Basel's Fundamental Review of the Trading Book: Implementation Principles for the Internal Models Approach

Christiaan Wessels and Gary van Vuuren*

Centre for Business Mathematics and Informatics, North-West University, Potchefstroom Campus, Potchefstroom, South Africa.

Abstract: ***Design Methodology*:** A substantial overhaul of the aggregation, measurement and assessment of trading book regulatory market risks was introduced by the Basel Committee on Banking Supervision (BCBS) in 2016. Full compliance with these rules was originally set at January 2022, but the COVID-19 pandemic has pushed this date outwards to somewhere between 2022 and 2024 depending on the jurisdiction. Using a simple portfolio of assets and tradeable securities, we simulate a worked example of the sequence of steps required to determine the market risk regulatory capital under the Basel IV FRTB's internal models approach.

***Purpose*:** While regulatory market risk rules have allowed banks to choose a standardised approach or an internal models approach since the Basel addendum introduced in 1996, the new rules are considerably more complex and discriminating. Establishing and implementing the requisite calculations for the latter approach are complex and daunting. Using a set of stylised example trades, we elucidate common pitfalls and highlight important considerations of the estimation of regulatory market risk capital.

***Findings*:** The new regulatory market risk rules are more conservative than the old, capturing risks previously unaccounted for. Most quantitative impact studies show that trading book capital will increase for most banks. This work demonstrates how to capture and calculate various risk metrics under the internal model's approach.

***Research Limitations*:** The portfolio of trades used is necessarily a non-complex, small one. The trading possibilities using real bank portfolios are endless and would only lead to deeper confusion. Using a small, stylised portfolio, comprising sensible commonly used traded assets should provide more useful and usable information than a large, complex trading book portfolio.

Practical Implications: This work explores the rules governing the internal models approach market risk capital calculations using practical, worked examples. Although simple portfolios are used, these should be useful to many banks which qualify for the internal models approach yet struggle with its innate complexity. A subsequent article will provide practical examples for banks opting for the standardised approach.

***Social Implications*:** None.

***Originality*:** Studies providing simple implementation guidance are scarce to non-existent. This work introduces and demystifies the required calculations for the internal models approach of the FRTB for the first time.

Keywords: Market risk, Value-at-Risk, expected shortfall, capital requirements, liquidity horizons, FRTB.
JEL Classification: G18, G21, G32.

1. INTRODUCTION

The original framework for market risk capital requirements emerged as an amendment (BCBS, 1996) to the Basel Committee on Banking Supervision's (BCBS) Basel I accord (BCBS, 1988). The modification adopted JP Morgan's Value at Risk (VaR) measure as the chosen market risk metric (JP Morgan, 1996). This framework was simple, comprising a standardised approach (SA) for which instrument characteristic specific risk weights – and hence market risk capital – were prescribed, and an internal models approach (IMA) which required banks to estimate their own market risk capital using risk estimates of current trading positions to protect against adverse market movements. The Basel II accord, which launched in 2008 (BCBS, 2005) replaced the 1988 Basel accord and introduced substantial changes to prevailing credit and operational risk approaches but left the market risk capital methodology unchanged.

The global financial crisis (GFC) of 2007 – 2008 revealed several weaknesses in the determination of regulatory market risk capital. Many banks found their trading book exposures

*Address correspondence to this author at the Centre for Business Mathematics and Informatics, North-West University, Potchefstroom Campus, Potchefstroom, South Africa; ORCID: 0000-0001-6811-0538;
E-mail: vvgary@hotmail.com

to be severely undercapitalised and experienced considerable losses and bankruptcies as a result (Committee on the Global Financial System, 2018). In the years following the crisis and as a stopgap attempt to better manage market risks, the BCBS launched Basel 2.5 which *inter alia* accounted for default risk in trading book positions and introduced the highly procyclical stressed VaR metric (BCBS, 2011).

