EDITORIAL

This was a good week for the finance media, with two high-profile headlines for a certain class of journalist to tuck into as they continue to highlight the still-diminishing public reputation of the City of London.

The first was the sentence handed down to Tom Hayes for his part in the LIBOR rigging scandal. While everyone I spoke to within the industry thought it was unduly (and pointlessly) harsh, everyone I spoke to outside the City didn’t seem to think it was a problem, even when I observed that rapists, drug dealers and people smugglers receive shorter sentences. It seems that sympathy is thin on the ground for City people in general, as it has been since the bank crash and the subsequent revelations, not only of LIBOR rigging, but also other instances of poor conduct by banks, such as the derivatives misselling and FX market rigging scandals.

The second news item that stood out was the announcement by the Treasury that Gertjan Vlieghe had been appointed as the newest external member of the Bank of England’s Monetary Policy Committee (MPC). Mr Vlieghe will be allowed to remain a partner, and draw down a salary, at the hedge fund Brevan Howard, where he was his economist. Reuters reported that Vlieghe would retain a financial interest in a Brevan Howard vehicle, allowing him to receive long-term incentive payments based on the hedge fund’s size.

Let’s remind ourselves that the MPC sets monetary policy for the UK economy. And Brevan Howard is a hedge fund. A hedge fund! To quote the Treasury that Gertjan Vlieghe had been appointed as the newest external member of the Bank of England’s Monetary Policy Committee (MPC). Mr Vlieghe will be allowed to remain a partner, and draw down a salary, at the hedge fund Brevan Howard, where he was his economist. Reuters reported that Vlieghe would retain a financial interest in a Brevan Howard vehicle, allowing him to receive long-term incentive payments based on the hedge fund’s size.

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I am sure the Treasury is right. But it left me wondering why, at this time, given all the other issues about the reputation and good-standing of the City of London, one would want to consider such a situation at all, when every single one of us with a connection or interest in the UK financial services industry should be trying our utmost, at all times, to try to enhance the image of the City. I don’t know Mr Vlieghe, and I am sure that he possesses top-notch credentials to be an MPC member, but it isn’t exactly a unique or very rare skill-set that we are talking about here is it? I mean, it’s not as if to be on the committee one has to be Jessica Ennis-Hill or Roger Federer or Sir Paul McCartney. The candidate pool is not a limited one. So the choice was curious, to say the least.

I mentioned the first news item because it seems to me to reflect just how poor the reputation of the City remains with the public at large, seven years after the bank bailout. And the second item stood out if only to remind oneself that if there is any way at all one can avoid even the merest whiff of a potential negative news story about our industry, ideally one should always try to do so.

This quarter, we present our usual set of practitioner-orientated papers, but this time there is a common theme to them. Stress-testing has become a bit of an industry since the crash, with regulators and consultants spending a lot of time reviewing the work undertaken, over another lot of time, by banks to check that their capital and liquidity levels are resilient. For many practitioners the issues remain arcane, which is why we welcome Quintin Rayer’s paper on dissecting the stress-testing process. Enrique Benito remains on the ‘crash’ theme with an insightful paper on the impact of Basel III liquidity requirements on asset encumbrance issues. This is an important balance sheet management topic and I’ve been surprised at how little attention it has received in the financial literature up to now, given the regulators’ scrutiny of the matter. So Mr Benito’s paper is welcome.

Our third paper, from Mohamoud Dualeh, looks again at Basel III liquidity, and, indeed, at the wider risk management implications of the crash, but this time from a culture and teamwork perspective. If the team works properly, risk management takes care of itself, I concluded from his paper.

Finally, just a quick note to mention that the next issue of RoFM will be the last one I work on, as I will be stepping down as Editor in December. It’s been good fun and for me very worthwhile setting up RoFM with the CISI. I’ve always been keen on knowledge dissemination at all levels in the City, and I hope that RoFM helped in some small part towards this. As always I’d like to thank our authors and our readers for their support from the start.

Enjoy the issue.

Professor Moorad Choudhry FCSI, Editor

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HAVE YOUR SAY

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INTRODUCTION
Portfolio stress-testing may be used when attempting to identify and quantify risks that are not particularly well captured by more conventional measures, particularly relating to the impact on a portfolio of difficult market conditions. This paper discusses portfolio stress-testing using historical and artificial scenarios, after commencing with a definition and classification of stress-testing methods. Four approaches are explored, two historical and two hypothetical stress tests. Examples are included and the advantages and disadvantages discussed.

DEFINITION OF PORTFOLIO STRESS-TESTING
Portfolio managers associate a number of activities with stress-testing, including looking at the potential downside risk of portfolios, or methods to see what response might be expected under difficult ('stressed') conditions. Although stress-testing cannot be guaranteed to identify actual impacts on a portfolio of future events, it is another tool in the portfolio or risk manager's armoury. Stress tests are designed to determine how a portfolio might respond to adverse developments, so that weak spots can be detected early and preventative action taken, typically focusing on key risks such as market risk, credit risk and liquidity risk.

Consider the following definition of portfolio stress-testing [1]:

- A method of the quantification of potential future extreme, adverse outcomes in a portfolio of financial instruments.
- A palliative for the anxiety that is experienced by managers with significant risk exposures.

This definition highlights some key points. Quantitative estimates of stress test outcomes are required, in monetary terms, but stress tests do not necessarily provide statistical estimates of outcome likelihoods. The scenarios indicate potential future outcomes under extreme conditions; a scenario is not a stress test unless the outcome is adverse. Portfolio investment scenarios that do not anticipate adverse outcomes are not stress tests. For an example see [2].

Stress-testing only identifies potential problems, without resolving them. Thus stress-testing may be palliative (reducing pain but not offering a cure) by reassuring a practitioner if no outstanding issues are detected, but leaving unresolved questions as to what to do about problems that have been identified, or even whether the selected stressed scenarios are sufficient to identify all key portfolio weaknesses.

