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The Model Quantitative Firm

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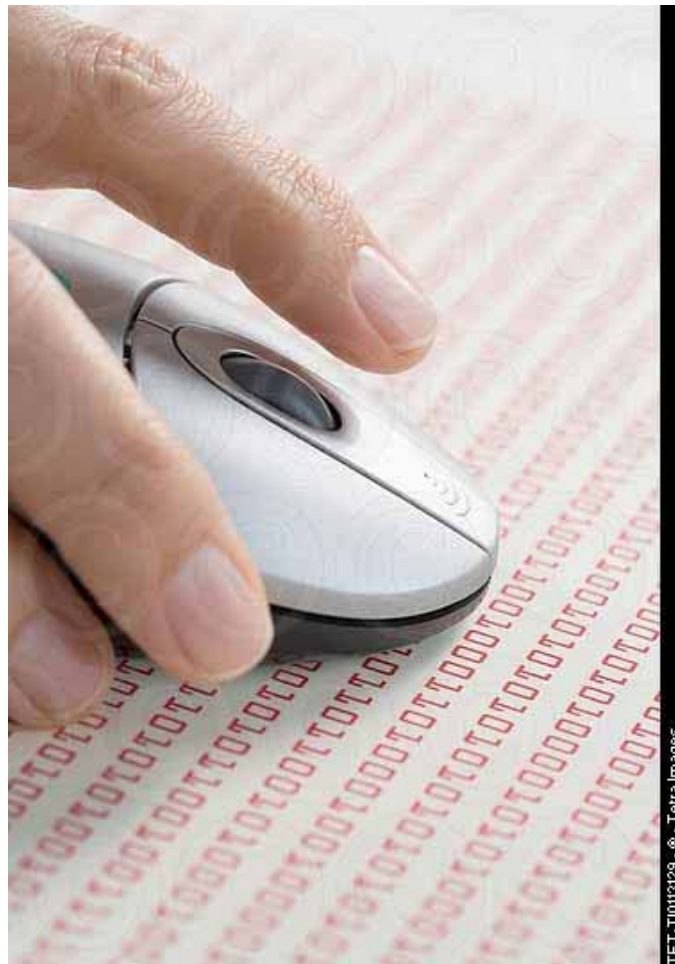
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# Inspiration

The dream of many quantitatively inclined financial practitioners is to build a complete quantitative model of the financial organization and use this as the basis for managing that organization. It is a dream of clarity, consistency, rationality and efficiency, and yet most practitioners know it is far from realized. Certainly we are much closer to that dream now than we were twenty years ago, with increases in model sophistication for many sources of financial risk and increased computational capability. Models are readily used in pricing, risk management and strategy analysis. Different models are used for different purposes and there are inconsistencies. Practical limitations keep organizations from operating under a single unified model which raises the question of why and whether this needs to be the case. Models are simplifications, and choosing your simplifications to suit your application is a good starting point but what else is involved and is there a good alternative? Further, wise practitioners are generally wary of decisions based too heavily on models. This comes from hard earned experience to which recent market events have further contributed. This raises the question of what exactly are the technical problems that trip us up.