In 2016, the BCBS presented a revised market risk framework (BCBS, 2016) and in 2019 further amendments were added to the final document (BCBS, 2019a). Known as the Fundamental Review of the Trading Book (FRTB) this new approach constitutes a catalogue of revisions to the market risk framework to update the now ageing market risk rules and help prevent the losses which occurred in the GFC from happening again. Because Basel 2.5 has been almost entirely supplanted by the FRTB and the FRTB (although it has been absorbed into and included as a simplified SA in the new rules) it is not discussed in detail here and only referred to where or if necessary (BCBS, 2011).

This revised framework is considerably more complex. Not only are the SA and IMAs almost entirely overhauled, but the way banks must activate either is now much more entwined and dependent upon prevailing market conditions. VaR calculations that previously used a single liquidity horizon of 10 days (deemed sufficient to exit or hedge all positions in a trading portfolio without affecting the underlying asset prices) have been replaced with a complex set of rules incorporating a spectrum of instrument-dependent liquidity horizons (five in total, ranging from 10 to 120 days, are now used). The well-established VaR metric has also been replaced[1] with the more conservative expected shortfall (ES) measure, an expected value of the change in portfolio value in the tail of the profit and loss (P&L) distribution that exceeds VaR, so ES will *always* be more conservative than VaR (by design).

Examples of how to implement these complex approaches are absent in the literature. This work aimed to explore the vagaries of the FRTB's IMA for market risk capital and provide some worked examples of the implementation thereof. We believe this will benefit many banks, particularly those used to a simpler market risk regime under Basel II.

The remainder of the article is structured as follows: Section 2 provides some background on how the FRTB revisions arose and how these changes are expected to improve the risk management for banks. Section 3 sets out the FRTB IMA methodology and explains the simple portfolios used to demonstrate the relevant regulatory market risk capital calculations. The results of the implementation of these rules follows in Section 4 and Section 5 provides recommendations for future research and improvements and concludes.

2. BACKGROUND AND DESCRIPTION

The revised minimum capital requirements for market risk were devised and instituted to address the shortcomings – exacerbated by the GFC – of the previous framework. Considerable feature changes have been made to the SA and IMA models as well as the models' approval processes. Understanding and implementing the approaches governed by this revised framework pose challenges for many banks, particularly those familiar with less onerous procedures (BCBS, 2015). The BCBS have not, as far as we are aware, provided numerical examples to guide this implementation.

Farag (2018) discussed anomalies found in both the SA and the IMA of the FRTB but averred that this may be unintentional and easily resolved through clarification or rephrasing of the FRTB text. While the anomalies vary in their impact on capital, they could lead to significant misrepresentation of risk in either direction and the authors propose simple adjustments to address these issues, which require neither recalibration nor major changes to the framework.

Pederzoli and Torricelli (2021) assessed the impact of the FRTB on capital requirements using a simplified portfolio that is sensitive to the risk factors and applies the new regulations using both the SA and IMA. The results provide an estimate of the magnitude of the increase in capital requirements under the two approaches and analyse the expected impact of the FRTB on both. Capital requirements increased significantly, particularly under the SA.

McCullagh, Cummins and Killian (2022) investigate whether the new criteria introduced by the FRTB (P&L attribution tests and desk-level back tests) could impact risk and portfolio management practices, specifically in terms of portfolio construction and choice of risk models. Although profit and loss attribution (PLA) tests require alignment with risk factors, back tests do not encourage the use of superior risk models – a finding that has significant implications for the effectiveness of the capital-based regulatory system.

2.1. Feature Changes to the Market Risk Framework

The revised framework introduced six main changes to help ensure that banks were adequately protected against market risk in the future. This section introduces each of these changes and look at what the BCBS aimed to achieve with each of them.

Revised Boundary between Banking Book and Trading Book

Banks are required to classify their assets as either trading or banking assets. Assets in the banking book are typically held to maturity, where trading book assets are regularly traded or for sale. Depending on asset classification, certain regulatory capital charges would then apply to these assets. But without a clear boundary of which assets may be classified where, banks were left with opportunities for regulatory arbitrage. In the past, banks found ways to avoid certain capital charges by moving assets between the two books. Previous amendments to the regulatory treatment of these assets failed to

[1] Artzner et al. (1999) present a critique of VaR due to its lack of subadditivity, arguing that VaR fails to satisfy the property of subadditivity, meaning that the VaR of a portfolio can exceed the sum of the VaRs of the individual assets within that portfolio. Consequently, VaR is deemed an inadequate and "incoherent" measure of risk. The issue arises because VaR is calculated as a quantile on the profit and loss distribution, rather than being based on an expectation and as a result, the shape of the tail before and after the VaR probability does not necessarily affect the actual VaR value. The existence of unrecognized violations of VaR subadditivity can lead to significant implications for risk models.