CLASSIFICATION OF PORTFOLIO STRESS-TESTING
Stress-testing covers a wide range of methodologies, and various terms are used in the literature rather loosely [3], thus a full classification may be difficult. The classification below frames the current discussion and may help other practitioners. Often historical events provide a source of stressed conditions; however, practitioners are free to imagine any damaging situation and attempt to quantify its portfolio impact. A key distinction is between historical scenarios (re-enactments of particular market events with a defined start and end date) and artificial scenarios (invented to capture a particular concern and often involving assumptions), see Figure 1. Thereafter, classification divisions may become more judgmental. This classification follows aspects of [1] by splitting artificial scenarios into hypothetical and algorithmic scenarios. The main types of stress tests are described in Table 1, together with advantages and disadvantages.

![Figure 1: Stress-testing classification. The stress test examples in this paper do not include the italicised types](cisi.org/academic)
can attempt to include the impact of changes (or anticipated changes) on markets, perhaps due to regulatory developments, new currencies and so on. An artificial test can also isolate specific concerns in a portfolio.

IMPLEMENTING PORTFOLIO STRESS-TESTING

Stress-testing tends to be an ad hoc practical activity rather than theoretically based [3]. A balance between art and science is required, with the identification and imagining of dangerous scenarios followed by efforts to examine their impacts on a portfolio. The definition of stress test scenarios requires judgment, even if implementation of the selected scenarios can become more scientific. Selection of scenarios will depend on various assumptions, which should be broadly regarded as ‘unlikely but plausible’ [3].

The judgmental aspects of defining stressed scenarios means involvement of stakeholders (including portfolio managers) is essential, with unequivocal support by senior management. This will likely be better achieved if stress-testing is an integral part of portfolio management rather than an add-on. Indeed, a portfolio manager’s input is likely to be critical in identifying issues of concern, as well as determining the appropriate severity of a stressed scenario, which requires a balance between being challenging but possible. Stress-testing should not be seen as an inconvenience, but as a reassurance to managers of the quality of their investment decisions.

Robust stress-testing may also be seen from a corporate social responsibility perspective. By making investment outcomes more robust, clients should benefit and management reputation should be enhanced.

Implementing stress-testing can be seen as a four-step process [4]:

1. **Risk identification**: historical events or anticipated concerns
2. **Definition of stressed scenarios**: involvement of stakeholders, support of senior management, integration within investment decision-making
3. **Execution of stress-test scenarios**: derivation of portfolio value
4. **Analysis of results**: commentary in periodic reporting.

The definition of stress test scenarios cannot be regarded as a ‘once and forever’ activity. Existing scenarios should be constantly reviewed, re-evaluated and possibly adjusted to maintain their usefulness, with a policy established to review stressed scenarios periodically to assist in establishing good discipline and to learn from experience⁴.

HISTORICAL STRESS-TESTING USING VAR

Historical scenarios comprise a period with defined start and end dates that span an interval when the asset or portfolio of interest performed poorly. The asset price behaviours over the period are applied to the current portfolio to see how it would respond.

Under stressed conditions, parametric Value-at-Risk (VaR) might be inadequate due to the assumption of normally (or log-normally) distributed returns, making historical VaR more appropriate. Historical VaR takes actual period returns over some interval, assigning an equal probability to each [1], so can be seen as a scenario analysis. Further, one could add selected ‘stressed period’ returns, equally-weighted with the non-stressed returns and recalculate the VaR, thereby creating a stress test with a stressed historical VaR.

Table 1: Stress test types with advantages and disadvantages.

<table>
<thead>
<tr>
<th>Approach</th>
<th>Summary</th>
<th>Description</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Historical</td>
<td>Replay crisis event</td>
<td>Re-enactment of a particular historical market event of significance. Scenario shocks. It must be reasonable since it actually occurred</td>
<td>• It actually happened that way</td>
<td>• Proxy shocks may be numerous</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• No probabilistic interpretation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• No guarantee of ‘worst case’</td>
</tr>
<tr>
<td>Hypothetical</td>
<td>• Covariance matrix</td>
<td>Modify covariance matrix to reflect higher asset correlations. Specify hypothetical shocks to market factors (often historical events can be a guide). Definition of a systemic liquidity event. Shock specific identified risk factors while neglecting correlation. Explore a mixture</td>
<td>• Relatively easy</td>
<td>• Empirical support mixed</td>
</tr>
<tr>
<td></td>
<td>• Create event</td>
<td></td>
<td></td>
<td>• No guarantee of ‘worst case’</td>
</tr>
<tr>
<td></td>
<td>• Sensitivity analysis</td>
<td></td>
<td></td>
<td>• Limited risk information</td>
</tr>
<tr>
<td>Algorithmic</td>
<td>• Factor push</td>
<td>Attempt to systematically identify the worst outcome within a defined feasible envelope. Push each risk factor a number of standard deviations in a direction that results in losses. Identify the set of changes in market risk factors that results in the greatest loss</td>
<td>• Minimal qualitative elements</td>
<td>• No guarantee of ‘worst case’</td>
</tr>
<tr>
<td></td>
<td>• Maximum loss</td>
<td></td>
<td></td>
<td>• Ignores correlations</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Assumes data from normal periods are relevant</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Computationally intensive</td>
</tr>
</tbody>
</table>

4. Indeed, approaches for defining and maintaining a library of stressed scenarios could be seen as a large topic in its own right, which is beyond the scope of the current article.
An example illustrates the process. Suppose for some asset, the 95% historical weekly VaR is calculated over two years to current date (104 weekly returns). The historical VaR calculation comprises sorting returns into ascending order and identifying the 5% lower quantile return. With 104 returns, the 5% limit would be the rank 5.2 lowest return. Suppose a four-week period in 1987 has been identified with a severe impact on the returns of our asset. The four additional weekly returns for the stressed period can be added to the current returns already collected. The new total of 108 weekly returns is re-sorted with the 5% lower quantile being the rank 5.4 lowest return. The resulting value would be the 95% weekly historical stressed VaR under the scenario.

