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Risk Management For Intelligent Trading Portfolios

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Part I

Risk Measurement in Derivatives Portfolios

Contents

1. Introduction

This article introduces a short series on risk management issues specifically oriented towards trading portfolios and provides an introduction to the use of available Artificial Intelligence (AI) technologies for risk management. Rabatin Investment Technology provides bespoke development in Evolutionary Computing around its own proprietary engines.

In these articles however, we will keep the contents focused on technology rather than products and focus on the risk management process.

This first article concentrates on risk measurement and how risk measurement can be integrated into the decision making process for a trading portfolio. We will not yet discuss AI methodologies here as we provide the groundwork for the issues that lead to AI technology being introduced to portfolio risk management.

2. What makes Derivatives Portfolios Different?

Derivatives have "securitised" what leveraged or margin trading has already done: seperating risk from capital. In conventional asset investing portfolios, the risk exposure is directly linked to the capital exposure that portfolio. Derivatives instruments or leveraged investment in assets creates risk exposure that may have very different properties than the capital utilised to support that exposure. Time-Bound investments, such as options, represent positions subject to an array of different risk factors, especially the time to expiration.

Even the most basic derivative available for trading - exchange traded futures contracts - turns out to be misunderstood from time to time. A large German commodity trading and processing firm, Metallgesellschaft, which is linked to Germany's largest bank Deutsche Bank, went nearly bankrupt in 1993 after it entered into crude oil futures positions to hedge OTC products it had offered to clients. It faced a huge "basis risk", i.e. the risk that the futures contract and the underlying cash instrument do not move entirely parallel. Changes in the basis result in changes in the the hedge ratio between futures and cash instrument. Sharp changes in the oil prices lead to drastic changes in the basis, resulting in new margin calls to Metallgesellschaft to cover huge open positions in the futures positions.

This series looks at risk in trading positions, not hedging strategies. Trading positions represent risk taken in order to achieve higher returns.Although this differs from hedging, which in principal is oriented towards eliminating risk, the issues raised in these articles will also be applicable to any hedging situation which involves dynamic hedging or overlay strategies.

3. Risk Management Process – Structure

Intelligent portfolio trading systems are complex trading models, able to learn behaviour rules through their own learning process, without human interference, and able to adapt their rules to new market environment circumstances. Because these trading models have to perform all tasks of a human portfolio manager, these models must also be capable of learning a risk management decision process.

Risk management requirements for intelligent computational systems are basically not different from the requirements for human portfolio managers. The implementation of risk management strategies within self-adaptive intelligent models requires however a systematic and entirely quantitative decision making process. Such a defined process is not only beneficial to artificial intelligence trading models but can also be applied to other systematic or non-systematic, i.e. discretional trading strategies.

The risk management process describes how the application of risk thresholds and risk parameters affects portfolio performance and the risk/return profile of a trading strategy. It translates the risk measurement and monitoring process into a model for a decision making strategy which is central to any trading portfolio management process.

4. The Risk Management Process

The implementation of risk management systems is a three-tier process:

- defining risk measurement
- implementing a risk monitoring process
- defining the active risk management process as decision making process following the analysis of risk.

Typically, an institution (or individual trader or fund manager) implementing or refining a risk management process will follow that process sequence, because risk monitoring will require risk measurement, and it will result in management decisions to be taken on portfolio allocation and risk exposure. This process also describes how the theoretical foundations of risk management have developed historically, beginning the use of variance of returns as proxy for risk, up to autonomous, artificially intelligent trading models, such as adaptive portfolio trading models developed by Rabatin Investment Technology.

Now, the need for effective risk management and risk monitoring is generally recognised. For banking institutions, their ability to measure and monitor trading portfolio risks correctly, is directly tied to the costs of capital, as it is enforced by international regulatory rules developed by the BIS (see [BIS]). The growing market of "out-sourcing" the actual trading decision in institutional asset management also increases risk management requirements. For pensions funds, the largest section of institutional investors, risk constraints are highly significant as pension funds face fixed long-term liabilities against which the investment returns have to be matched.