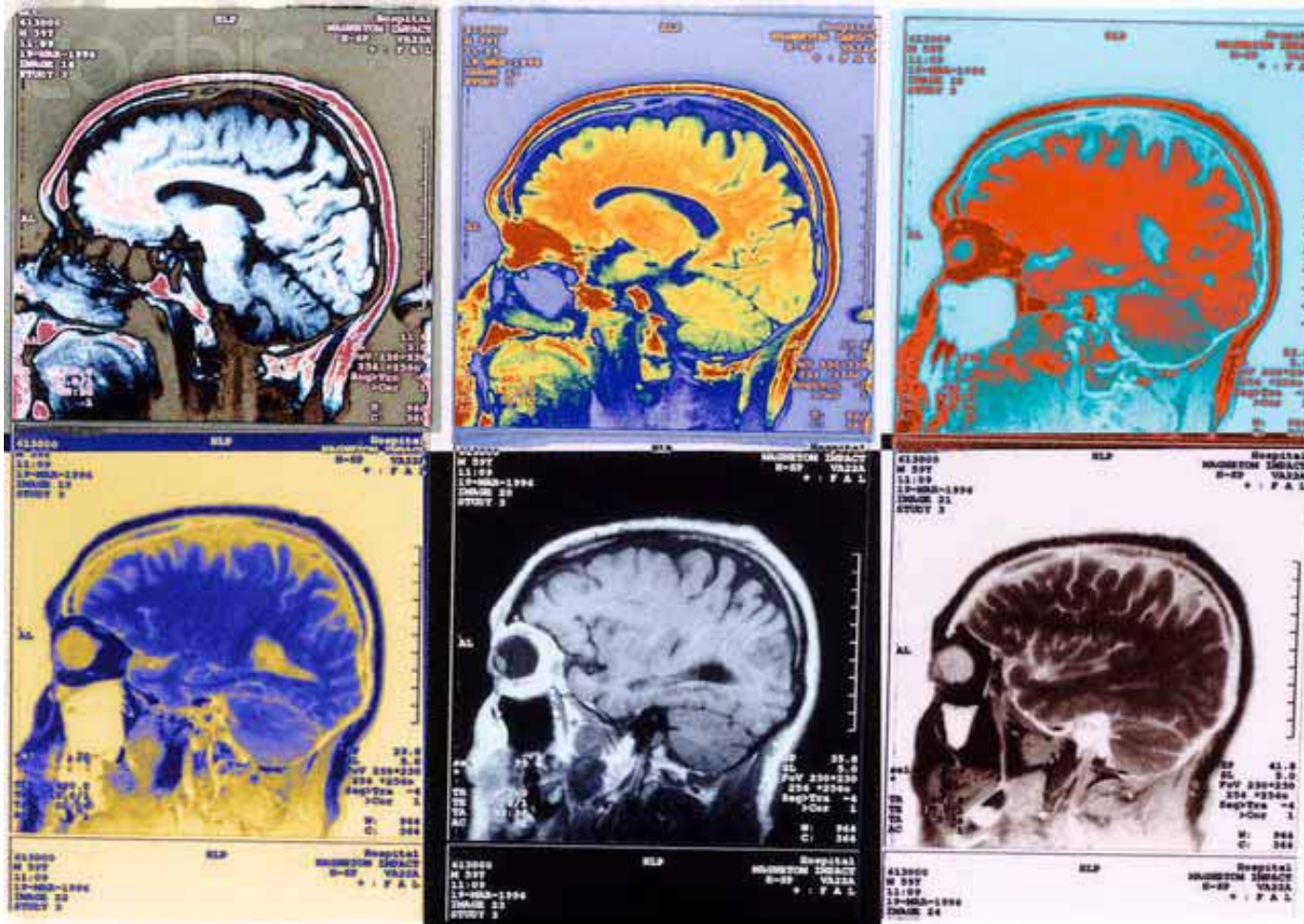
# Inspiration



# Outline

- Approaches to Strategic Analysis
- Assumption Setting
- Curse of Dimensionality
- Complexity Management
- Closing Thoughts

# Approaches to Strategic Analysis



# Approaches to Strategic Analysis

- Approach 1: Build a problem model and then analyze this model to evaluate the implications of different strategies.
  - e.g. VaR, Efficient Frontier Analysis, Pricing
  - Generally the model employed is designed for each specific problem. Made as simple as possible, but not too simple.
  - Question: Could one model be used for all risk and strategy analysis in a firm?
- This is sometimes referred to as the “model of the world approach” and it is the basis of many analytic methods, but not typically the way people or organizations make decisions.