The addition of a small number of stressed-period returns has only slightly altered the 5% lower quantile rank (5.2 to 5.4), but since the stressed period, returns might reasonably be expected to comprise returns lower (or amongst the lowest), compared with the 104 weekly returns to current date. The resulting stressed VaR can be considerably worse.

This identifies some strengths and weaknesses of the historical VaR stress test. Recent returns were blended with a small sample of historical returns from some stressed period that otherwise would have been excluded. Instead of using a distribution of weekly returns over the period two years to current date, we have arbitrarily added a further four weekly returns from some period when the asset performed poorly. In the example, the stressed period was much shorter than the usual period analysed, and thus had little effect on the rank used in the ordered returns to calculate historical VaR. Broadly, if the stressed-period returns are all higher than the non-stressed historical VaR, the stressed VaR will be little different from the non-stressed VaR. Equally, if the stressed-period returns are all rather lower than the non-stressed VaR, then the value of the stressed historical VaR will be largely determined by the stressed-period returns. Naturally, for a longer stressed-period merged with a shorter non-stressed current historical VaR, the result will not be so clear-cut.

Historical VaR uses a fixed period to date. One criticism is that any market event prior to the start of that period will be completely excluded. The above adjusts the historical VaR to include the impact of a selected crisis period that would otherwise lie outside the VaR window, addressing this criticism. Additionally, the historical VaR uses actual returns, and therefore has a return distribution of arbitrary shape. By adding crisis period returns, which would likely lie deep in the negative tail of the distribution, it is probable that the resulting distribution would be more negatively skewed than otherwise, which would seem desirable for a stressed VaR analysis. However, this analysis has not replicated the entire returns distribution for the stressed period. Also, by using the distribution quantile, no path-dependency has been included and no underlying economic analysis has been conducted.

**HISTORICAL STRESS-TESTING USING EVENT PERIODS**

Here, a different process is used to apply the asset price behaviours from a historical period of poor performance to the current portfolio. For an individual market index, a crisis period might seem well-defined, however, in reality, historical scenarios may play out over extended periods due to market linkages and feedback. For a portfolio of varied instruments, defining a start and end date may be harder. This is illustrated in Figure 2, with two approaches identified.

5. The fractional rank being obtained, by linear interpolation, say, as a weighted sum of 0.8 of the 5th worst weekly return and 0.2 of the 6th worst weekly return.
6. The stressed period returns would be expected to lie in a time period not included in the usual non-stressed historical VaR calculation.
7. Again, linear interpolation could be used to obtain the fractional rank return as a weighted sum of 0.6 of the 5th worst weekly return and 0.4 of the 6th worst weekly return.
8. No assumption of normally or log-normally distributed returns.
the entire period is probably preferred, since it results in a more plausible scenario, although it may remain more vulnerable to correct identification of suitable start and end dates and neglect impacts within the window.

HYPOTHETICAL STRESS-TESTING USING THE VARIANCE-COVARIANCE MATRIX

Volatility and VaR are often used to quantify risk, with de-correlated assets to achieve diversification, thus reducing a portfolio’s volatility and parametric VaR. Accepting the intuition that correlations often increase during market crashes, to stress-test diversification we may increase correlations to quantify the impact this would have on portfolio volatility and VaR.

For a multi-asset portfolio, we construct an $n \times n$ volatility matrix $\mathbf{v}$ with the volatilities of the $n$ assets down the leading diagonal. Using correlation matrix $\mathbf{R}$, we obtain the variance-covariance matrix $\mathbf{S}=\mathbf{vRv}$. The asset weight vector $\mathbf{w}$ gives a portfolio variance $\mathbf{w}^\top \mathbf{S} \mathbf{w}=\sigma^2$, and portfolio parametric VaR, $\mathbf{VaR}_\sigma=[-N\delta t^{1/2}]$, where $N$ is the number of standard deviations for the confidence level we require. We can increase both individual asset volatilities and correlations to reflect some stressed scenario.

Consider a four-asset portfolio, with assets A–D, weights $w_A=0.25$, $w_B=0.40$, $w_C=0.30$, $w_D=0.05$ and annual volatilities $\sigma_A=9.78\%$, $\sigma_B=3.76\%$, $\sigma_C=11.17\%$, $\sigma_D=14.84\%$. Now suppose a non-stressed correlation matrix:

$$
\mathbf{R} = \begin{bmatrix}
1 & -0.21 & 0.87 & 0.59 \\
-0.21 & 1 & -0.16 & 0.05 \\
0.87 & -0.16 & 1 & 0.73 \\
0.59 & 0.05 & 0.73 & 1 \\
\end{bmatrix}
$$

This leads to a portfolio volatility of 6.08%/pa, and a 95% monthly parametric VaR of 2.89%/10.

Now stress-test by increasing the volatilities to $\sigma_A'=14\%$, $\sigma_B'=5\%$, $\sigma_C'=16\%$, $\sigma_D'=23\%$ and correlations to:

$$
\mathbf{R}' = \begin{bmatrix}
1 & 0 & 0.91 & 0.79 \\
0 & 1 & 0.16 & 0.16 \\
0.91 & 0.16 & 1 & 0.87 \\
0.79 & 0.16 & 0.87 & 1 \\
\end{bmatrix}
$$

We obtain a stressed portfolio volatility of 9.55%/pa and stressed 95% monthly parametric VaR of 4.54%. In fact, common practice would suggest applying a multiplier of 4 to the portfolio volatility [1], increasing the VaR to 18.14%/11.

However, we are not at liberty to modify the correlation matrix arbitrarily. Some combinations of correlations can result in implausible stressed returns and variance-covariance matrices that are not positive semi-definite, meaning that negative variances can arise. This can be circumvented by taking a correlation matrix from a stressed historical period, but it makes the stress test more like a historical scenario, and may not explore the asset correlations of primary concern. Alternatively, mathematical techniques can be used to construct the correlation matrix appropriately. Two such approaches are discussed here.