5. Sources of Risk

Risk management often distinguishes between different sources of risk. Main sources of risk are:

- price risk (market view may be wrong)
- liquidity risk (a position cannot be liquidated under extreme circumstances; more likely a case in derivatives, particularly options).
- credit risk / settlement risk (a market counterpart is failing to meet contractual obligations)
- regulatory risk (government or regulatory authorities implement measures that affect existing contracts).

Market price risk is the type of risk any trading operations is mostly confronted with.

Different types of trading operations however also may weight sources of risk differently. Emerging market operations, for instance, may put liquidity or regulatory risk higher in its significance. Credit risk might be considered most important under extreme circumstances or when regulatory environments do not enforce appropriate corporate governance. The significance of risk is also determined by how easily an operations can hedge or cut portfolio risk, either by liquidating positions or by using hedging instruments.

The main focus of the portfolio management process, and its implementation in intelligent trading models within the Adaptive Portfolio Trading (APT) framework, is on market price risk.

As it will be seen, however, many aspects of defining risk for trading decisions within portfolios can be applied to other types of portfolio components and risk estimates.

6. Risk Measurement and Monitoring Process

A measurement of portfolio risk always represents an estimate based on assumptions on the underlying distribution of data. This risk estimate also serves as an estimate for future, expected risk, that is inherent in the portfolio structure or market environment.

It is important to note that accepting any such risk prediction is inherently a decision under risk itself, because the actual risk in the future might exceed the estimate significantly.

Especially short term changes in the correlation of portfolio component returns can dramatically effect the risk behaviour of the total portfolio.

The currently most widely used risk measurement tool is Value At Risk (VAR). VAR acknowledges two fundamental aspects of risk estimate:
- risk estimates have to be associated with their respective confidence limits.
- risk estimates are always made relative to a time frame.

While confidence limits are a standard statistical tool, estimating risk relative to an investors / trading supervisors time frame is an important aspect of VAR. This is not an entirely new concept per se, as risk has long been estimated to grow at the square root of time, in the case of VAR however it is formally integrated into a time-frame dependent estimate for the aggregated portfolio risk.

VAR does not escape the problem of using assumptions on the underlying data distribution as basic assumptions, so it will be also relevant on how the risk management decision process is able to deal with the risk inherent in the VAR forecast itself.

Risk monitoring is the process of actually measuring portfolio risk at necessary time intervals. Although often regarded as a purely "operational issue" – such as simply performing computer calculations to run an end-of-day mark to market – risk monitoring provides the operational basis for making risk management decisions. If the risk monitoring function fails to provide sufficiently up-to-date data, actual portfolio risk may exceed the expected threshold and lead to a deterioration of the portfolios risk/return profile.

7. Risk Management Process – Implementation: Trading Model / Risk Model Integration

The management of portfolio risk requires the trader to make portfolio management decisions, based on risk control requirements, rather than on the sole purpose of increased returns.

This has two significant consequences:

- When trading an individual market, the ability to forecast market prices is not the only factor determining the trading success.

- For a diversified portfolio, risk thresholds are defined for the total exposure; the performance of each individual portfolio component is not only the result of risk management rules applied to that instrument, but also the result of how it is affected by the performance of the total portfolio. For each individual portfolio component, the impact resulting from the total portfolio's risk thresholds is a essentially a random event which cannot be predicted by analysing the individual component only.

Consequently, it can be stated, that the evaluation of a market timing - or market forecasting - strategy is only possible when the required risk management thresholds are applied and tested simultaneously.

One market timing strategy might be superior to another in it's accuracy - due to its more accurate forecast - , but it might be a worse trading strategy when applied in a portfolio because it might create temporary risks that exceeds risk management thresholds and results in positions to reduced or liquidated, which eventually would have produced profitable results.

