NORTHFIELD modeling financial markets worldwide

Multi-Asset Class Risk Assessment for Asset Owners

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Today's Theme: Analysis Revealed

- *The mental features discoursed of as the analytical, are in themselves but little susceptible to analysis. We appreciate them only in their effects. We know of them, among other things, that they are always to their possessor when inordinately possessed, a source of the liveliest enjoyment. As the strong man exults in his physical ability, so glories the analyst in that moral activity which disentangles. He derives pleasure even from the most trivial occupation which brings this talent into play. He is found of enigmas, conundrums, hieroglyphics; exhibiting in his solutions of each a degree of acumen which appears to the ordinary apprehension as praeternatural. His results, brought about by the very soul and essence of method have, in truth, the whole air of intuition.*

Agenda

- This presentation will address a number of topics relating to the multi-asset class risk assessment services provided to asset owners by Northfield.
  - Corporate and Personal Introduction
  - Risk Assessment Concepts
  - Multi-Asset Class Risk and the model of “Everything, Everywhere”
  - Liquidity Risks: Illiquid Assets and Large Positions
  - Multi-Asset Class Risk Methods to Improve Asset Allocation
  - Risk Decomposition and Reporting
  - Conclusions

Northfield Background

- Northfield was founded 1985.
- Our mission was to provide was to provide cutting edge analytics to investors in a cost effective manner by utilizing the then emerging technology of desktop computers.
  - We have over 300 financial institution clients in more than thirty countries. The client profile extends across large asset owners (e.g. ADIA, CalPERS, PSP, Telstra Super), asset managers, hedge funds and wealth management organizations The largest single client by revenue is Fidelity.
- Our services are redistributed by many large vendors including FactSet, Charles River, MUREX, State Street Bank, Reuters and Standard and Poors. In every case, we were approached by these organizations on the basis of our superior analytical sophistication.

Personal Background

- Northfield founder in 1985.
  - I still control 93% of the shares.
- More than thirty major publications including books, textbook chapters, and peer-reviewed research journals.
- Eight years as a Visiting Professor at the CARISMA risk research institute at Brunel University London.
- In 2010 named by *Institutional Investor Magazine* as one of the forty most influential people in financial technology.
- Admitted in both US Federal and State courts as an expert witness in several high profile investment related cases.
- Board member or officer in numerous industry associations including IAQF, PRMIA, CQA, BEC
- Editor in Chief, *Journal of Asset Management*

The Northfield Difference

- As a privately held organization we are not subject to shareholder pressures for earnings. We focus on "best practice" research irrespective of immediate commercial application.
  - Research on new methods in sovereign credit risk won the 2013 PRMIA New Frontiers in Risk Research Award
  - Research on management of illiquid assets won the Practitioner Paper of the Year 2015 from the American Real Estate Society.
  - My 2010 award from Institutional Investor largely related to our research which was instrumental in uncovering the Bernard Madoff fraud.
- We treat research materials in an academic fashion, not as marketing material. We routinely publish in peer-reviewed journals. Our work has been licensed by both CFA and the Society of Actuaries as training material.
- Client education program includes monthly webinars, more than 800 technical documents, and a global series of live seminars.

Risk and Investor Objectives: Three Views

- "Investors have a hard time describing what risk is, but all agree that less risk is preferable to more" (paraphrase)
  - Daniel Bernoulli (1715)

- "(Investor decisions) can only be taken as the result of animal spirits – a spontaneous urge for action rather than inaction, and not as the weighted average of outcomes multiplied by quantitative probabilities"
  - Lord John Maynard Keynes, 1923

- "The age of the computer, systematic analysis, and rational decisions based on economic theory has dawned"
  - Rudd and Clasing, *Modern Portfolio Theory*, 1982

Risk Assessment Basics

- Risk is the potential for future negative outcomes.
- As such risk can never be measured. It can only be assessed or estimated for specified time horizon (e.g. a week, a year, a decade)
- For ADIA risk has four components
  - Unconditional Volatility: The dispersion of events we estimate based on observations of relevant history. Always positive.
  - Volatility Conditioning: We must observe and adjust for the fact that current conditions will never be exactly like the average of the past. This may contribute positively or negatively.
  - Estimation Error: Our assessments can be wrong by virtue of flawed methods or simply that our sample of historical data is finite. Always positive.
  - Knightian Uncertainty: the potential for conditions to materially change between now and the time horizon of interest. Always positive and increasing in the time dimension. (the unknown unknowns).