If return histories on portfolio assets are available, the correlation matrix can be revised following Finger [1], [5]. Correlations are adjusted by modifying selected return vectors period-by-period, and must be rescaled if the original asset variances are to be unchanged. Consequently, not only are targeted correlations changed, but also other correlations in the same matrix rows and columns. Numpacharoen and Bunwong (N&B) [6] propose an alternative, whereby the correlation matrix is adjusted directly. Cholesky decomposition ensures that a positive semi-definite correlation matrix is obtained, correlations are represented using trigonometrical functions and changes made in a counter-clockwise angle. This ensures correlations lie within $\pm 1$, and the resulting adjusted correlation matrix has the necessary mathematical properties.

These two approaches are not expected to give the same adjusted correlation matrix, for example [6], with initial and target correlation matrices of:

$$
\mathbf{R}_{\text{Initial}} = \begin{bmatrix}
1 & -0.3 & 0.3 \\
-0.3 & 1 & 0.3 \\
0.3 & 0.3 & 1 \\
\end{bmatrix}; \quad \mathbf{R}_{\text{Target}} = \begin{bmatrix}
1 & -0.3 & 0.85 \\
-0.3 & 1 & 0.3 \\
0.85 & 0.3 & 1 \\
\end{bmatrix}
$$

Adjusted correlation matrices are generated:

$$
\mathbf{R}_{\text{Finger}} = \begin{bmatrix}
1 & -0.14 & 0.85 \\
-0.14 & 1 & 0.14 \\
0.85 & 0.14 & 1 \\
\end{bmatrix} \quad \text{and} \quad \mathbf{R}_{\text{N&B}} = \begin{bmatrix}
1 & -0.3 & 0.85 \\
-0.3 & 1 & -0.04 \\
0.85 & -0.04 & 1 \\
\end{bmatrix}
$$

It is not entirely clear which method should be preferred. Finger’s approach has intuitive appeal, since returns are adjusted towards an average to increase correlation. However, a goal-seek algorithm is required and, for a large multi-asset portfolio, a long history of returns has to be adjusted (potentially including rescaling for volatilities), which might become cumbersome. In some cases, a suitable asset return history may not be available. In this case, N&B’s approach seems practical, since only the correlation matrix is required, although the mathematical sophistication may discourage some practitioners. Although N&B’s method ensures the resulting correlation matrix has the correct properties, there is no guarantee of economic validity. In practical terms, choice between the two methods may be dictated by availability of asset returns for Finger [5], and access to a Cholesky decomposition algorithm (and level of intellectual comfort) for N&B [6].

HYPOTHETICAL STRESS-TESTING USING CREATED EVENTS

A hypothetical created event stress test is an invented scenario which attempts to capture a particular concern. One, several or many factors that may impact the portfolio are selected and deliberately tweaked to assess portfolio response. The practitioner has almost complete freedom in identifying relevant factors to shock, revealing a weakness of the approach, since it can be difficult to create economically meaningful stressed scenarios. An envelope approach can be used [3], which helps ensure a degree of consistency and makes it easier to include important factors, although may not guarantee economic consistency [10].

Figure 3 illustrates the stress-envelope approach. Stress factors are identified and, for each, the worst possible shock determined. Individual scenarios are based on envelope values. Generally, not all of the factors will be used, and the stressed scenario levels chosen will be somewhat lower than the envelope maximums. Multiple stressed scenarios will reflect differing concerns. Nothing in this process ensures the economic consistency of individual scenarios thus created, so there is no guarantee that the scenarios created are realistic, possible or extreme enough.

9. A number of academic studies debate this point, a discussion can be found in [1].
10. $N=1.645$, $\delta t=1/12$, so $\mathbf{VaR}_\sigma=[1.645\times6.08\times\sqrt{(1/12)}]=2.89\%$.
11. Calculated as $\mathbf{VaR}_\sigma=[1.645\times4\times9.55\times\sqrt{(1/12)}]=18.14\%$.
12. In an ideal world, one would have a complete global market model to which shocks could be applied and from which the responses of all portfolio assets could be obtained. Since such a model does not exist, practitioners constructing a hypothetical scenario should try to make it as realistic as they reasonably can.
Following [3], an example illustrates the process. Consider an envelope of four factors as follows:

1. European equities fall by 25%
2. World ex-Europe equities fall by 20%
3. A parallel downward shift in the yield curve of 200bp
4. Foreign exchange rates: EUR weakens relative to USD by 10%.

Based on this envelope, one scenario is created as:

- European equities fall by 20%
- World ex-Europe equities fall by 15%
- A parallel downward shift in the yield curve of 50bp.

Only a subset of factors has been selected and, in each case, the size of the factor shock is not greater than that of the envelope. A judgment must be made whether the shocks selected are economically feasible.

Implementing the stress test involves determining the impact on the portfolio of the maximum shock for each factor individually, and then pro-rating these for the overall impact, as shown in Table 2. While the linear interpolation used to evaluate the impact of factors may appear simplistic, [3] argues that it is actually conservative.

An advantage is flexibility to assess the impact of any imagined scenario. However, its weakness is that there is no guarantee that the events created are realistic, possible or extreme enough. Elements such as portfolio diversification and correlation are ignored. Historical events may be used as a guide in creating such scenarios, which would support credibility. However, the advantage of the created event is that an historical event can be modified to incorporate new aspects, such as changes to regulations, developments in markets, geopolitics and so forth, giving an opportunity to add real value.

### SUMMARY AND DISCUSSION

Following a definition of portfolio stress-testing and a classification of stress-testing types, examples of four kinds of stress tests have been presented: two historical and two artificial. Table 1 lists advantages and disadvantages of the main types, while Table 3 captures key differences between the approaches.

The selection of a stress-testing methodology will depend on the requirements of the practitioner (consider Table 3). With concern to how an historical event might impact the current portfolio, a historical stress test would be required, although history may be used as a guide in generating hypothetical correlation matrices or created events. But if the objective is to address concerns over new market developments, regulations and so forth, hypothetical stress tests may be more appropriate.

There are other considerations. If a stressed-VaR measure is desired, then a choice between parametric or historical returns distributions may lead to either historical VaR or hypothetical variance-covariance matrix approaches. When testing the diversification benefits of a portfolio, then historical event-periods could be used, although hypothetical variance-covariance matrix testing comes into its own when explicitly exploring correlations and volatilities.