A market timing/forecasting strategy must therefore be compatible to the required risk parameters - otherwise the actual trading performance will be very low correlated to the expected forecasting result.

Investors exhibiting different risk thresholds in their trading books are an essential aspect of a liquid market. Although over a given period of time, two investors can have exactly the same view on the direction of prices, different risk management parameters will result in different trading strategies and consequently a difference in performance.

How can the link between the market forecasting model and risk management be defined in a quantitative trading model?

The key variable in the definition of a trading model correctly reflecting both market timing and risk management strategy, is the quantity traded. Variation of trading size (position size) is the factor that creates the discrepancy between price forecasting success and actual trading performance. Defining a systematic process for calculating trade size and subsequent position size turns the market timing model into a trading strategy, that can be applied to a real-time portfolio.

Trading model relying entirely on market forecasting may assume a risk element and may measure the risk adjusted success prediction. This, however, only addresses the problem partially. For a pure market timing model, risk is only defined as price risk for a constant number of units traded. The actual portfolio risk however is a function of both the size of the position (i.e. number of units traded) and the price risk per unit.

There are two reasons why it is not possible to replicate such a fixed-unit trading strategy in a real portfolio:

First, trading a fixed number of units (such as a constant number of contracts) yields changing levels of risk of the portfolio. Even if the expected risk per unit traded remains constant (e.g. in terms of price percentage), changing levels of portfolio value result in the constant price risk being different portfolio risk. Over a longer period of time, a successful portfolio would trade too little to yield an acceptable performance, or a losing portfolio would increase risk to a level that would also not be acceptable because each single trade might pose too much of a risk for the portfolio. Due to risk management requirement, trading a constant unit-size therefore is not possible.

Second, for a diversified trading portfolio, the portfolio is not invested into every instrument at the same time, all the time. In fact, the ability to be selective about taking market views is an important contributing factor to an improved performance of the market timing model itself. As a result, it is difficult to determine what a constant trading size should be. If it is small enough to allow the system to take positions in all markets at the same time, then it is likely to be too small to yield a sufficient return at time when only a fraction of the portfolio is invested. At any other trade size definition, increasing the number of positions would necessarily require cutting (liquidating) positions in other markets within the portfolio, to maintain the portfolios exposure within risk thresholds.

Percentage risk and percentage return do not have a symmetric effect on the portfolio, because the required percentage return to recoup a given loss (in percent) increases geometrically with the size of the loss, as shown in the following chart.