A Taxonomy of Risk Drivers

- Investment risks vary act in response to three defined sets of inputs
  - News: This is any information about relevant events which is entirely unexpected.
  - Announcements: This is information where the timing of the release is known (e.g. company earnings, economic statistics) but the content is not. We know the "when" but not the "what".
  - "Volcano" Risks: This is the case where a future negative event is assumed to be inevitable (e.g. a volcanic eruption) but the timing is functionally unknown. We know the "what" but not the "when"

- *When crossing streets, you get hit by the car you don't see coming.*

A Taxonomy of Risk Outcomes

- Risk outcomes are either short term or long term.
  - The short term potential risks are usually defined in terms of drawdowns, Value at Risk and other formulations that are largely related to the volatility of the portfolio.
  - The long term potential risk is *variance drain,* the extent to which the geometric mean return is reduced relative to the arithmetic mean return.
  - Volatility reduces compounding. This long term cost of risk is proportional to the **square of the volatility** and hence has a much stronger effect on long term institutions.
  - *For example, the long run value of an investment with (a) a 6% annual fixed return or (b) an 8% annual average with volatility 20% is identical. The 2% difference is the variance drain.*

Risk: Correlation and Causality

- Even trained statisticians fail to appreciate the extent to which statistics are vitiated by the unrecorded assumptions of their interpreters…. It is easy to prove that the wearing of tall hats and the carrying of umbrellas enlarges the chest, prolongs life and confers comparative immunity from disease. A university degree, a daily bath, the owning of thirty pairs of trousers, a knowledge of Wagner's music, a pew in church, anything in short that implies more means and better nurture, can be statistically palmed off as conveying all sorts of privileges….. The mathematician whose correlations would fill a Newton with admiration, may in collecting and accepting data and drawing conclusions from them may fall into quite crude errors by just such popular oversights as I have been describing.
  - George Bernard Shaw in *The Doctor's Dilemma*

Use of Factor Models By Asset Owners

- We're talking about three different concepts.
  - Making broad strategic asset allocation decisions like the percentage of stocks, bonds and real estate to hold based on a factor process.
  - The use of forward looking factor models to estimate the risk and sources of risk of a particular portfolio (e.g. we hired Manager XYZ to run a portfolio of small cap European equities) is nearly universal. It is also crucial to managing the fee structure of external managers because without it you don't know if the various managers are overlapping too much, http://www.northinfo.com/documents/634.pdf
  - Using forward looking factor models to *understand how risks aggregate across asset classes* (e.g. interest rates impact all asset classes). This is a prerequisite to making tactical decisions about how to change the risk profile of a fund.

Factor Representation of Portfolio Risk

- There is an overriding rationale for representing the covariance of security returns with a factor model rather than by simple statistical estimation of historically observed covariance.
  - By expressing the covariance structure in the form of a factor model, we filter out historic occurrences that are not likely to be repeated in the future.
  - For example, we might have two firms that are completely unrelated except by the fact that both their respective CEOs are killed in the same plane crash. If the two firms both experience negative returns by virtue of this tragedy, the sample covariance values will make the firms appear positively related.
  - By expressing the covariance across firms through an appropriate factor structure, we are able to mitigate the inaccuracy that would otherwise arise. We should always recall that for any factor representation of covariance, we can calculate the numerically equivalent full covariance matrix across the set of assets, as described in diBartolomeo (1998).