Should economically meaningful scenarios be the primary consideration, then the historical methods are likely to be preferred (although note ‘new market developments' in Table 3). However, historical event-period scenarios may not be appropriate if maximum-peak-to-trough price movements are used, and the variance-covariance matrix scenarios could be based on historical correlations and volatilities, making them economically realistic.

Regarding flexibility in scenario creation, historical stress tests are limited to historical events, while hypothetical methods allow more freedom. For the ability to isolate specific concerns, historical events tend to be ‘messy’ with many knock-on effects, while the hypothetical methods permit a focus on individual portfolio aspects. Similarly, to explore extreme events, the historical methods only permit this if suitable events lie within the historical record, while the hypothetical methods permit the option of pushing factors further.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Maximum stress envelope shocks</th>
<th>Maximum scenario shocks</th>
<th>Scenario shock weights</th>
<th>Scenario values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe equities</td>
<td>-25%</td>
<td>-€1000</td>
<td>20/25 = 0.8</td>
<td>-€800</td>
</tr>
<tr>
<td>World ex-Europe equities</td>
<td>-20%</td>
<td>-€800</td>
<td>15/20 = 0.75</td>
<td>-€600</td>
</tr>
<tr>
<td>A parallel downward shift in the yield curve</td>
<td>-200bp</td>
<td>+€200</td>
<td>50/200 = 0.25</td>
<td>+€50</td>
</tr>
<tr>
<td>Foreign exchange rates</td>
<td>-10%</td>
<td>+€150</td>
<td>Not used</td>
<td>Not used</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total -€1350</td>
</tr>
</tbody>
</table>

13. In reality, one would expect the envelope to contain many more than four factors, however this is sufficient to illustrate the example.
A practical consideration may be data availability. The historical scenarios that can be replicated will be limited by data availability on each asset, so for less recent events this could be a significant issue. Potentially, the hypothetical variance-covariance matrix test can get away with only the current portfolio correlation matrix, while hypothetical created events probably have the least demanding data requirements of all, being essentially limited to the current portfolio.

Thus, in practice, the choice of stress-testing method used for a portfolio would depend on the objectives and requirements of those setting the stress-testing programme, as well as the resources and data available.

REFERENCES


Bank executives responsible for asset-liability management (ALM) often need to evaluate and compare alternative funding arrangements and their impact on the institution’s regulatory constraints. In this article, we present a simple framework to evaluate the impact of funding arrangements on a set of constraints, including the Basel III liquidity ratios and the bank’s asset encumbrance level. The framework can be used under several settings, including normal and stress conditions and business models.

BACKGROUND

Bank executives responsible for ALM often need to evaluate and compare financing alternatives and their impact on the institution’s regulatory constraints. Examples can include the following:

- Evaluating the optimal funding strategy for a new project or investment
- Assessing the regulatory impact of particular funding options
- Articulating and ranking a set of management actions that can be invoked under stress in order to obtain additional funding, as articulated in the Contingency Funding Plan (CFP)
- Evaluating the costs and benefits of marginal funding, as required in the Funds Transfer Pricing (FTP) framework.

The regulatory constraints in play generally include liquidity requirements, such as minimum holdings of liquid assets, or structural funding and balance sheet constraints.

The Basel III framework has introduced two new liquidity standards: the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR). The LCR requires minimum holdings of high-quality liquid assets (HQLA) to withstand net cash outflows (gross outflows minus gross inflows capped at 75%) during a stress scenario that lasts 30 days. The minimum requirement is stated as follows:

\[
\frac{\text{Stock of HQLA}}{\text{Net cash outflows over the next 30 days}} \geq 100\%
\]

The measure aims to make banks less prone to acute adverse liquidity shocks. Although the minimum ratio is already applicable in several jurisdictions, it is expected that the LCR will be fully in force in most jurisdictions adopting Basel III by the end of 2015.

The NSFR requires banks to hold a minimum amount of Available Stable Funding (ASF) to cover a certain amount of Required Stable Funding (RSF). The ASF and RSF are calculated by applying certain percentage factors to the bank’s liabilities and assets respectively, calibrated using a stress period of up to one year. The minimum requirement is stated as follows:

\[
\frac{\text{Available amount of stable funding}}{\text{Required amount of stable funding}} \geq 100\%
\]

The NSFR is designed to promote the structural funding position of banks in order to reduce maturity mismatches and over-reliance on short-term wholesale funding, and is expected to enter into force in 2018.

As a result, the LCR imposes the requirement that the stock of HQLA is unencumbered, and the NSFR imposes the highest possible RSF factor (i.e., 100%) to assets that are encumbered for longer than six months. In addition, additional constraints may limit the amount and quality of assets that a bank can encumber, such as limits to covered bond issuances, capital requirements under Pillar 2 or credit rating objectives.

Two metrics are frequently used to measure asset encumbrance. The ‘encumbrance ratio’ is stated as follows:

\[
\frac{\text{Encumbered assets}}{\text{Total assets}}
\]

The higher the ratio, the higher the encumbrance level. In Europe, there are specific regulatory reporting requirements in place that toughen if an institution’s encumbrance level exceeds 15% (measured as the ratio of encumbered assets over total assets).

An alternative is to use the ‘ratio of unsecured liabilities to unencumbered assets’:

\[
\frac{\text{Unsecured liabilities}}{\text{Unencumbered assets}}
\]

Similarly to the encumbrance ratio, the higher the ratio, the higher the encumbrance level. This metric has several advantages. Firstly, it depicts the actual impact of encumbrance on unsecured creditors. Secondly, variations of the ratio can be computed by selecting only unencumbered assets of particular quality (e.g., HQLA), allowing analysis of the actual quality of assets available for encumbrance. The measurement of unsecured liabilities, however, presents difficulties, particularly with relation to the treatment of deposits. Although deposits do not generally generate encumbrance (unless collateralised), depositor preference rules can change the priority of claims under insolvency. The influence of depositor preference on asset encumbrance levels can be evaluated by including or excluding retail deposits to the liabilities when computing the ratio.