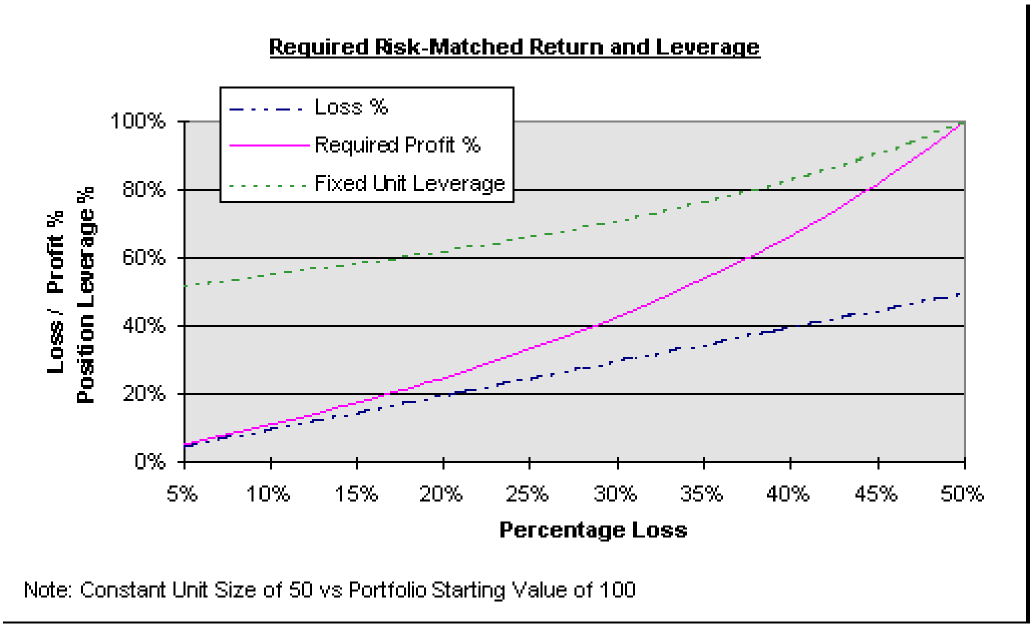

Chart 1: Percentage Gain required to Recoup Portfolio Loss.

The yellow line shows how a fixed size trading unit of 50 vs. an initial portfolio value of 100 will result in an increased leverage up to 100% of the portfolio value during increased losses on the portfolio.

Clearly, a loss of 50% requires a return of 100% in order to return to the original portfolio value.

Not adjusting the trading size to the portfolio value (by decreasing with greater risk) would lead to an increase of risk at an increasing rate (as expressed by the increasing leverage of a fixed-size trading position).

7.1 Risk of Ruin as Porfolio Constraint

Measuring risk-of-ruin is done by estimating the likelihood that a certain drawdown occurs, which would lead to the portfolio trading being closed. This probability estimate is based on the distribution of previous returns.

More important however is the actual level of drawdown an investor (or trading manager) would consider "ruin". While a private investor might consider "ruin" at a the level of 100% drawdowns, an institutional investor has a much tighter threshold. A pension fund is restricted to drawdowns that the fund is able to recoup from in order to meet long-term liabilities.

Guaranteed products have a limited margin of capital that can be put at risk before the guarantee kicks in and yield-enhancement strategy has to be stopped.

Generally, investment managers define a level of ruin, which is the "wall" that must not be touched by the portfolio. The aim of managing risk is to avoid the point of ruin, because the portfolio cannot recover from that level; at least not with continuation of the same strategy.
Varying trading size (position size) is the most important aspect in adjusting to such a risk-limit.

8. Optimal Fractional Portfolio Risk (Calculating Optimum Value-At-Risk Exposure)

Assuming a measurement for risk exists for a given trading strategy or portfolio, it can be said that for every trading decision (in fact, during every trading day where an open position exists), a certain percentage of the portfolio is put at risk.

Every decision on position size and on accepted price risk is therefore also a decision to put a fraction of the portfolio at risk - although the decision to the amount of fractional risk might not be made explicitly, but is accepted as a consequence of e.g. the market view taken or market volatility.

Commonly it is assumed that the optimum level of risk is a decision entirely determined by the investor according to his/her risk tolerance. It is also assumed that (being on the efficient frontier of a portfolio) increasing the risk an investor is prepared to accept will lead to an increase in returns (note that we use a concept of risk here which refers to the fraction of the portfolio put at risk and not variance of return). In short, it is assumed, if the percentage of the portfolio put at risk is doubled, any positive return would be doubled as well.

It can be shown that both assumptions are not correct (this topic is discussed in detail in [Vince90], [Vince92] and [Vince95]).

While an investor's risk tolerance certainly a function of his/her personal risk adversity, the optimum risk level is a function of the distribution of equity changes in a portfolio. Further, for every distribution of equity changes (or stream of trade profits/losses) there is exactly one optimum level of risk, i.e. a level of risk that returns the highest return. Increasing risk beyond that level leads to a decrease in performance, up to total loss of the portfolio.

The following chart shows a portfolio for which various risk levels and their associated return level are shown. The return is simply measured as "Terminal Wealth Ratio", TWR, i.e.:

TWR = (Final Portfolio Value) / (Beginning Value).

