	0.694	0.218
Inappropriate Risk Decisions	0.127	0.582	0.778	0.207	0.6	0.132	0.350
External Underlying or Trigger Causes	0.687	0.309	0.059	0.058	0.2	0.174	0.430

Appendix D Risk Factors of Internal Models

Table D1. Relevant Risk Factors for Inadequate or Failed Internal Processes (Weight: 0.218)

C.R. = 0.095	Data Risk	Technology Risk	Model Management Risk	Operational Risk	Priorities	Weighted Priorities
Data Risk	1	5	1/3	1/7	0.125	0.027
Technology Risk	1/5	1	1/7	1/7	0.044	0.010
Model Management Risk	3	7	1	1	0.356	0.078
Operational Risk	7	7	1	1	0.474	0.104

Table D2. Relevant Risk Factors for Inappropriate Risk Decisions (Weight: 0.350)

C.R. = 0.021	Model Expense Risk	Dependence Assumption Risk	Model Risk	Priorities	Weighted Priorities
Model Expense Risk	1	1/7	1/9	0.057	0.020
Dependence Assumption Risk	7	1	1/2	0.346	0.121
Model Risk	9	2	1	0.597	0.209

Table D3. Relevant Risk Factors for External Underlying or Trigger Causes

C.R. = 0.052	Systemic Risk	Supervision Risk	Competition Distortion Risk	Priorities	Weighted Priorities
Systemic Risk	1	2	5	0.559	0.240
Supervision Risk	1/2	1	5	0.352	0.151
Competition Distortion Risk	1/5	1/5	1	0.089	0.038