---

1. Funds Transfer Pricing or FTP refers to the mechanism by which costs, benefits and risks relating to liquidity and funding are allocated to the bank’s business units (see Choudhry, 2012, The Principles of Banking, Chapter 15).
2. See Benito (2015) for a discussion of potential constraints to asset encumbrance.
3. Depositor preference rules that if a bank enters insolvency, the priority of claims may be altered by providing preferential treatment to retail deposits and subordinating other unsecured creditors.
In this section, we present a framework to evaluate the impact of funding arrangements on the constraints outlined above. We consider and evaluate the net impact of four different funding options on the LCR, NSFR and asset encumbrance ratios, using the latest policy releases by the Basel Committee (see BCBS 2013; 2014):

- deposits to retail and small business customers
- unsecured wholesale funding
- secured wholesale funding backed by eligible HQLA; and
- secured wholesale funding backed by non-HQLA.

Since our aim is to compare funding alternatives, the asset side can be safely ignored. As illustrated in Tables 1–3, the net impact will depend on the contractual maturity of the transaction and counterparty type.

In Table 1, deposits to retail and small business customers provide a favourable treatment across all metrics, with high ASF factors, high rollover rates and no associated encumbrance. Unsecured wholesale funding does not generate encumbrance, but the impact on the LCR and NSFR in terms of outflow rates and ASF respectively, can vary considerably depending on the residual maturity and counterparty.

Tables 2 and 3 illustrate the impact of secured funding when HQLA or non-HQLA are provided as collateral respectively. Changes to encumbrance metrics depend on the magnitude of over-collateralisation, which tends to be lower when using HQLA compared to non-HQLAs collateral. As opposed to the other options, using HQLA as collateral would also provide a more favourable treatment across all metrics, with high ASF factors, high rollover rates and no associated encumbrance.

---

5. We exclude operational deposits.
6. This implicitly assumes that the proceeds obtained from any of the arrangements subject to evaluation would be invested on identical assets.
7. Over-collateralisation refers to the requirement that the collateral provided is of higher value than the underlying exposure that the collateral is securing, acting as a form of protection to the secured party against potential decreases in the actual market value of the collateral. This is usually undertaken by means of a 'haircut' or 'margin ratio'.

---

<table>
<thead>
<tr>
<th>Funding type</th>
<th>Residual maturity</th>
<th>Counterparty</th>
<th>Asset encumbrance ratio</th>
<th>NSFR</th>
<th>LCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retail and small businesses</td>
<td>&gt;1y</td>
<td>Retail and small businesses</td>
<td>-</td>
<td>90%-95% ASF</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>&gt;1m &lt;1y</td>
<td>Retail and small businesses</td>
<td>-</td>
<td>90%-95% ASF</td>
<td>3%-10% outflow</td>
</tr>
<tr>
<td></td>
<td>&lt;1m</td>
<td>Retail and small businesses</td>
<td>-</td>
<td>90%-95% ASF</td>
<td>-</td>
</tr>
</tbody>
</table>

**Table 1** – NFC: non-financial corporations; MDBs: multilateral development banks, PSEs: public sector entities; CBs: central banks; FIs: Financial institutions.

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<table>
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<tr>
<th>Funding type</th>
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<th>Counterparty</th>
<th>Asset encumbrance ratio</th>
<th>NSFR</th>
<th>LCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secured (HQLA collateral)</td>
<td>&gt;1y</td>
<td>Any</td>
<td>Increase encumbrance (lower O/C %)</td>
<td>Increased RSF (see table 4)</td>
<td>Reduction of stock of HQLA</td>
</tr>
<tr>
<td></td>
<td>&gt;1m &lt;1y</td>
<td>NFC, Sovereigns, MDBs, PSEs</td>
<td>Increase encumbrance (lower O/C %)</td>
<td>50% ASF</td>
<td>Reduction of stock of HQLA</td>
</tr>
<tr>
<td></td>
<td>&lt;1m</td>
<td>CBs, FIs</td>
<td>Increase encumbrance (lower O/C %)</td>
<td>0%-50% ASF</td>
<td>Reduction of stock of HQLA</td>
</tr>
</tbody>
</table>

**Table 2** – NFC: non-financial corporations; MDBs: multilateral development banks, PSEs: public sector entities; CBs: central banks; FIs: financial institutions.

---

<table>
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<tr>
<th>Funding type</th>
<th>Residual maturity</th>
<th>Counterparty</th>
<th>Asset encumbrance ratio</th>
<th>NSFR</th>
<th>LCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secured (non-HQLA collateral)</td>
<td>&gt;1y</td>
<td>Any</td>
<td>Increase encumbrance (higher O/C %)</td>
<td>Increased RSF (see table 4)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>&gt;1m &lt;1y</td>
<td>Domestic sovereigns, MDBs, domestic PSEs</td>
<td>Increase encumbrance (higher O/C %)</td>
<td>50% ASF</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>&lt;1m</td>
<td>CBs</td>
<td>Increase encumbrance (higher O/C %)</td>
<td>0% ASF</td>
<td>25% outflow</td>
</tr>
</tbody>
</table>

**Table 3** – NFC: non-financial corporations; MDBs: multilateral development banks, PSEs: public sector entities; CBs: central banks; FIs: financial institutions; O/C %: Over-collateralisation percentage.
The impact of secured funding on the NSFR depends on (i) the ASF factor assigned to the particular option considered and (ii) a potential increase of the RSF due to the encumbrance of collateral.

If the transaction has a residual maturity of less than one year, then it will carry an ASF factor between 0% and 50%, depending on the quality of the collateral, the counterparty and residual maturity. There is no ASF requirement for transactions with residual maturity longer than one year.