TWR can also expressed in different form, as the multiplikative sum of holding period returns (HPRs) over N Periods:

$$TWR = \prod_{n=1}^{N} HPR_n$$

HPR is the holding period return, which is (for a portfolio that is marked-to-market daily), the daily percentage change of the portfolio value, expressed as

$$HPR_t = P_t / P_{t-1}$$

P_t denotes the portfolio value at time t.

It is important to note that the portfolio growth function is geometrical. The "average return" of each period is best expressed using the geometric mean, which essentially is the geometric average holding page return:

$$G = TWR^{1/N}$$

G ... Geometric Average HPR
N ... Number of Periods

This simplified text assumes that holding periods are of equal length (e.g. measuring daily equity changes) and that only one instrument is traded (or the portfolio is looked as a one single investment).

Holding periods differ when comparing not equity changes but results of individual trades. When comparing different market components, the HPRs must also be adjusted for different weighting of the component within the portfolio.

The following explanations are illustrated with an example based on a simulated stream of percentage equity changes which is generated with a random function. Each event is calculated with a fixed probability of 55% as profitable.

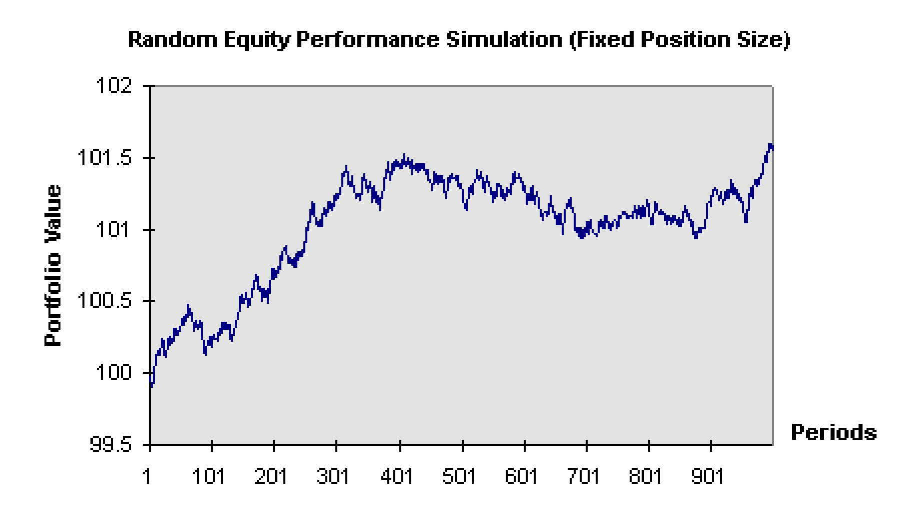

Chart 2: Simulated Random Equity Performance (1000 Events). Probability of Profit: 55%

This equity performance curve could represent any kind of individual instrument traded over 1000 periods (or trades, when adjusted for holding period length).

Fixed fractional trading means that the trading size is a function of risk; i.e. the trading size is restricted by the risk taken on a given trade (or a given period).

Any trading decision will be at a given risk level (will commit a certain percentage, fraction of the portfolio). Even when this value is not used for calculating the trading size, it is still important to know at which point of the risk/reward curve the trading system is operating. For an Artificial Intelligence System, this value is an input it can use to create a more sophisticated model of the portfolio allocation and position size decision.

To find the TWR values corresponding to each level of risk, we created a loop testing risk levels from 0.1%, incremented at 0.1%. The loop continues up until the TWR becomes zero (a TWR value of 1.0 indicates a profit, of zero: a total loss of the portfolio value).

