# An analytic environment for systemic risk- Risk modeling support for financial policy makers

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***Abstract*— Systemic risk in the U.S. financial system has drawn the attention of leaders in government and business alike. The abundance of systemic risk measures and risk models has added to the complex task of understanding, discussing, and acting on the implications of that risk. Tools that assist decision makers to interpret risk measures, and recognize their underlying assumptions may lead to deeper understanding and more effective discussion. This paper describes some initial considerations for building an integrated modeling and analysis environment to aid in assessing complex financial data. The modeling environment is engineered to support execution of quantitative models including agent based and network models against equivalent scenarios of economic conditions. The environment provides tools to compare and visualize model outputs, and to allow decision makers to maintain traceability from model outputs back to their underlying assumptions. This capability may facilitate the operation of a modeling forum where disparate teams of analysts can collaborate to provide insights into the nation's exposure to systemic financial risk.**

*Index Terms*—Computational modeling, Computer simulation, Interconnected systems, Multilevel systems, Communication effectiveness

## I. Introduction

THIS project was initiated to demonstrate the use of a secure, multilevel modeling environment in facilitating explicit discussions among decision makers about uncertain and complex aspects of systemic risk in the U.S. economy. The objective is not to generate a "correct" answer, but rather to allow unbiased comparisons of several different answers.

The nation's exposure to financial risk arising from a broad range of diverse and additive effects has gained recent attention from leaders in government and the financial services industry. These complex systemic risks have proven to be difficult to quantify with most traditional tools, and even harder to articulate and discuss during the process of deciding how government and industry should respond when risks arise.

This work is motivated by the belief that a secure modeling environment that can host a wide variety of models and execute them on equivalent scenarios while maintaining traceability to their underlying assumptions will be useful to decision makers who seek to have fact-based discussions during the decision making process.

There are numerous finance, economic, and risk models that have been developed to represent aspects of the nation's systemic risk. This project is intended to prototype an environment that would allow an array of those models to be brought together both to form aggregated views of the composite situation, and to perform unbiased comparisons of any conflicting forecasts that they might produce.

## II. Discussion

Many authoritative practitioners of finance and economics base their assessments of the level of systemic risk in the economy on differing methods and assumptions. For example, one practitioner might use measures of default risk in the financial services industry as a prominent factor that influences an assessment of risk, while another might place primary emphasis on factors such as change in equity market indices. If these two practitioners produced conflicting assessments of the level of national systemic risk, it might be difficult for a consumer of their assessments to determine the importance of that disagreement if the consumer did not have access to the likely differences in underlying assumptions, input data, and methods of calculation that were required by the two different approaches that the practitioners used.

It is often the case that the existence of two different assessments does not mean that one is right and the other is wrong. It may be the case that if both methods had been applied with the same assumptions or the same input data, the two resulting assessments would have been more consistent.

This project is intended to demonstrate a modeling environment in which the two practitioners described above could apply their separate methods against the same scenario and use consistent data to generate their assessments of systemic risk. Consumers of those assessments could then compare them and trace back to the underlying assumptions of the methods used while they evaluate and discuss the output. Providing this traceability might be a mechanism for managing the complexity of making decisions on how to respond to systemic risk. Our expectation is that such a secure modeling environment would be useful to holding that sort of fact-based deliberation. It may also be true that those fact-based deliberations would enable more effective discussion

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and consensus building around the actual level of risk.

This effort is organized into five tasks according to the primary disciplines required.

### A. Data Management Environment

An environment that supports a wide variety of models requires an ability to provide access to a wide variety of data. This project requires the ability to securely host large volumes of sensitive data that may receive updates once each quarter, or many times each second. The specific data sources maintained will be driven by both the input requirements of the individual models, and the data required to provide context to the collected outputs. Sources will include data on specific industries and markets as well as national level data such as:

- Key interest rates
- Equity and commodity indices
- Labor productivity
- Employment rates
- Inflation rates

At least one index of legal identifiers will be required to allow disambiguation of entities that appear in more than one data set under more than one name. (For example data on the International Business Machines Corporation might also be indexed by the names IBM, and IBM Canada.)

Major functions required of the data management environment include:

*Data Acquisition*- The processes required to access data from the originating source and make it available for use within the environment.

*Data Preparation*- The process required to examine data for inconsistencies, incomplete records, unreadable data, and other issues that might make the data difficult to use.