Table 1. Estimated capital Requirements Under SA Relative to IMA for Banks Currently Using the IMA.

Risk class	Median SA Market Capital Relative to Current IMA Market Capital	Banks Included in Sample
General interest rate risk	1.5	31
Credit spread risk: non-securitisation exposures	1.1	24
Equity risk	1.8	24
Commodity risk	1.6	22
Foreign exchange (FX) risk	2.2	31

clear up the confusion or vulnerability of the boundary between trading and banking assets (BCBS, 2019b). The new framework clearly demarcates the banking and trading books, removing such opportunities. The newly defined boundary specifies lists of assets or instruments that must be classified under a certain book, with banks not being allowed to deviate from these lists. Furthermore, a list of assets or instruments "presumed" to be in the trading book complement the new definitions of the banking and trading books. Banks require supervisory approval for any departures from these presumptions (BCBS, 2019a).

An Entirely Novel SA

The SA to calculating capital requirements under the BCBS's market risk framework is the alternative approach for banks or trading desks that do not qualify to use their own internal model. The exposure-by-exposure building block SA in the older framework meant that banks using it quickly found themselves with capital requirements that were much higher than expected. It has been established that the old SA was overly risk insensitive (BCBS, 2016) and somewhat outdated (given the rules governing it remained unaltered since 1996). Banks which used the old SA were required to maintain high capital requirements (BCBS, 2019b).

The new SA attempts to align capital requirements with banks' risk drivers, making it far more suitable and relevant. The trade-off made by the BCBS to introduce the new SA is that it is substantially more complex in form and function. Banks with small unsophisticated trading portfolios could face challenges when implementing this new approach. For this reason, the BCBS allowed the SA under the previous Basel 2.5 framework to remain in the revised framework as a simplified alternative to the new SA. This simplified alternative will be subject each risk class to scaling factors to ensure conservative calibration. One major change requires banks to calculate their capital requirement under the SA as a fallback, regardless of whether the IMA will be used or not. This begs the question as to whether the extra cost and effort of implementing the IMA will be worth it at all? BCBS's Quantitative Impact Studies (QIS) aimed to address such questions (BCBS, 2015).

Table **1** shows the median size of a bank's capital requirements under the SA relative to their current capital requirement for banks that use the IMA. The data which populate Table **1** were adopted from the BCBS's most recent QIS (BCBS, 2019b). Note that not all banks included in the survey are exposed to *all* risk classes within their trading books, so sample sizes vary.

Table **1** demonstrates that the IMA could still be worth implementing, especially for banks exposed to significant equity, commodity, or FX risks.

Adequate Capture of Credit Risk in Trading Positions

VaR (and hence regulatory market risk capital) under the old SA and IMA did not account for the risk of default or the risk of credit rating downgrades in banks' trading positions (BCBS, 2019b). The introduction of a default risk charge (DRC) aims to capture credit risk in these trading positions effectively, robustly, and consistently. The DRC has been introduced in the form of a VaR calculation with a 99.9% confidence interval.

Change in Risk Measure from VaR to ES

The well-known risk measure, VaR, has been a part of the market risk framework since 1996. As a frequency measure, it captures the largest possible loss over a period for a given probability on a portfolio of assets. One of VaR's major drawbacks is that it informs little about the possible magnitude of the possible loss beyond the confidence level (Visser and van Vuuren, 2016). This led the BCBS to replace the long-standing measure with a measure of severity in the form of ES. ES captures tail risk more effectively than VaR as it accounts for both the size and the likelihood of the losses. As ES is intrinsically more conservative than VaR, so the BCBS mandates a confidence level for ES to be beyond $VaR_{97.5\%}^{10d}$ (compared with the previous approaches which used $VaR_{99.0\%}^{10d}$ as the relevant metric) (BCBS, 2019a).