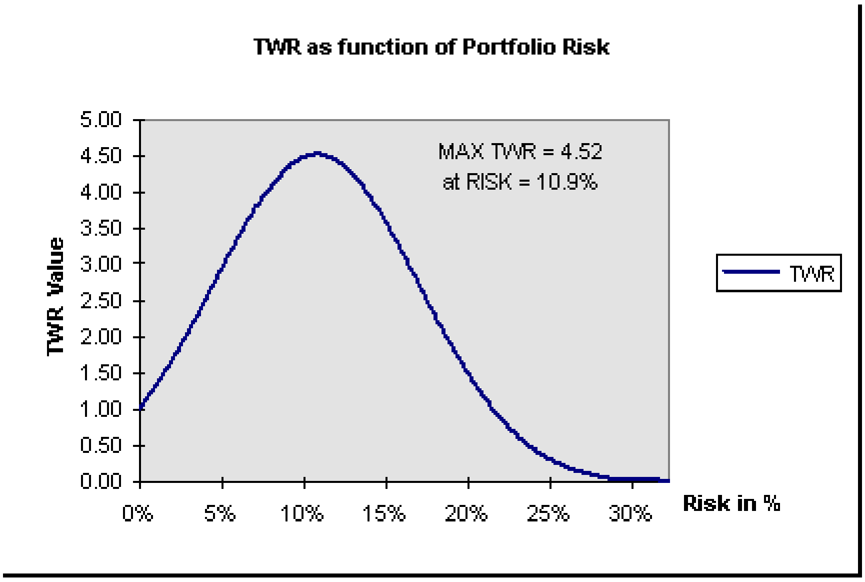

Chart 3: TWR levels at changing risk levels for a given distribution of equity changes (Example).

The following chart shows the Geometric Mean HPR minus 1.00, i.e. the average percentage profit/loss per holding period. The highest TWR correspondents to the highest average HPR.

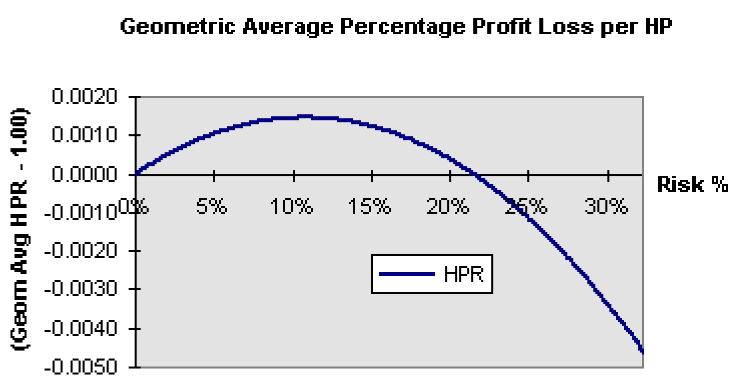

Chart 4: Geometric Average HPR at changing risk levels

Note that the standard deviation of HPR increases linearly as the risk is increased on the portfolio:

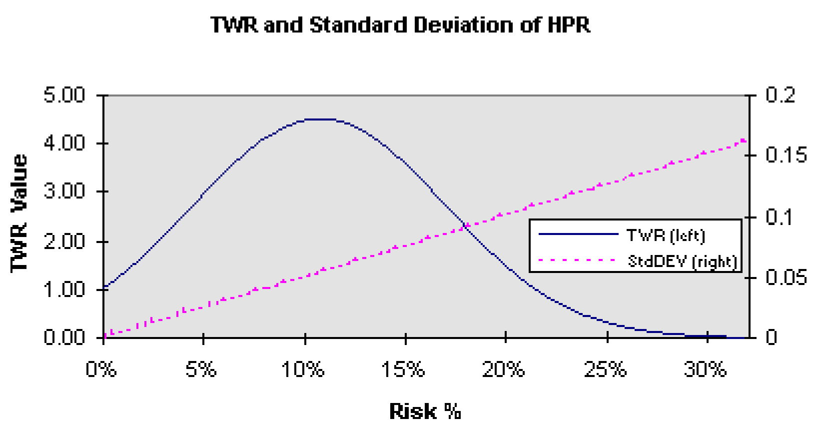

Chart 5: TWR and Standard Deviation of HPRs at increased risk levels.