*Data Integration*- The process that allows data to be accessed consistently even if the original source employed non-standard indexing. [Rosenthal and Seligman, 2011]

*Data Management*- The processes, hardware, and software used to manage, store, and manipulate data once preparation is complete.

The data management environment may also host limited analytic capabilities to integrate and interpret information available within and across data sets. [Seligman, 2011]

### B. Model Hosting and Execution Environment

The objective of a secure modeling environment for the analysis of systemic risk imposes some challenges on any facility that might be used to host it. Many of the models that reside in the environment will employ sensitive algorithms and produce outputs that will require stringent measures to secure data, software, and hardware against unauthorized access. There may be cases when model outputs will need to be integrated anonymously to ensure that assessments can not be attributed to any one source. In addition to providing security, features such as anonymization of outputs, and role based access to both data and models may serve to encourage broader participation from potential collaborators in industry who have particular concerns about the proprietary nature of their methods. The ability to manage and execute a diverse range of models will require a level of flexibility and robustness that goes beyond what might be used in a typical institutional environment.

Developing scenarios that apply consistently across heterogeneous model types will require both imagination and discipline. Representing units of time, especially in integrated outputs will be especially challenging since there will be models that keep time in milliseconds running alongside models that keep time in quarters of a year.

The major areas of functionality to be provided by the hosting environment include:

*Model Hosting*- The ability to securely host, maintain, and execute multiple diverse models.

*Validation and verification*- The ability to certify that a given model is executing and producing output within the secure environment in accordance with its original design.

*Scenario Generation*- The ability to configure and execute diverse models in a manner that causes their output to reflect the same exogenous conditions and assumptions.

*Data Transformation*- The ability to convert output data from the disparate models into a uniform format that supports analysis by decision makers.

*Analysis and Visualization*- The ability to generate metrics of interest and provide a robust analysis and visualization capability. [Shenoy, 2011]

### C. Comparison and Measurement Across Disparate Models

Not all models relevant to systemic risk seek to assess the same scope of the financial system. Some models are focused on a particular industry, or a specific class of assets. Some models express their output as Financial Soundness Indicators (FSI) that are aggregated from metrics like:

- Capital adequacy
- Asset quality
- Earnings and profitability
- Liquidity
- Sensitivity to market risk

Some other models express their output through measures such as probability of default (PoD), loss given default (LGD), and contagion risk. There are many types of output that might be produced, some of which are reasonable to compare directly to each other, and others that are not. For those models that make sense to compare, a part of this effort will develop tools to facilitate that comparison. Making such comparisons effectively will be challenging because of the different levels of resolution and the scales of time, domain, and geography involved in each of the different methods.

#### *Metric to Metric Comparisons*

If two (or more) assessments are indeed comparable, it is necessary to ensure that the appropriate components of their output are being compared. For example, if one assessment produces a probability of default (PoD) for a nation's top ten financial institutions, while another assessment produces the probability of default (PoD) for a nation's top ten manufacturers, it may not be meaningful to expect that the probability of default (PoD) projected by the two techniques have the same implications to an assessment of national risk (even if the probabilities are all related.)

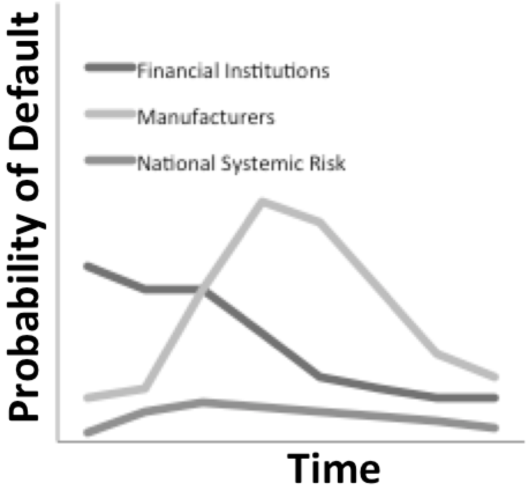


**Figure 1 Visualization of metrics that are different but related**

*Time Series Comparisons*

The output of any assessment describes a particular period of time, although not all assessments will be relevant to the same time frame. One technique might model expected performance for a three month period that is four quarters in the future, while another might model performance for a 12 month period that is one fiscal year in the future.