Just a Bit of Math

The most popular representation of a factor model is

$$R_{it} = \Sigma_{j=1 \text{ to } n} B_{ijt} F_{jt} + e_t$$

R_{it} = the return on security i during period t

B_{ijt} = the exposure of security i to factor j during period t

F_{jt} = the return to factor j during period t

E_t = the residual return of security i during period t

With this representation we may choose to estimate both the future return and volatility of a security or portfolio

Three Basic Models

- Fundamental (Endogenous): We observe the B values and statistically estimate the F values via cross-sectional regressions.
- Exogenous: We observe the F values and estimate the B values via time series regressions.
- Statistical: We simultaneously estimate both B and F values via a maximum likelihood statistical process.
- The key difference is that the accuracy of endogenous models is insensitive to portfolio diversification, while exogenous models improve with diversification.

The Great Debate: Pros and Cons

- There is much debate among theoreticians and financial market participants as to which of these processes is most effective in ex-ante forecasting of portfolio volatility.
  - Even if we believe that no one type of model is inherently superior to another, we may choose a particular specification for reasons other than simply the predictive power of the model.
  - Investment personnel may find the factors chosen for a particular model to be more intuitive than others.
  - *We may care more about absolute or benchmark relative risk. Some specifications are much easier to extend to multi-asset class cases.*
  - Market conditions differ from country to country and often dictate differing degrees of diversification within portfolios.
  - The availability, quality, and accounting standards for company fundamental data vary greatly from country to country.
  - Finally, investors may have high or low turnover portfolio strategies.

Hybrid Models

- One useful practical solution to the model design problem is to combine the statistical model process with an existing endogenous or exogenous model.
- Since 2003, Northfield has used a "hybrid" design where we construct a statistical model only from observed returns that are left unexplained by an existing model. This allow the model to adapt with changing market conditions, and capture transient factors (e.g. "tech bubble", "global financial crisis").
- *This structure has been found preferable.* Scowcroft and Sefton (2006) and Menchero and Mitra (2008) have suggested that a generally satisfactory factor specification must be a *hybrid* of the specified and implicit factor methods.

Conditional Models

- A different approach is embodied in the concept of conditional models that are based on a vector of state variables.
  - This approach allows any chosen model to adapt rapidly to changes in market conditions, but to retain the existing factor definitions and factor exposures.
  - In effect, we ask ourselves how are market conditions today different than they were on average during the period of history used to estimate the usual model. To judge the degree of difference, an information set of state variables are defined that describe contemporaneous aspects of the financial conditions but that are not normally used in the risk model.
  - Such variables might include the implied volatility of options on stock indexes (e.g. VIX) and bond futures, yield spreads between different credit qualities of bonds, and the cross-sectional dispersion of stock returns among different sectors and countries.

Risk Systems That Read®

- Since 2017, most Northfield models have their "conditional" aspect further enhanced through text analytics.
  - First published in diBartolomeo, Mitra and Mitra 2009).
  - Northfield analyzes about five thousand articles in a typical day which mention between seven to ten thousand firms. The content is analyzed for the number of articles, the length of articles and the "sentiment of the text".
  - The impact of news on risk estimates is separated into factor and specific portions by the methods in diBartolomeo and Warrick (2005) and Shah (2008).
  - Information is also aggregated at the country and industry level.
  - Also impacts perceived credit risk in multi-asset class models.

Multi-Asset Class Models

- Estimating the risk of a portfolio that spans multiple asset classes represents a complex problem for large financial institutions.
  - To achieve coherent risk estimates disparate assets must be analyzed under consistent underlying assumptions. In addition some asset classes may represent particular difficulties.
  - Some assets such as convertible bonds and many derivatives have highly non-linear properties with skewed return distributions.
  - Higher moments of return distributions tend to diversify away over a broad portfolio and over multiple time periods. Highly levered organizations may go bankrupt before multiple periods are over, but you can't go broke if you don't anyone any money.
  - Other asset classes such as "direct-owned" real estate or private equity have no readily observable pricing, returns or risk information.

The Patchwork Quilt

- One approach is to model risk for each portfolio separately and aggregate the risks might be called the "bottom up" approach. It might be thought of as akin to a "patchwork quilt" where each panel represents the risk analysis of an asset class.
  - The advantage is a certain degree of internal consistency. You are using the same model to measure the risk of each asset class as part of the whole, as you use for measuring the risk of that asset class as a stand-alone portfolio.
  - However, there are there are serious limitations to this methodology. As each asset class would be modeled with the set of factors most relevant to that asset, factor exposures will not be additive across the many disparate models that are used within the aggregate portfolio.
  - The method is rank deficient which causes statistical instability. There are too many factors for the available data to support.

