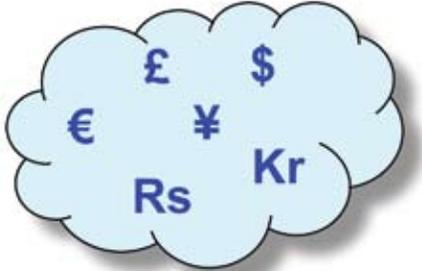


## Financial Engineering Done Right!



### A Control Systems Perspective on Financial Crises

Financial engineering is about risk assessment and risk management. At an individual (including institutional) level, the key issues are to assess the risk/reward trade-off of one's investment portfolio and to minimize if not eliminate risk due to factors beyond one's control. At an aggregate (national) level, the challenge for policy makers is to assess the collective risk of the entire economy. Both tasks are closely related and require the development and calibration of suitable statistical models, as well as methodologies based on these models. Armed with such strategies, individuals, retirement fund managers, investment bankers, and policy makers can make well-informed decisions or, in some cases, offer well-informed recommendations. Actually implementing the recommendations, however, will require political will.

### What Went Wrong?

The Basel II norms for risk assessment and management permitted each institution (such as banks) to use its own internally developed model provided the model afforded adequate risk protection over historical data. Unfortunately, the validation of these in-house models was for the most part based on short-term data, from the benign period from 2002 to 2007. Most of these risk models proved inadequate in assessing the level of risk during the events of late 2007. Even if the models had gone as far back as just 15 or 20 years, it would have been obvious that risk levels were being seriously underestimated.

Certain basic notions such as correlation were ignored in the recent financial crisis. To cite just one instance, there are 50 states in the U.S., about 15 of which are large states. When the risk of mortgage-backed instruments defaulting was estimated, the probability of default in each state was assumed to be an independent random variable! The simple idea that if there is a recession in Michigan, there is likely to be one Florida too seems to have escaped everyone! Many other such simple modeling errors can be pointed out post facto.

Most fundamentally, those tasked with assessing risk must recognize that financial models, no matter how well supported by data and intuition, are not physical laws! There is no " $F = ma$ " in mathematical finance!

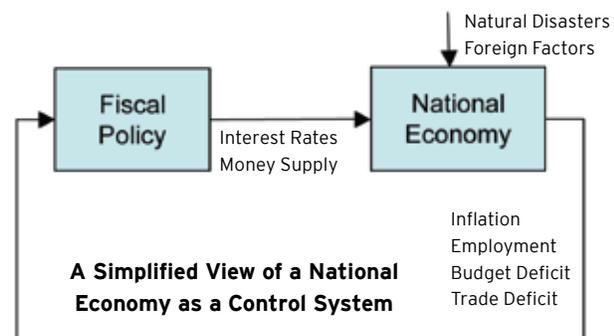
### Value at Risk

The financial industry uses the concept of VaR (Value at Risk) as a metric. VaR is the 99<sup>th</sup> percentile of the probability distribution function (of an individual or institutional portfolio), but can also be applied at a national level. The philosophy is that, using whatever statistical methods we have at our disposal, we can estimate an amount of loss that is likely to be exceeded with a probability of only 1%. This is a useful metric and offers an excellent approach to regulation.

### First Targets

A controls perspective has the greatest potential for impact at societal, national, or global levels, rather than in terms of assisting individuals or institutions. In particular, helping governments make informed policy decisions provides the greatest opportunities for advanced control.

For example, accurately assessing the risk of default on household or sovereign debt (which led to problems in the U.S. and Europe) is an area where a controls perspective can have an immediate impact. On the flip side, banning naked credit default swaps would probably do more to stabilize the bond market than any highbrow controls strategy, but that requires political courage.



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## Heavy-Tailed Distributions

Another problem is that of “heavy tails.” When we try to fit probability distributions on values that are far beyond those usually observed, the standard Gaussian distribution seriously underestimates the risk of extreme events. So we need different kinds of laws of large numbers to study heavy tails. Such theories already exist in the probability theory community, but they have not been applied in the financial community to estimating risk or to crafting suitable regulations based on the risk assessment. To give one specific example, the Black-Scholes formula for valuing options assumes a geometric Brownian motion model. This is unrealistic—data from around the world over several decades have shown that actual asset prices have heavy tails.

The controls community can act as a bridge between the worlds of pure probability theory and the financial sector (including regulators). We can help regulators assess the level of risk in the finance system. We can warn that the credit markets are getting overheated or that the risk of certain banks defaulting is beyond acceptable levels.

Figure 1 illustrates the difference between a heavy-tailed distribution (in red) and a Gaussian distribution. Figure 2 shows a histogram of the S&P 500 fund index (daily logarithmic returns over a 17-year period) along with a normal distribution fit.

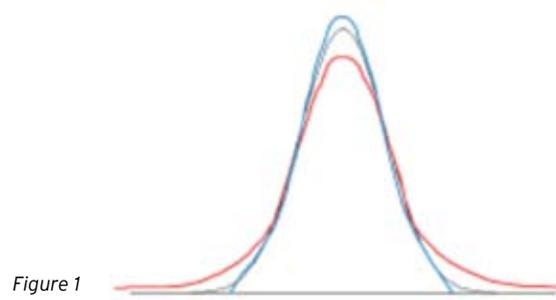


Figure 1

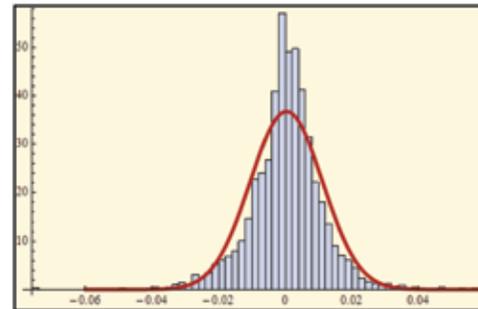


Figure 2

<http://www.mathestate.com/tools/Financial/wp1/MarketTheory.html>

## The Importance of System Identification

If we view financial systems as dynamical systems under feedback, we can clearly see that control technologies have a substantial role to play in financial engineering.

The relevance of system identification especially bears emphasis. “First-principles” models of economic systems are generally unavailable or unreliable; models must be identified from data. However, the levels of uncertainty, the presence of delays, even the possibility that the system we’re trying to model is nonstationary . . . such factors create challenges that are often not encountered in usual control engineering domains.