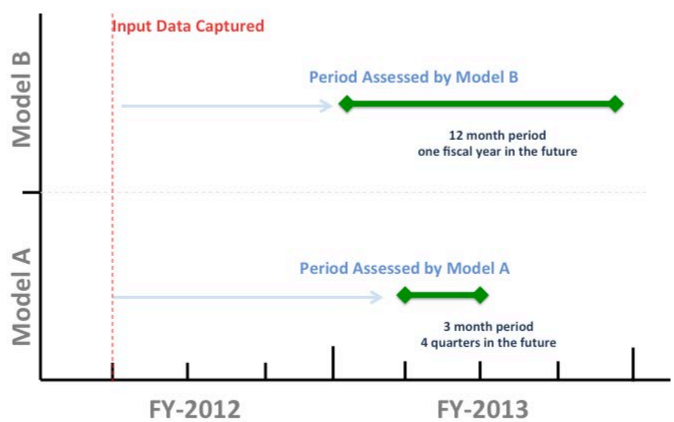


**Figure 2 Comparison of time periods assessed by different methods**

Consumers of the assessments need to be alerted to the difference in the time frames being considered. As displayed in figure 2, Model A and Model B could use the same input data, give different answers, and still both be correct.

### D. *Aggregation of Risk Components*

Since many assessments of national systemic risk focus on specific components of that risk, this effort will develop tools for aggregating those component assessments into a national assessment in meaningful and repeatable ways. For example, if a decision maker received financial soundness indicators (FSI) for several key industries, and each of those FSIs were composed of industry specific metrics (capital adequacy, asset quality, earnings and profitability, liquidity, and sensitivity to market risk); there might be value in a repeatable method for combining those industry specific FSIs and other available metrics into an assessment of national systemic risk. This is another task that will be challenging because of the different levels of resolution and the scales of time, domain, and geography involved in each of the different methods

This effort will demonstrate a method for performing that aggregation. [Guharay and Rosen, 2012]

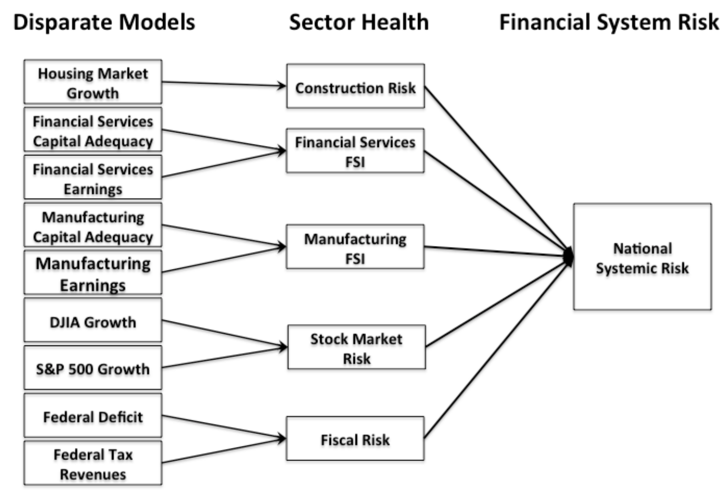


**Figure 3 Aggregation of disparate metrics into an assessment of national systemic risk**

### E. *Component Risk Models*

This effort is focused on the hosting and management of analytic models. There is a vast range of expertise on the components of risk available from industry, government, and academia. In order to demonstrate the use of a secure, multilevel modeling environment, it will be necessary to host a variety of models that represent the U.S. economy at multiple levels of abstraction. The component risk models will come from a variety of sources and will support efforts to prototype the data management, output comparison, and metric aggregation activities discussed above. In order to bootstrap this work, the first group of models hosted will come from within the project team. More authoritative models will be added later with the help of external collaborators.

*Initial Models Tested*

The following models were the first available for integration and prototyping:

*Banking System Risk*

*Iterative Link Based Model of Bank Risk*- The project team developed a model of the network of banks in the U.S. which allows the default risk of each bank to be influenced by banks that share a linkage. This model provides a visualization of the banks with the highest expected default risk, and the other banks they are most closely connected to. [Worrell, Brady, and Bala, 2012]

*Cascading Graph Model of Bank Risk*- The project team developed a model that uses a cascading graph technique to determine the banks that have the greatest influence on the default risk of other banks. [Shi, 2010]

*Equity Market Risk*

*Farmer Derived Model of Market Risk*- The project team replicated an agent based model developed by Doyne Farmer which concentrates on demonstrating market order-book structure and price behavior with respect to randomly placed (zero intelligence) trades. [Farmer, 2005; Tivnan et al, 2010]

*Cont Derived Model of Market Risk*- The project team replicated an agent based model by Rama Cont which introduces the notions of heterogeneity and price feedback. [Cont, 2005; Tivnan, et al 2010]

*Behavioral Model of Market Risk*- The project team developed their own agent based model of market behavior as described in Tivnan et al, 2010.