In addition, if the transaction has a residual maturity longer than six months, then the RSF assigned to the assets used as collateral may marginally increase. This is because assets on the balance sheet that are encumbered receive a higher RSF factor than if they were unencumbered. This is illustrated in the tables below. If the collateral becomes encumbered for one year or more, it would receive a 100% RSF factor. If the collateral is encumbered for a period between six months and one year, it would receive an RSF factor of 50% or higher. It is easy to note that using collateral of lower quality may result in a reduced net impact on the NSFR, compared to using collateral of higher quality, such as level 1 or level 2A assets.

### Baseline III and the Critical Challenge for Bank Risk Management
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**ABSTRACT**

The art of banking is that of managing liquidity. While capital is correctly viewed as being of utmost importance to a bank's viability and public perception, the practitioners’ common saying that 'capital kills you slowly, while liquidity kills you quickly' is an accurate one. Genuine pure liquidity-scarcity events are rare, however, the experience of the UK bank Northern Rock in 2007 illustrates the key risk for banks and regulators: that of the risk of complacency.

This article suggests that the critical challenge concerns that of banks’ culture, and ensuring that control and governance infrastructure put in place today is maintained over the long term. A change in the Treasury and risk management operating model is a necessary step towards ensuring this longevity in liquidity risk management principles.

**ART OF LIQUIDITY RISK MANAGEMENT**

Liquidity in banking is commonly defined as having the ability to meet obligations when they become due.

The important part to understand is exactly what is meant by ‘when they become due’. From the risk management perspective, this means in perpetuity, or at least as long as we wish the bank to remain a going concern. In other words, maintenance of liquidity at all times is the paramount order of banking.

Bank risk management is the practice of balance sheet management. The risks in question are those affecting the balance sheet, which are capital, liquidity and funding (generally grouped together under ‘asset-liability management’ or ALM). We categorise balance sheet risk as the process of:

- managing the bank’s capital
- managing the liquidity mismatch, arising from the fundamental ingredient of banking termed 'maturity transformation'
- recognition that loans (assets) generally have a longer tenor than deposits (liabilities).

This is also the paradox of banking, which creates maturity mismatches between assets and liabilities, because assets are invariably long-dated and liabilities are short-dated, and this creates liquidity risk. To undertake banking is to assume a continuous ability to roll over funding, otherwise banks would never originate long-dated illiquid assets, such as residential mortgages or project finance loans. As it is not good business practice to rely on assumptions, prudent liquidity risk management dictates that all leveraged financial institutions need to set in place an infrastructure and governance ability to ensure that liquidity is always available, to cover for when market conditions deteriorate. The fundamental challenge for all

### Funding Ratio:

### Baseline III and the Critical Challenge for Bank Risk Management
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#### Table 1: Impact of Secured Funding on the NSFR

<table>
<thead>
<tr>
<th>Residual maturity</th>
<th>Before encumbrance</th>
<th>After encumbrance</th>
<th>Net impact on RSF</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;1y</td>
<td>0%-5%</td>
<td>100%</td>
<td>95%-100%</td>
</tr>
<tr>
<td>Backed by HQLA (Level 1)</td>
<td>15%</td>
<td>100%</td>
<td>85%</td>
</tr>
<tr>
<td>Backed by HQLA (Level 2A)</td>
<td>50%</td>
<td>100%</td>
<td>50%</td>
</tr>
<tr>
<td>Backed by non-HQLA</td>
<td>10%-85%</td>
<td>100%</td>
<td>15%-90%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Residual maturity</th>
<th>Before encumbrance</th>
<th>After encumbrance</th>
<th>Net impact on RSF</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;6m and &lt;1y</td>
<td>0%-5%</td>
<td>50%</td>
<td>45%-50%</td>
</tr>
<tr>
<td>Backed by HQLA (Level 1)</td>
<td>15%</td>
<td>50%</td>
<td>35%</td>
</tr>
<tr>
<td>Backed by HQLA (Level 2A)</td>
<td>50%</td>
<td>50%</td>
<td>0%</td>
</tr>
<tr>
<td>Backed by non-HQLA</td>
<td>10%-85%</td>
<td>50%-85%</td>
<td>0%-40%</td>
</tr>
</tbody>
</table>

8. Note that if the original RSF factor before encumbrance was higher than 50%, then this factor would be retained after encumbrance.
9. Note that this is based on the assumption that the HQLA assets considered qualify as liquidity buffer, which may not always be the case if additional operational requirements are not met.

### REFERENCES


banks is to maintain this robust control infrastructure and governance over the long term.

THE SCOPE OF LIQUIDITY RISK

Basel I and II were not concerned with liquidity, only capital. The Basel III regime, which will be fully implemented by 2019, makes material demands on banks with respect to the way they manage liquidity. However, liquidity risk management is not simply a matter of liquidity metrics and ratios. There are important governance and policy issues that also need to be built into the infrastructure and workings of a bank’s treasury and risk departments. Liquidity risk management needs to be addressed at the highest level of a bank’s management: the board of directors. The board will delegate this responsibility to a management operating committee such as ALCO, but it is the board that owns liquidity policy. If it does not own it, then it is not following business best practice. Given this, it is important that the board understands every aspect of liquidity risk management.

Basel III enshrines the new risk approach in formal regulatory law with two new structural risk metrics, one for short-term and one for long-term funding. On the face of it, these represent a step-change in liquidity management culture, but that is only because principles accepted as commonplace in the 1860s or 1960s had been discarded by 2008. Nevertheless, they will prove to be a challenge to work towards for many banks.

The stated objective of the Basel III liquidity coverage ratio (LCR) is to promote short-term resilience of banks to liquidity shocks. Setting a limit for it, and requiring banks to hold a stock of sufficient high-quality genuinely liquid assets, is designed to ensure a more stable funding regime that will be less susceptible to a freeze in interbank markets, of the kind observed in October 2008. The LCR requirement results in banks having to maintain a liquidity buffer that matches expected cash outflows in a stressed environment. The amount of funds that might be observed in a market stress situation is given by the stress tests that banks run every month, under specified assumptions. The time period covered in the stress test is 30 days. This implies that a stressed environment would last only for a month, which is unrealistically short. For this reason some regulators, including the UK’s Prudential Regulation Authority, impose a 90-day time period over which the stress would be assumed to take place.

