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A systematic design for coping with model risk

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ABSTRACT

Model risk has become an important risk that must be taken into account by financial institutions when they make the strategic-level decision of company's solvency control and risk management through simulating and analyzing company's financial situation. To effectively cope with the model risk, the strategic-level simulation system (SSS) that implements the business view and economic environment and generates various useful financial and risk management reports cannot be treated as a static information system. Rather, SSS represents a family of possibilities because the senior manager who performs the simulation has a role in how the simulation is actually carried out. The extent of these variations is likely to increase when the business environment changes, the relevant financial theories evolve, and the senior manager assesses the system flexibility of SSS. Hereby, the system flexibility of SSS means its users, normally the senior manager, can have the luxury of modifying themselves the embedded functions associated with certain risk factors through the (user-friendly) interface. Based upon the guidance of design science, this study proposes a systematical way of designing a SSS that can effectively cope with the model risk. Specifically, this study takes the Dynamic Financial Analysis system as an example to illustrate the proposed system design.

1. Model risk and system flexibility requirement

In addition to the traditional risks, such as market risk, credit risk, and operational risk, model risk has become an important risk that must be taken into account by financial institutions when they make the strategic-level decision of company's solvency control and risk management through simulating and analyzing company's financial situation (Derman, 1996; Green & Figlewski, 1999; Hull & Suo, 2002; Rebonato, 2002; Hull, 2007; Jorion, 2007). The model risk corresponds to the risk of embedding systematic errors in the simulated results, which are attributed to the use of inadequate models of risk factors (e.g. interest rates, stock market returns, and bond market returns). Green and Figlewski (1999) pointed out an inadequate model might give rise to several problems to financial institutions. Problems will stimulated the price either too low to sell or too high to purchase. In addition, the problems could anticipate a bad hedging strategy as for being used or cause market risk, and also lead to severe error in credit risk measures. In fact, Derman (1996) had listed numerous reasons to explain why the model has inadequacy based on the badly specified, incorrectly implemented, improper model parameters estimated and so on. For instance, in the case of Dynamic Financial Analysis (DFA) system (Berger & Madsen, 1999; Emma, 1999; Eling & Parnitzke, 2007) shown in Fig. 1, if the particular functional form or assumption chosen in models of risk factors for valuing an asset or a liability is incorrect, an incorrect surplus distribution will be generated; as a result, the insurer will be misled in risk management and strategy evaluation. However, insured risks lack adequate data for accurate modeling and the fat-tail nature of some businesses' returns also makes the modeling more difficult. Furthermore, as the regulatory and competitive environments change, the adopted DFA model must be refined to respond to the change.

To properly address the challenge of model risk, embedded models of risk factors not only should be well defined and developed at the beginning for setting up the corresponding strategic-level simulation system (SSS), but also should be continually refined and extended. In other words, the realistic modeling process associated with a complex financial business environment needs be cyclic as stated in Table 1. Such a cyclic phenomenon leads to the *system flexibility* requirement in designing the corresponding SSS. Hereby, the system flexibility of SSS means its users, normally the senior manager, can have the luxury of modifying themselves the embedded functions associated with certain risk factors through the (user-friendly) interface. With the system flexibility, SSS is not a static information system. Rather, it represents a family of possibilities because senior managers who perform strategic-level decision-making should have a role in what and how models of risk factors involving in the decision analysis are actually carried out. The extent of these variations is likely to increase when the

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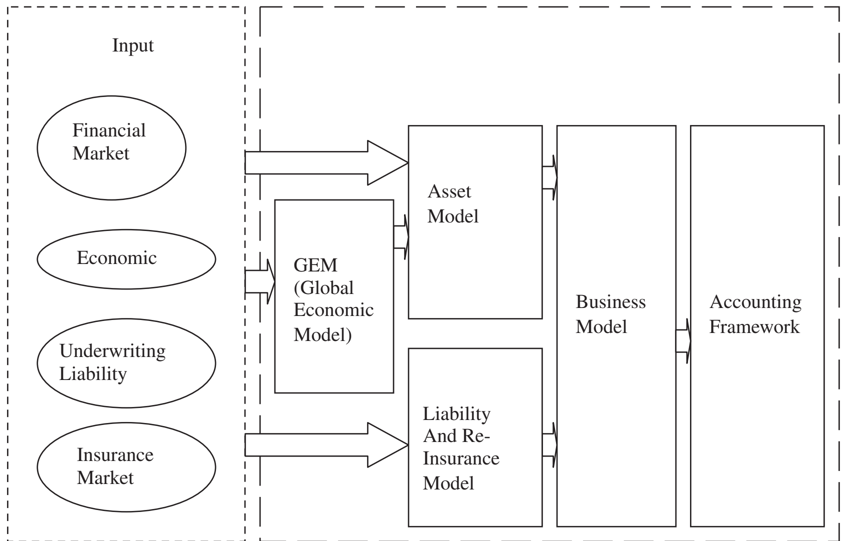

Fig. 1. American Re-Insurance Company's risk management system. (Source: Berger and Madsen, 1999).