# Approaches to Strategic Analysis

- Approach 2: Start with a solution and refine with experience.
  1. Develop a heuristic strategy description.
  2. Evaluate this strategy on a variety of simple models.
    - How would it have worked in recent past?
    - What kind of results would it provide under historical averages?
    - What kind of VaR figures does it produce?
  3. Revise heuristic strategy as new events indicate problems or ready opportunities.
    - Do more of what has been effective (e.g. ABS).
    - Copy solutions (Avoid disasters) from peers.
    - Try past solutions for new problems.
- Can view as using the world as the model.

# Approaches to Strategic Analysis

- Approach 1 is the typical analytical approach.
  - A1 is sensitive to model errors and prone to systematic failure.
  - A1 offers the potential of a best solution, considering all issues.
  - A1 can immediately consider new conditions.
  - A1 has challenges with more complex problems.
  - Approach 2 is the way humans (and corporations) manage most issues.
  - A2 is a more robust approach.
  - A2 subject to missed opportunities & inconsistencies.
  - A2 will struggle with changing conditions.
  - A2 is more manageable in complex environments.
- Understanding pros/cons of both is the key to finding a better solution. Likely can improve Approach 1 with some insights from Approach 2.



# Approaches to Strategic Analysis

Three fundamental challenges for Approach 1:

1. Assumption Setting
2. The Curse of Dimensionality
3. Complexity Management



# 1. Assumption Setting

- To effectively use Approach 1, you need an accurate model.
- If you base your analysis on an incorrect model, the solution will likely say more about the problems in the model than finding a good decision.
- In fields where there are not very large amounts of data and stable processes (like physical reactions), or alternatively definite known processes (games like chess), verifying your model is not possible.
- Most financial processes have relatively limited data and a complex adaptive process.

# 1. Assumption Setting



# 1. Assumption Setting

- Example Problem Assumptions:
  - How large should the equity risk premium be?
  - What is the correlation or copula assumptions to use between different markets?
  - How do markets adapt to exploitation of inefficiencies?
- The problem is there is not enough historical data to answer these questions with much precision.
- Changes in these assumptions can lead to very different analysis results.
- Can use structural theory to squeeze a little more out of the data (Option Pricing a good example of this).

# 1. Assumption Setting

- Incorporating robustness testing in analysis
  - i.e. How bad can results be if our assumptions are incorrect?
  - Use distributions of assumptions and evaluate downside of results on these distributions.
  - Don't be tempted by the expectations as then you're just working with a more complex model of the same thing.
- Imperfect models are useful for weeding out very poor strategies.
- One way to improve robustness is to limit the alternative solutions to generic strategies that are less likely to take advantage of model weaknesses.

# 1. Assumption Setting

- Illustration of Robustness Testing
  - Develop distributions for key model parameters
  - Perform analysis to find solution strategy with best estimates.
  - Re-evaluate solution strategy with random parameter draws.
  - Look at distribution of results and compare with alternative solutions.
  - Is time consuming and computationally intensive.

## 2. The Curse of Dimensionality

- Why is Chess harder than Checkers, and Checkers harder than TicTacToe?
- As the number of decision alternatives grows and these are compounded by multiple decision points, the evaluation tree can become unmanageable.
- For TicTacToe humans can work out all the options, but for higher dimensional problems this quickly becomes infeasible.
- Term coined by Richard Bellman, who developed dynamic programming.
- Most actuarial investment problems cannot be fully explored quantitatively.

## 2. The Curse of Dimensionality



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## 2. The Curse of Dimensionality

- Consider the simplified investment allocation decision between cash, long bonds, and equities for a pension fund applied on a monthly basis over a 20 year time period (relatively short given the liabilities).
  - The choice between three asset classes (stocks, cash and bonds) broken into 5% increments has 231 options (presuming no short positions).
  - Reducing this to 100 options for simplicity and considering monthly decisions for 20 years is  $10^{480}$  alternative solutions.
  - This is a number larger than the number of seconds the universe has existed (a mere  $4.3 \times 10^{17}$  seconds or 13.73 ( $\pm 0.12$ ) billion years)
  - It is not possible to computationally evaluate every alternative for such higher dimensional problems.