Fifty Nine Words That Could Change The World

- Vigorous writing is concise. A sentence should contain no unnecessary words, a paragraph no unnecessary sentences, for the same reason that a drawing should have no unnecessary lines and a machine no unnecessary parts. This requires not that the writer make all sentences short or avoid all detail, and treat subjects only in outline, *but that every word tell.*
  - Strunk and White, *The Elements of Style*

- In the same way, every factor in a model must tell a meaningful part of the story. Factor structures are often embellished to falsely appear more granular.

A Parsimonious Model of Everything Everywhere

- In such an approach, all assets in the world are related to the same consistent set of factors, so interrelationships are easily observed and understood, and the limited number of factors allows for stable estimation of factor relationships.
  - In such a model, the complexity arises in determining how to represent the returns and risks of many different asset classes as functions of the same tractable set of underlying factors.
  - Basically, we take complex financial instruments and break them into sets of simpler pieces which can be analyzed separately in a pretty simple model then added back together.
  - For example, the approach of Merton (1974) allows us to transform corporate bond credit risk into equity risk for aggregation with other equity driven risks.
  - Models with this approach are necessarily a compromise across asset classes and geography. As such, this type of model should not replace asset class specific models for day to day portfolio management.

An Example of Everything, Everywhere

- One good example of a complex instrument is a convertible bond.
  - To effectively analyze this type of instrument we must consider a portfolio that contains a default free bond that is only subject to interest rate risk, a credit default swap and an equity warrant (long term call option). The analysis becomes particularly complex because the strike price of the equity option is the market value of the bond, and hence is variable unlike the fixed strike price of a conventional option.
  - To carry out such an analysis in the context of a factor model we can represent the variability of interest rates as occurring by a process of paths through a binomial tree that represents the passage of time. At each branching of the tree, we can allow the interest rate to rise or fall. The probability of the interest rate rising or falling at each branching can be calibrated to the current yield curve as in Black, Derman and Toy (1990).

Alternative Assets

- Our compact design for the Everything, Everywhere model also for easy inclusion of alternative assets held mostly by asset owners.
  - There are processes in place for dealing with non-transparent hedge funds, http://www.northinfo.com/Documents/508.pdf.
  - A separate procedure is can be used to prepare bespoke analyses of specific real estate holdings. http://www.northinfo.com/Documents/191.pdf
  - Similar processes are in place for private equity and infrastructure holdings.
  - Proxy holdings of "generic" alternatives are available at the investment level (i.e. an investment by a private equity fund in a specific firm) rather than at the partnership or asset class index level. More than 1500 generic alternatives are available.

Liquidity Considerations

- The risk of liquid positions can be reduced by selling the asset, or by hedging. If we think of the *unavoidable risk of a portfolio*, this concept will be dominated by illiquid assets that cannot be sold, or easily hedged.
- Similarly even presumably liquid positions such as equities become difficult to sell when positions are sufficiently large.
- There are three useful mitigations:
  - Analyze risk of illiquid positions as carefully as possible as you mostly just have to live it.
  - The EE model puts both liquid and illiquid assets in the same framework making it easier to hedge illiquid risks to the extent possible.
  - Consider adjusting short horizon risk estimates (e.g. VaR) for liquidity costs in a crisis situation. Our systems do this already.

Model Testing: Fitness for a Purpose

- The first thing we need in a discussion of "Model N is better than Model A or Model B", is *"better for what?"*.
  - Each different purpose will have a different model design that is best for that specific purpose. There is no "one size fits all
  - Northfield's long history of having multiple different designs reflects the desire to not only provide "a factor model" but "the most appropriate model for a given purpose.
  - To thoroughly test the effectiveness of a risk model involves simulating hundreds of portfolios over long periods (e.g. 20 years). The sort of test procedures you need are described in http://www.northinfo.com/documents/657.pdf and http://www.northinfo.com/documents/675.pdf. Our results are available to clients with a non-disclosure agreement.