The relevance of each bank’s stress tests are themselves only as great as the assumptions behind them. Any analysis undertaken under assumed conditions is always at risk of inaccuracy, which is why continuous review and back-testing is also part of a bank’s risk management regime. The implication of the LCR for the world’s banks is that in theory they will have to hold, in differing amounts, a stock of theoretically genuine liquid assets. The challenge comes from the impact this will have on the bottom line, as a risk-free portfolio generates less income (if it is run at a profit at all), and so, all else being equal, a bank’s profits will reduce.

The foundation LCR calculation relates to the short-term (30-day) stressed outflow amount of a bank’s liabilities. The critical long-term metric is the net stable funding ratio (NSFR). The NSFR is designed to promote resilience over the long-term. Setting a limit for it in theory ensures that sufficient long-term funding is in place to support a bank’s balance sheet. In other words, maintaining an adequate NSFR should help considerably in ensuring a stable funding structure, because more of a bank’s liabilities will be comprised of longer-dated funding.

Setting a minimum level for term funding would reduce dependency on short-term funding, while increasing cost of business, as more liabilities are moved into longer-term funding. Again, the issue for banks is one of cost, and impact on profits. Longer-dated liabilities cost more than short-dated liabilities, and in a stressed environment are difficult to raise. The challenge for risk managers and regulators is ensuring that the spirit of NSFR, which has not yet been enshrined in formal legislation, is maintained throughout the business cycle.

ESTABLISHING A GENUINE RISK GOVERNANCE CULTURE

This article’s premise is that the cultural challenge, and its wider impact on stakeholders, especially shareholders, is a more difficult one to address than the regulation-related requirements banks have faced up to now. Nevertheless, it is imperative that this challenge be met at all levels, to ensure a greater ability to mitigate the impact of the next crash. What the current debate in banks needs to focus on is the need for a genuine, firm-wide approach to balance sheet risk. To effect this, it becomes necessary to establish the ALM committee or ALCO as the premier risk management forum in the bank, with board-delegated authority.

As we all recognise, culture is set from the top down. To remove their dependence on individuals, banks need to consider their operating model and risk infrastructure, and how exactly capital, balance sheet and liquidity are to be managed. The issues are:

- operating model and internal organisation
- risk governance infrastructure, and the risk management ‘triumvirate’ of the CRO, CFO and treasury. This must be organised so that the three constituents of the triumvirate are able to work together effectively.

The challenge is for banks to establish a cultural mindset and operating framework that embeds balance sheet risk in everyone’s thinking. In other words, something beyond the regulatory requirements set out under Basel III.

Exhibit 1 overleaf appears to state the obvious, but in fact is making a much more subtle, and potentially controversial, point. The three departments are peers, therefore the reporting line could not logically subordinate one to the other. Crucially, ALCO would have the oversight for all balance sheet risk, including credit risk policy at the high level. Any credit risk committee or CRO forum would be subordinated to it.

The logic for this is clear. As the membership of ALCO covers both front-office business line heads with profit and loss responsibilities, as well as risk management persons, it has the primary balance sheet view that an ‘Enterprise Risk Management’ (ERM) forum may not. It makes sense to make ALCO the premier risk management body.

For treasury, the reporting line is a key influencer of the extent of the risk culture. From its position in the triumvirate, treasury will need to report to the same level as the CFO and CRO. This would logically be the CEO, and such an arrangement is common.

In some cases, the reporting line is higher. One large western European bank organises the treasury function as a direct report of the board, with the group treasurer reporting in to a named non-executive director. This removes any conflict of interest issues, while ensuring that balance sheet risk management is undertaken at the appropriate level of seniority. It also clears the way for the treasurer to chair the ALCO, something that is usually undertaken by the CEO or the CFO. When one remembers that treasury is the only department in a bank that looks at the entire balance sheet, assets and liabilities, and is both inward and outward looking, this arrangement carries logic.
Exhibit 1 Bank balance sheet risk management triumvirate

ENSURING EFFECTIVE TEAMWORK

Changes in culture and operating methods are perhaps the hardest to make in any firm, including a bank. The larger the bank, the more bureaucratic the process of risk management is. In large firms, there is a danger that risk management becomes more of a forms-based box-ticking process than a genuine exercise in managing risk exposure. However, effective teamwork is essential if these teams are to work together efficiently.

One way to try to address the issues raised by a growing bureaucracy and process is to drive a culture of genuine teamwork. Exhibit 2 (top right) shows that the treasury function is a multidisciplinary one, with a diverse set of objectives and deliverables, and Exhibit 3 (centre right) illustrates the recommended team building doctrine. These are better served if members of the team are able to support each other. This is not something that can be implemented overnight. It requires experience and learned judgment, together with a genuinely open and transparent culture, to work properly. But if it can be operated successfully, it makes balance sheet risk management much easier to be implemented firm-wide, because the triumvirate of CRO, CFO and treasurer, and their teams, will be able to work much more effectively.

Eight years after the first signs of the crash, the discipline of risk management and the need to have a rigorous risk framework in place at all banks with respect to capital, liquidity and funding, is accepted universally. There is no disagreement with what Basel III, and national regulators, wish to implement with respect to levels of capital and liquidity.

The real challenge comes with the need to embed a genuine risk management culture in the bank. If this is successful, it will ensure that principles of balance sheet risk are adhered to throughout the cycle, particularly when bull market conditions return. A change in operating model style and firm culture, to one of genuine openness and understanding, will help to ensure that this becomes the case.

CONCLUSION

Liquidity management is a discipline that is as old as banking, but from historical observation we conclude that its principles need to be refreshed and maintained throughout the business cycle. Under Basel III, the need to adhere to old-fashioned beliefs on sound liquidity practice is something that will be enshrined in law. However, the two new funding metrics reflect banking logic, and the principles behind them should be followed regardless, simply because bank management should be aware of their importance.

Exhibit 2: Diversity of treasury deliverables

Exhibit 3: ‘Total treasury’ team building doctrine

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