The relationship between geometric average (expressed in the TWR), arithmetic average and standard deviation of HPRs is called by R Vince in [Vince92], the "fundamental equation of trading", which can be derived by re-writing some of the previous formulae.

The Geometric Mean of HPRs can be estimated using

$$G = \sqrt{A^2 - S^2}$$

G ... Geometric Mean
A ... Arithmetic Mean
S ... Standard Deviation

Re-writing the expression for by re-solving G into TWR:

$$TWR = (\sqrt{A^2 - S^2})^N$$

N ... Number of periods (Trades)

Maximising the return on a portfolio therefore requires maximising the geometric average of HPR's which, as seen in above function, corresponds to maximising the arithmetic average HPR minus the standard deviation of returns!

Increasing the TWR in absolute terms is further achieved by increasing the number of trades or trading periods N. Because the number of periods traded is not a decision of trading model design, the actual aim is the optimisation of the function's coefficient.

The "fundamental equation of trading" is therfore

$$A^2 = G^2 + S^2$$

which can be illustrated through a Pythagorean triangle. It describes the trade-offs involved by maximising one "leg" of the equation.

This method of measuring return depended on the level of risk is a fundamental aspect of the definition of a risk management strategy. It adds an additional dimension to the risk management process in defining risk thresholds not directly implemented by the investor or trading manager, but inherent in the distribution of equity changes.

9. Improving Risk Estimate Using Monte-Carlo Simulation

Because the optimum risk / return level is dependent on the distribution of equity changes, a shift in the distribution pattern will result in different optimum risk./return levels.
This change in the distribution of equity changes can be utilised to estimate future optimum risk levels by applying a random re-distributing of the same percentage changes in what is known as "Monte-Carlo Process".

To apply that process, the same array of data used to derive above data and charts, is randomly re-arranged ("re-shuffled") and then the optimum risk/reward level is calculated.

This is the best possible estimate of the risk inherent in the strategy because it assumes the same arithmetic average of HPR's, i.e. the same "quality" in trading performance, but in a different sequence of events.

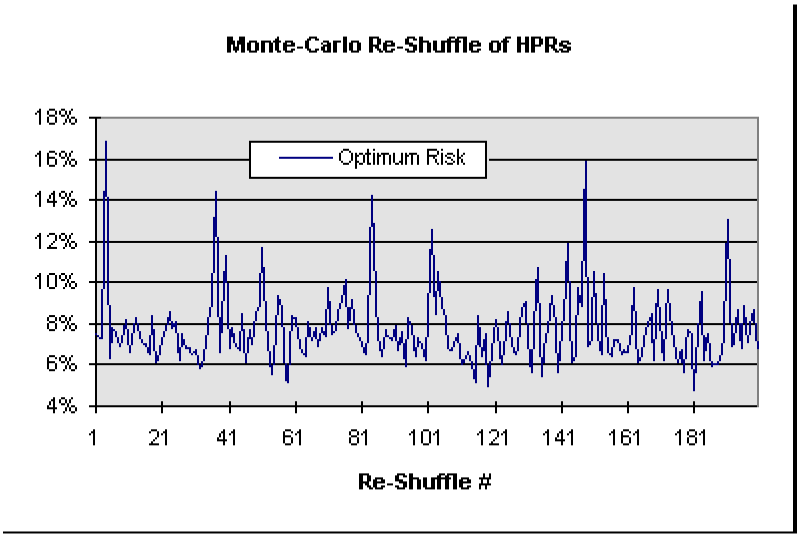

Chart 6: Changing Optimum Risk level after Monte-Carlo Re-Shuffle of Equity Distribution

This chart shows optimum risk levels for the same arithmetic average HPR in different order, at 200 random re-shuffles. The lowest optimum risk level is at 4.8%; the majority of events lies between 6% and 8%.

This simulation should be applied at any time a risk decision is to be made in order to estimate the dependency on a given distribution of equity events.

10. Reference

[BIS] Bank for International Settlements, Publications, http://www.bis.org/publ/index.htm
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