Independent Tests of Model Effectiveness

- I can only think of two efforts to test commercially available risk models
  - There was an article put out by the UBS quant research team, http://www.rsqrm.com/sites/default/files/files/Scowcroft%20%26%20Sefton%20-%20Understanding%20Multi-Factor%20Risk%20Models.pdf.
  - Their conclusion is that the "hybrid" design combining specified and statistical factors which Northfield pioneered was the best overall design. A hybrid structure was therefore chosen by UBS in building their internal model.
  - More recently, a group of MIT grad students did a research study on behalf of SSGA comparing the MSCI (Barra) and Northfield Global models. While I cannot comment on the quality of the research, the basic reports that were publicly posted suggested that the Northfield model was materially better overall.

The EE Model and Asset Allocation

- The EE model can be usefully employed to improve asset allocation decisions. Such decisions require the forecasting of volatility and correlation for the set of defined asset classes.
- Asset classes are not assets. They are collections of assets, typically defined by market indices holding the member assets of the asset class.
- Estimating the volatility and correlation of market indices ignores the evolution of the composition of the asset class.
  - For example, the estimated correlation of the S&P 500 with other markets would have been radically different in 1974 (oil crisis), 1999 (tech bubble), 2006 (pre GFC) and today.
  - Using historical data for asset classes merely represents the average past character without consideration of everything we know about how conditions have changed.

Volatility Forecasts 2017/11/01-2018/10/31

	MSCI World	S&P 500	RUSSELL 2000	DAX	NIKKEI	HANG SENG
Average Forecast	10.65*	10.27	13.40	13.98	11.09	20.48
Average Forecast Bias Adjusted	10.42*	10.20	13.39	14.08	11.29	20.34
Realized	10.50*	10.06	14.45	13.96	11.63	20.29

Risk Decomposition and Reporting

- It is the intent of every factor model to most efficiently explain the covariance between assets.
- If this is achieved, the residual or unexplained returns of assets will always be uncorrelated.
- There may be many different sets of factors that produce uncorrelated residuals. In such cases, every factor of every model is a linear combination of the factors in the other models.
- This means that even if different models all agree on the magnitude of risks, the decomposition can be adjusted to suit the intuition of the users, or customize the output for a particular purpose.

The Economics of Risk Assessment

- For a typical asset owner, the economics of budgeting for risk assessment are far different than for an asset manager. If an asset manager does a poor job of risk assessment, their clients lose money not themselves. It's a second order effect. For an asset owner, it's a first order problem.
- Assume a smaller asset owner with $30 Billion in assets
  - Their portfolio has an expected arithmetic mean return of 7% and a volatility of 10%. The expected geometric mean is 6.5%
  - 50% of the portfolio is liquid and 50% is illiquid.
  - Let's assume we cut the budget on risk and *the result is a 5% decline in the accuracy of risk assessment for the illiquid assets only.* Effectively our risk goes up since we know less about the risk we are taking.
  - As the risk goes up, our expectation of the geometric mean return goes down. The net cost is $25 million per year, far exceeding any savings from a plausible savings in the operating budget.
- For details see https://www.northinfo.com/Documents/850.pdf

Something to Watch For

- Our hybrid factor structure also allows transparency into unusual market conditions, as we can observe changes in the relative explanatory power of the two parts of the model.
- If we simply estimate the variance of our global benchmark we can observe how much of the risk is allocated to EE defined factors and how much is allocated to the "hybrid" factors that represent transient factors.
- Under normal conditions, the explanatory power of the hybrid factors for a global benchmark should be close to zero. As the explanatory power of the hybrid factors becomes material in the risk decomposition, *this is a signal that conditions are not normal and special care ought be devoted to risk assessment.*

Conclusions

- The process of good risk assessment for a large asset owner is a major undertaking. It requires a clear conception of the key elements of risk, its sources and effects.
  - *We believe that the Everything, Everywhere factor model is the best tool available because it is designed for "top of the house" assessment of risk.*
  - EE has many advanced features allowing a number of innovative uses.
  - For asset owners, the economics of risk management are such that most organizations should budget far more than they do.