Forensic risk analysis

This paper examines a number of important portfolio risk management issues by providing an example of risk budgets and risk management control processes during the turbulent period from January 2008 to August 2009. It reveals a high degree of risk concentration within a large stock portfolio, evidence of risk drift over the period, and significant breaches of initial portfolio and sector risk budgets.

PortFolio Risk Management involves a process of constant vigilance based on the routine measurement, analysis and forensic evaluation of risk signals, extracted from implemented portfolios. This process is based on an established risk management framework (AS/NZS 4360), and a vast body of literature and research on risk estimation, acceptable risk models and rigorous statistical procedures. At best, insight gained from a risk management process may provide the foresight required to mitigate against unacceptable financial losses. Often, the risk management process is more important than the selection of any single risk estimate.

Typical questions addressed in portfolio risk management are indicated in Table 1. These questions are as valid for individual DIY investors as they are for sophisticated institutions. Indeed, the additional complexity facing large investment institutions with responsibility for superannuation and non-superannuation portfolios stems mainly from the additional control and reporting systems they need to implement around their core risk management process.

Risk measurement

Popular risk measures such as variances and correlation derive their popularity from the portfolio theory developed by Markowitz (1952) based on the assumption that periodic returns on risky assets are characterised by a normal probability distribution. Extensions to portfolio theory, due to Sharpe (1962) and others, led to a focus on relative risk measures such as 'betas', which share the same underlying assumption of normality. The increased popularity of 'benchmark-aware' portfolios led to minor variations on measures of relative risk, such as the standard deviation of 'tracking error'. In more recent times, statistical transformations of the variance of the return distribution have resulted in Value at Risk (VaR) and Expected Shortfall (ES) – both of which focus on 'the risk of loss' at (or beyond) a given confidence limit rather than 'total risk' in a 'normal' statistical world.

However, where the empirical distribution of periodic returns is non-normal, risk measures need to be modified to accommodate portfolio skew and kurtosis as well as co-skewness and co-kurtosis between securities within the portfolio. One such risk measure, Modified Expected Shortfall (MES), is used in this paper. MES estimates the expected portfolio losses greater than, or equal to, Modified Value at Risk (MVaR) for a given level of confidence. These 'modified' risk measures have the added advantage that, if the empirical distribution of returns happens to be normal, then they will converge to ES and VaR, respectively.

It is desirable that the appropriate risk measure allows for valid 'slicing and dicing' of the total risk of the portfolio. This permits a natural discussion of required risk exposures.
and acceptable variations in risk over time – often collectively known as risk budgets. Most importantly, risk budgets are able to be identified, measured and controlled for any portfolio. Nevertheless, since the ‘true’ distribution of portfolio returns is always unknown; risk budgets are subject to sampling error – suggesting that, in practice, risk budgeting demands a flexible approach.

A detailed understanding of the target portfolio risk and its components may suggest the ‘risk limits’ that create flexibility in the risk management process over time. Essentially, risk limits are ‘tolerances’ around target portfolio risk in the same way that policy ranges are exposure tolerances relative to a benchmark asset allocation. Setting ‘risk limits’ on the portfolio is one way to manage risk tolerance and control risk within the portfolio.

A risk budget for a portfolio is determined by the expected behaviour of the different investments held. The overall risk budget can be partitioned by sub-portfolio, asset class, industry sector, external manager, or any other meaningful ‘responsibility centre’. Such component ‘risk budgets’ indicate a deliberate ‘concentration’ of risk within the overall portfolio that is expected to deliver proportionate returns. It follows that the success or failure of the responsibility centre can then be evaluated through a comparison of the intended ratio of return to risk against the actual ratio over any defined period.

The illustrative portfolio, TOP24, used in this paper is assumed to be worth $1 million at the end of January 2008 with holdings in the top 24 securities weighted according to their market capitalisation. January 2008 is deemed to be the portfolio origination date with required risk exposure and risk budgets taken across industry sectors at that date. The risk structure of this portfolio is then monitored over the period February 2008 through to August 2009 inclusive and the relevant core risk management questions are addressed using simple risk control charts and tables.