Table 1
The cyclic phenomenon of a realistic modeling process of simulation for properly coping with model risk of strategic-level decision-making.

	Explanation
Step 1. Identify and model essential risk factors	For projecting the balance sheet and operating statement of the company onto the planning horizon, the most relevant risks that affect assets, liabilities, underwriting, or investment income need to be considered
Step 2. Model variables from risk factors	For each individual risk factor, numerous possible models from Actuarial Science, Finance and Economics are available. For instance, both Vasicek and Cox, Ingersoll, Ross (CIR) models are widely adopted for modeling the interest rate. Thus, the senior manager needs to decide how the risk factors are assumed to behave on the forecast horizon
Step 3. Consolidate different risk factors	Many risk factors are interrelated in a complex manner; for example, a change in interest rates would lead to a different movement in the value of existing assets. Risk factors should be consolidated carefully
Step 4. Build up the strategic-level financial information system	The conceptual models derived from the above steps are coded in a computer-recognizable form and integrated into the strategic-level financial information system, which is a simulation system
Step 5. Input initial positions and conditions	Necessary data including financial and economical information and model assumptions are fed into the strategic-level financial information system
Step 6. Generate results	The simulation is performed to generate results
Step 7. Analyze results	Sophisticated analysis becomes necessary for extracting information from the simulation results
Step 8. If necessary, repeat Steps 1 to 7	Embedded models of risk factors are not only defined and developed at the beginning, but also continually refined and extended

business environment changes, the relevant financial theories evolve, and the senior manager assesses the system flexibility of SSS.

Researchers and practitioners desire a systematical way of designing a SSS that can effectively cope with the model risk, as we do here. However, most discussions in literatures of risk management (Pennings & Smidts, 2000; Iversen, Mathiassen, & Nielson, 2004; Benaroch, Lichtenstein, & Robinson, 2006; Dewan & Ren, 2007; Gefen, Wyss, & Lichtenstein, 2008; Berkowits, Christoffersen, & Pelletier, 2009; Lin & Ko, 2009; Roisenberg, Schoeninger, & da Silva, 2009) do not seem to generalize to present a systematical way of designing such a SSS.

Based upon the guidance of design science (Hevner, March, Park, & Ram, 2004; Gregor & Jones, 2007; Lee, Wyner, & Pentland, 2008; March & Storey, 2008), this study proposes a systematical way of designing a SSS that can effectively cope with the model risk. Specifically, this study takes the DFA system as an example to illustrate the proposed system design.

The proposed system design of the DFA system is briefed as follows. The senior manager usually has a (default) DFA model that describes the business view of the firm and the economic environment as well as an idea about all entities and their associated attributes that will be calculated according to the accounting requirement. The given DFA model leads to a (static) DFA system that represents the present situation in the system space.

To take care of tasks of the constructing phase, the simulating phase, and the analyzing phase in the process of a realistic cycle shown in Fig. 2, the desired DFA system should consist of model builder, model simulator, and model analyzer. Design Science states that through adding artifacts to the given DFA model, the system engineer could develop such a DFA system that represents the desire situation in the system space.

Based upon the proposed architecture in Fig. 3, we figure out a set of seven artifacts that provide the system flexibility and help remove differences between desire and present situations in the system space. Here we also adopt a design concept similar to the one stated in (Tsaih, Liu, Liu, & Lien, 2004). That is, when some new model has been reasoned out, the senior manager can define the new model themselves via the model builder. Model builder then codes all models via transforming them into XML files and a translator mechanism will parse associated XML files and transform them into a set of dynamic linked libraries (DLL) that are stored into the back-end DLL database. Then, the senior manager uses the model simulator to pick up any existing models for the purpose of simulation. At the end, the senior manager uses the model analyzer to analyze simulation results. The corresponding simulation results can be stored and retrieved whenever needed. The entire process is conducted through a series of Graphic User Interfaces (GUI), leaving as much work as possible to the computer system.

The remainder of this article is organized as follows to provide more details. Section 2 outlines a feasible object-oriented framework for the DFA model. The purpose of having the object-oriented framework is to help integrate with additional artifacts. Section 3