## 2. The Curse of Dimensionality

- There are many different approaches, but basically you need to narrow the size of the tree to something more manageable. Ideally want to do this narrowing in an intelligent way.
- Pattern Recognition or other approximation methods (such as approximate dynamic programming) is one approach. Humans heavily rely on pattern recognition for managing complex issues.
- Rule based solutions are another approach which limits the problem dimension to the number of rule parameters.
- There are also methods for reducing dimensionality in data. Principal component analysis is a variation of this.
- Quantum computing is a potential solution in the future.
- Practically, at some level in computational analysis we will need to sacrifice model/decision precision for approximations.

## 3. Complexity Management Problem

- Firms use different models for different purposes (pricing, risk analysis, strategy) and different business areas (investments, liabilities)
- Often these models have inconsistent assumptions and could benefit from leveraging the knowledge of other areas (overall firm results based on investments, investments based on credit, etc)
- It would be ideal if a firm could use a single model, incorporating all risks and managed in an integrated fashion, to evaluate all risks and decisions in a consistent fashion.
- Why weren't MBS models integrated with macro-economic models to predict the systematic risk?
- Experienced practitioners will tell you that practically it is just too hard to integrate these models. You end up with a non-functional complex mess.

## 3. Complexity Management Problem



## 3. Complexity Management Problem

- Anecdotal stories from usually involve a small group of people responsible for “the model” who are overwhelmed by requests for improvements from different application areas and leading to:
  - complex model no one understands,
  - that takes long periods to run,
  - often has obvious flaws no one has time to address, and
  - painful and discouraging experiences.
- It is the problem of over centralization. Running everything through a central hub makes that a source of congestion as anyone who has driven in a large city or dealt with the government can attest.
- Such models are also very difficult to change or improve, because everything affects everything and the ripple effects are immobilizing.

## 3. Complexity Management Problem

- There are successful solutions to this type of problem.
- They take the form of standardization, market systems, and delegation of responsibilities.
  - Standardized parts for manufacturing or standard software components, languages, etc
  - Use of Currency and the market system for coordinating economic resource allocation.
  - Biological Systems such as cellular structure, organ development, and even social structures”.
  - Professional and academic specialization.

## 3. Complexity Management Problem

- Need an architecture for integrating model components.
  - Standard model languages.
  - Model languages that enable separable components and the ability to run subsets of the model.
  - This would enable independent development and maintenance of the components.
- Another solution would be higher level systems that learn to approximate specialized lower level systems.
  - This can be done with machine learning.
  - The higher level system would have more speed and could call the lower level system only when more precision needed.

# Closing Thoughts





## Closing Thoughts

- Approach 1 is what is behind many key AFIR topics:
  1. Portfolio and risk management
  2. Dynamic asset allocation over the life cycle
  3. Asset and derivative pricing
  4. Asset/Liability Management (ALM)
- Each of these has met with practical challenges and the current solutions have real limitations.
- Understanding the weaknesses in Approach 1 can help us improve solutions in these areas.
- Larger organizations have more complexity and thus the difficulties are even greater.

# Closing Thoughts

- Modern computing power gives us a way to leverage Approach 2 with greater integrated use of Approach 1.
  - Decision making that incorporates **robustness analysis** for how wrong the analysis can be from errors in the model and expresses solutions as generic rules to reduce model exploitation.
  - Approximation methods and **pattern recognition** solutions to focus search/evaluation on key parts of the tree. Computational analysis ultimately requires a **level of approximation**.
  - Component based modelling, **model framework standards for integration** and models that learn from other models.
- Understanding the challenges and developing innovative solutions that harness modern computing power will provide us with better solutions for tomorrow.

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