Table 2 presents some basic risk statistics for the TOP24 portfolio as at January 2008. In Table 2, the estimated Modified Expected Shortfall (MES) of -7.51% per month may be taken as an acceptable risk budget for the portfolio. If so, an investor holding this portfolio is willing to accept a 5% chance that the expected loss may be 7.51% in any month (i.e. approximately $75,100). Otherwise, an alternative portfolio may be more advisable for that investor.

Within the TOP24 portfolio, industry sectors may be considered meaningful segments of the total risk budget. Their contribution to portfolio MES is presented in Table 3.

<table>
<thead>
<tr>
<th>No.</th>
<th>Questions</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>How much risk is the portfolio intended to generate?</td>
<td>Portfolio owner or sponsor in consultation with independent experts. Develop a statement of risk tolerance that is consistent with overall investment objectives. Communicate risk budgets as required, possibly within defined risk limits, for the portfolio and any sub-portfolio segments.</td>
</tr>
<tr>
<td>2.</td>
<td>Where is the portfolio risk meant to be concentrated?</td>
<td>Portfolio manager. Provide periodic independent reports based on approved risk and return measures extracted from an accredited risk and performance system.</td>
</tr>
<tr>
<td>3.</td>
<td>How much risk does the portfolio currently exhibit?</td>
<td>Portfolio manager in consultation with portfolio owner or sponsor. Periodic independent reports from an accredited risk and performance system providing a direct comparison with required risk budgets/limits for the portfolio and any sub-portfolio segments.</td>
</tr>
<tr>
<td>4.</td>
<td>Where is the portfolio risk currently concentrated?</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Are current risks and their concentrations acceptable?</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>What mitigation strategies are available if acceptable risk limits are breached?</td>
<td></td>
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</tbody>
</table>
-2.63% and -2.37%, respectively, of the -7.51% initial risk budget for the entire portfolio. The remaining -2.5% MES risk is expected to be contributed to the portfolio by the other 11 sectors held in the portfolio.

If required, it is also feasible to define risk budgets for individual securities. For example, the -2.63% risk budget allowed for the materials sector can be further decomposed into individual risk budgets for securities NCM (-0.23%); FMG (-0.31%); AAI (-0.26%); RIO (-0.57%); and BHP (-1.26%). Similarly, for the banks sector within the TOP24 portfolio, the initial risk budgets by security would be: ANZ (-0.51%); NAB (-0.58%); WBC (-0.65%); and CBA (-0.63%).

Thus the major concentration of risk is among only six of the 24 securities held, with BHP, RIO and the four banks together accounting for -4.2% of the -7.51% initial risk budget for the overall TOP24 portfolio.

### Monitoring risk and performance

As portfolio risk evolves over time and is affected by the latest performance statistics, risk budgets are critical to address two important issues:

1. **Has there been an unexpected risk shift?** Each month, if the downside portfolio return exceeds its risk limit and/or if the return on any industry sector exceeds its risk limit, further investigation may be warranted (i.e. performance shock event);

2. **Is risk drift within acceptable bounds?** Each month, recalculated risk budgets for the portfolio and its industry sectors can be compared to current target levels. Unacceptable drift may require further investigation (i.e. risk drift event).

Figure 1 presents a snapshot of a simple risk control chart for the TOP24 portfolio as at August 2009. This chart focuses on portfolio value, return and MES (i.e. the portfolio risk budget).

The overall picture presented in Figure 1 indicates that:

- **Without intervention**, the portfolio lost 17.9% ($178,808) of its value over the period February 2008 through to August 2009 inclusive (19 months).