*Government Fiscal Risk*

*Tax Compliance Analytics Model*- The project team developed an agent based model of tax compliance behavior as described in Andrei, 2011.

*Additional Models Sought*

The project team is seeking collaborators with additional models to be hosted in this secure environment to add to the range of assessments that can be aggregated and compared. [Markeloff, 2011] Some examples of collaborators being sought appear in table 1.

**Table 1 Additional models sought**

| **Model** | **Authors** |
|---|---|
| CoVar | Adrian and Brunnermeier |
| Co-Risk | Chan-Lau, Espinosa, Giesecke, and Solé |
| Network Models and Financial Stability | Nier, Yang, Yorulmazer, and Alentorn |
| Agent-Based Model of the Leverage Cycle | Thurner |
| Systemic Expected Shortfall (SES) | Acharya, Pedersen, Philippon, and Richardson |
| Distress Insurance Premium (DIP) | Huang, Zhou, and Zhu |
| PCA and Granger-Causality | Billio, Getmansky, Lo and Pelizzon |
| Distress Dependency | Segoviano and Goodhart |
| Systemic CCA | Gray and Jobst |

## III. Conclusion

This effort will demonstrate the use of a secure modeling environment in facilitating discussions among decision makers about systemic risk in the U.S. economy. The objective is not to generate a “correct” answer, but rather to allow unbiased comparisons of several different answers.

If effective, this modeling environment could enable fact based discussion and improved consensus building among decision makers. This capability might support formation of a systemic risk modeling forum where analysts, modelers, and decision makers could collaborate to perform what-if analyses of risk in the national economy.

There are three operating models under consideration for how this modeling forum might operate:

*Glass Box Ensemble*

Various modelers submit their models to the modeling forum for integration into the secure hosting environment. Assumptions for all models are documented, data is acquired, and scenarios are written. Models are executed, assessments are generated, and then comparisons and visualizations are produced. Decision makers would review the work products in support of their deliberations. This is analogous to a data analysis process used in an aviation safety program known as ASIAS (Aviation Safety Information Analysis and Sharing.) Details on ASIAS are available at www.asias.faa.gov.

This operating model would allow a high degree of collaboration among contributing modelers, while potentially providing decision makers with the most direct access to unbiased quantitative data. A structured communication technique such as the Delphi Method might be used to help participants reach consensus.

*Working Group Ensemble*

In support of pending decisions, an expert working group might be assembled to generate assessments of the economy using data and toolsets of their choice in the secure model hosting environment. The working group would produce a report elaborating the range of potential outcomes that result from modeling the designated what-if scenarios under consideration. Decision makers would review the report in support of their deliberations. This approach is comparable to that used by the Stanford Energy Modeling Forum. Details on the Energy Modeling Forum are available at www.emf.stanford.edu. [Weyant and Huntington, 2006]

This operating model results in the highest degree of collaboration among modelers and delivers a more easily interpreted output to decision makers. A working group might also employ a structured communication technique to assist in reaching consensus.

*Loose Ensemble*

Decision makers and researchers with specific questions would gain access to the secure model hosting environment for support in their investigations. They would receive support in designing their scenarios and executing the what-if inquiries with the full range of tools available to them through the forum. Their results would then be available to other forum members. This type of collaboration is similar to that used at the Inter-industry Forecasting Project at the University of Maryland (INFORUM). Details on INFORUM are available at www.inforum.umd.edu. [Werling, 2007]

This operating model requires the least collaboration between modelers and would likely produce more subjective assessments than the other approaches considered. The Loose Ensemble approach might enable faster response times to modelers with emergent needs than other approaches.

Any of the three modeling forum operating models would offer decision makers improved access to unbiased, detailed analyses of risk.

## IV. Topics for Additional Research

There is much additional research needed to demonstrate the secure hosting capability envisioned in this project. Some of the most immediate needs include:

Integrating additional models and model types beyond those available at the time of this writing.

Expanding the model execution ability to support both ensembles of related models and federations of tightly integrated models that interact and share data during execution.

Incorporation of additional visualization and output reporting techniques that aid in the task of interpreting complex numerical data.

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