- For individual months September and October 2008, the negative actual return on the portfolio was -10.8% and -8.7%, respectively, exceeding the level expected by the 95% MES (-7.7%) in those months. In other words, negative returns on the actual portfolio in each of those months was significant at the 0.05 level – and more so in September 2008 where the probability of an extreme MES of -10.8% in any month would be estimated as closer to 0.008, or an 8 in 1,000 chance.

- There were sequences of large negative monthly portfolio returns that individually did not breach the MES risk limit. For example, from November 2008 to February 2009 inclusive, the portfolio lost $121,000

### Table 2: Summary risk statistics for the TOP24 Portfolio as at January 2008

<table>
<thead>
<tr>
<th>Date</th>
<th>Standard Deviation (% p.a.)</th>
<th>Portfolio Skew</th>
<th>Portfolio Kurtosis</th>
<th>95% Modified Value at Risk (MVar)</th>
<th>95% Modified Expected Shortfall (MES)</th>
<th>Portfolio Value ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200801</td>
<td>12.2</td>
<td>-0.43</td>
<td>2.6</td>
<td>-6.21</td>
<td>-7.51</td>
<td>1,000,000</td>
</tr>
</tbody>
</table>

1 Portfolio skew and kurtosis have an expected value of 0.0 and 3.0, respectively, for a normal distribution. An insignificant Jarque-Bera test for normality suggests that returns on the TOP24 portfolio are not significantly non-normal. MVaR and MES provide more conservative estimates of tail losses for any departure from normality.

### Table 3: Contribution to TOP24 Portfolio MES by major industry sectors as at January 2008

<table>
<thead>
<tr>
<th>Industry</th>
<th>MES</th>
<th>%MES</th>
<th>%Held</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
<td>-2.63</td>
<td>34.97</td>
<td>28.09</td>
</tr>
<tr>
<td>Banks</td>
<td>-2.37</td>
<td>31.61</td>
<td>29.80</td>
</tr>
<tr>
<td>Insurance</td>
<td>-0.60</td>
<td>8.02</td>
<td>7.02</td>
</tr>
<tr>
<td>Food &amp; Staples</td>
<td>-0.46</td>
<td>6.16</td>
<td>7.77</td>
</tr>
<tr>
<td>Diversified Financals</td>
<td>-0.26</td>
<td>3.44</td>
<td>2.16</td>
</tr>
<tr>
<td>Energy</td>
<td>-0.25</td>
<td>3.30</td>
<td>3.60</td>
</tr>
<tr>
<td>Real Estate</td>
<td>-0.24</td>
<td>3.14</td>
<td>6.45</td>
</tr>
<tr>
<td>6 Smaller Sectors Held</td>
<td>-0.70</td>
<td>9.36</td>
<td>15.11</td>
</tr>
<tr>
<td>11 Sectors Not Held</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>-7.51</strong></td>
<td><strong>100.0</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>
or 16.9% of its value as at October 2008. This emphasises the need for a continuous process of systematic risk analysis.

- The overall level for portfolio MES drifted downwards over the period from -7.51% to -8.50% indicating that the TOP24 portfolio, established in January 2008, became more risky by August 2009 if it had been managed on a ‘buy-and-hold’ basis.

A similar risk control chart is presented in Figure 2 for the materials sector, which accounted for 35% of the initial portfolio risk budget in January 2008.

At the sector level, several observations can be made in Figure 2:
- Exposure to the materials sector in the portfolio would have been responsible for approximately -7.58% of the highly significant -10.8% of total portfolio performance observed in Figure 1 for September 2008. In that month, the return contribution from the banks sector in the portfolio was only -0.18%.
- The drift in the marginal contribution to MES from the materials exposure of the portfolio from -2.63% to 3.51% over the period may be a prime driver of the drift in total portfolio MES from -7.51% in January 2008 to -8.70% in August 2009 (see Figure 1).

**FIGURE 1:** TOP24 portfolio risk control chart as at August 2009

**FIGURE 2:** Materials sector risk control chart as at August 2009
If relatively tight risk limits had been set at -2.5% to -3.0% (i.e. containing the risk budget of -2.63%), then the first intervention point addressing ‘risk drift’ for the materials sector may have been indicated at May 2008 when the -3% limit was breached by the updated estimate of MES at that time.

These simple risk control charts clearly indicate that portfolio risk management is not a ‘set and forget’ process. The application of risk budgets and risk limits provides guidance against which shifts in risk can be evaluated when they occur. The integration of risk and performance systems allows the risk process in Figures 1 and 2 to be combined with the return process for the portfolio, its industry sectors and even individual securities. In turn, risk-adjusted performance attribution becomes feasible.

A closer examination of the individual securities representing the materials sector within the TOP24 portfolio for September 2008 is presented in Table 3.

The analysis in Table 3 indicates that three securities (BHP, RIO and FMG) in the materials sector of the TOP24 portfolio were the major contributors to the portfolio risk breach indicated in September 2008. Further investigation is suggested and an exception report completed.

Risk evaluation and mitigation
Simple risk control charts, such as Figures 1 and 2, can be improved with visual and quantitative techniques that formally monitor and detect ‘drift’ in risk budgets, thereby replacing static risk limits with a more dynamic process that identifies significant risk events requiring further investigation.

Casual examination of Figures 1 and 2 suggests the possibility of a number of other ‘risk events’ where the actual return for the month and/or an updated MES estimate exceeded the current risk budget. Indeed, the insights from Figure 2 suggest that, prior to September 2008, three other risk events may have occurred in the materials segment of the portfolio in March 2008 (‘performance shock’); June 2008 (‘risk drift’); and July 2008 (‘performance shock’).

Each risk event detected by the risk management process must receive a detailed forensic analysis to determine causal factors that, in turn, may suggest an appropriate mitigation strategy:

- do nothing;
- rebalance the specific portfolio segment where the breach occurred;
- rebalance the entire portfolio; and/or
- introduce a temporary derivative overlay in one or more segments of the portfolio.

Clearly, evaluation and mitigation are not trivial tasks. In the current example, it should be noted that, if any/all of the risk events identified (above) had resulted in a portfolio rebalance, the performance and inferences from Figures 1 and 2 are likely to have changed from that point onwards.

Conclusions
This paper had three objectives. First, to present a simple framework within which core risk management questions are routinely answered and communicated effectively. Second, to use that framework to examine the degree of risk concentration and risk drift in a typical large cap value weighted portfolio over a volatile market period. Third, to emphasise that effective portfolio risk management requires direct interaction between the technical and behavioural facets of a funds management organisation.

The analysis revealed substantial concentration of risk in materials and banks for a large cap portfolio of 24 stocks at January 2008. Over time, risk drift in the overall portfolio was traced primarily to the materials component of the portfolio and to three of the major securities held in that sector. Early intervention may have been indicated on three occasions prior to the significant breach of the portfolio risk budget identified in September 2008.

There are a number of insights following from the analysis in this paper:

1. Portfolio risk management is a coordinated process that has many dependencies at every level of a funds management organisation from data acquisition to the Board and beyond. The weakest link in that chain will determine the overall effectiveness of the process.

2 Contribution to return from materials securities held in the TOP24 Portfolio.

2 Further research by security analysts and portfolio managers required to determine the security-specific factors that were responsible for the larger than expected negative return indicated by the 95% MES.

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>NCM</td>
<td>-0.2282</td>
<td>-0.2126</td>
<td>0.01</td>
<td>0.018</td>
<td></td>
</tr>
<tr>
<td>FMG</td>
<td>-0.3124</td>
<td>-0.3349</td>
<td>-1.09</td>
<td>0.019</td>
<td>Yes</td>
</tr>
<tr>
<td>AAI</td>
<td>-0.2596</td>
<td>-0.1714</td>
<td>0.00</td>
<td>0.053</td>
<td></td>
</tr>
<tr>
<td>RIO</td>
<td>-0.5657</td>
<td>-0.4801</td>
<td>-2.33</td>
<td>0.052</td>
<td>Yes</td>
</tr>
<tr>
<td>BHP</td>
<td>-1.2604</td>
<td>-1.4343</td>
<td>-4.15</td>
<td>0.139</td>
<td>Yes</td>
</tr>
<tr>
<td>TOTAL</td>
<td>-2.6263</td>
<td>-2.6333</td>
<td>-7.58</td>
<td>0.281</td>
<td></td>
</tr>
</tbody>
</table>

1 Contribution to return from materials securities held in the TOP24 Portfolio.
2 Further research by security analysts and portfolio managers required to determine the security-specific factors that were responsible for the larger than expected negative return indicated by the 95% MES.
2. Portfolio risk and performance are inextricably linked. A realised return on any component of a portfolio is an important signal from the underlying return generating distribution that defines risk. Effective portfolio risk management requires the integration of risk and performance systems.

3. Risk budgeting may be an effective control process if behavioural and quantitative processes are properly integrated. The natural automation of risk measurement needs to be accompanied by a reporting process that ensures: the implications of each risk event are fully evaluated; relevant corrective actions are highlighted; the exception process is followed; appropriate mitigation strategies are implemented; and the risk management system is returned to the 'in control' state.

Effective portfolio risk management requires direct interaction between the technical and behavioural facets of a funds management organisation.

Notes

1. The questions in Table 1 have parallels couched in terms of return, which lead to greater insights into portfolio performance and risk-adjusted returns. Clearly, there is a critical requirement for entities to integrate their performance and risk measurement systems. See C. Bacon 2008, Practical portfolio performance measurement and attribution, second ed., John Wiley & Sons Ltd.


5. See E. Jondeau and M. Rockinger 2006, ‘Optimal portfolio allocation under higher moments’, European Financial Management, vol. 12, no. 1, pp. 29–55; and references therein. It is shown that non-normality is highly significant in weekly and monthly data even at index level. Daily data for hedge funds holding securities with highly non-linear payoffs (e.g. options) are even more highly non-normal.


7. See P. Artzner, F. Delbaen, J.M. Eber and D. Heath 1999, ‘Coherent measures of risk’, Mathematical Finance, vol. 9, pp. 203–228. This literature shows that Expected Shortfall (also known as Conditional Value at Risk (CvaR)) possesses mathematical properties often required by finance theories and optimisation models that Value at Risk (VaR) does not exhibit.

8. Risk budgeting is most powerful within an integrated system for risk and performance. Then, responsibility centres (e.g. portfolio managers) can be evaluated in terms of ‘expected’ return and risk relative to ‘actual’ return and risk. It is also relatively straightforward to ensure that incentive schemes properly reward personnel who outperform on a risk-adjusted basis. See R.C. Urwin, S.J. Braban, T.M. Hodgson and A. Hunt 2001, ‘Risk budgeting in pension investment’, British Actuarial Journal, vol. 7, no. III, pp. 319–364 for a summary of ex ante risk budgeting in conventional pension fund management.

9. It is unrealistic to expect a ‘risk budget’ to remain constant over time and even conventional benchmark design implicitly incorporates variable risk budgets and risk limits. See N.A. Sinclair 1994, ‘Benchmark policy ranges – a trustee’s recipe for managing the manager’, Journal of the Securities Institute of Australia (JASSA), Issue 2, June, pp. 16–21.


11. The same portfolio is held throughout the period with no rebalancing. Although cash is held as an additional security for rebalancing purposes, it has a zero weight throughout.

12. It is also clear in Table 3, that the percentage held in any sector is not directly indicative of the amount of risk contributed to the portfolio by the sector. This cautions against using exposure reports as surrogates for proper risk analysis.