Factoring in market illiquidity risk

A liquidity horizon can be defined as the time it takes to exit or hedge a position without affecting its underlying price. Under the old framework, the accepted liquidity horizon for any position in the bank's trading book was fixed at 10 days. This proved to be inadequate for most banks subject to substantial trading book exposures which took far longer than 10 days (two trading weeks) to exit some positions without disrupting the market (International Monetary Fund, 2008). Moreover, the old framework's IMA employed the square-root-of-time rule as a scaling method to scale daily volatility into 1-day volatility. The square root of time rule for scaling tail risk requires the underlying portfolio return data to be independent and normally distributed, which much research has demonstrated to be flawed (some examples include Diebold, *et al.*, 1997; Jorion, 2001 and Wang, *et al.*, 2010).

The revised market risk framework recognised this shortcoming and introduced a new scaling method for ES. The ES calculation and liquidity horizon scaling are further described in Section 3. Four additional liquidity horizons were added to the familiar 10 days in the revised framework. Asset classes are now classified according to their market illiquidity risk and allocated an appropriate liquidity horizon, for example, large-cap equities are now subject to 10-day unwind horizons (as under the old regime) but credit-related securities, for example, have a liquidity horizon of 120 days. This addition recognises and penalises banks for holding excess illiquid assets. The full risk factor categorisation from the BCBS is listed in the appendix.

Risk-reducing Effects of Hedging or Diversification

The Basel 2.5 amendments to the market risk framework provided unconstrained diversification and hedging benefits for all IMA asset classes. This meant that asset classes that showed strong correlations in favour of diversification from historical data would have led to substantial reductions in capital charges (BCBS, 2019b). The global financial crisis demonstrated how these benefits could swiftly disappear, leaving banks once more undercapitalised (BCBS, 2019b). The revised framework introduces a limit to the diversification or hedging benefits that a bank may allow for when calculating the internally modelled capital charge.

2.2. Model Approval Process

The BCBS has moved away from a bank-wide model approval process to a more granular, trading desk-level process for both SA and IMA. This means that each trading desk requires approval to use the IMA even if the bank has acquired this approval. Unapproved trading desks must fall back to the SA to calculate their capital requirements. Furthermore, the profit and loss (P&L) attribution test has been introduced to enhance the validation process. This test determines whether the bank's IMA could measure the risks that drive the daily returns comprehensively (BCBS, 2019b). Fig. (**1**) illustrates this model approval process. Table **A1** in the appendix sets out the principle differences between the current (2023) BCS market risk capital requirements approach and the FRTB approach.

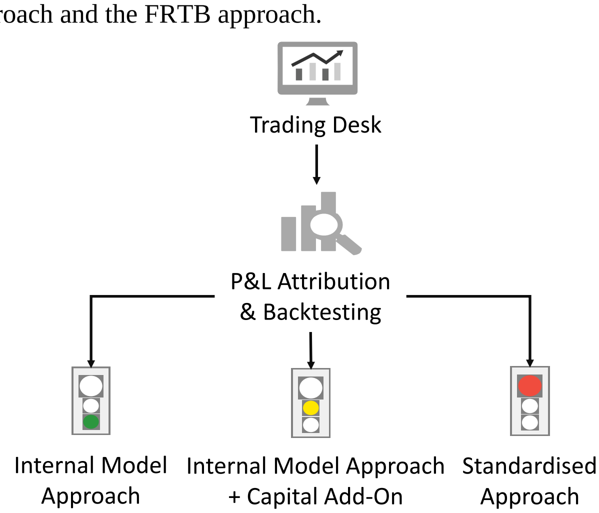

Fig. (1). Model approval process.

2.3. IMA

The IMA comprises three parts: the modellable risk factors, the non-modellable risk factors and the DRC. The BCBS defined a modellable risk factor to be a risk factor for which a sufficient reliable history of observations exists (BCBS, 2019a). Fig. (**2**) illustrates this approach under the BCBS's green light.

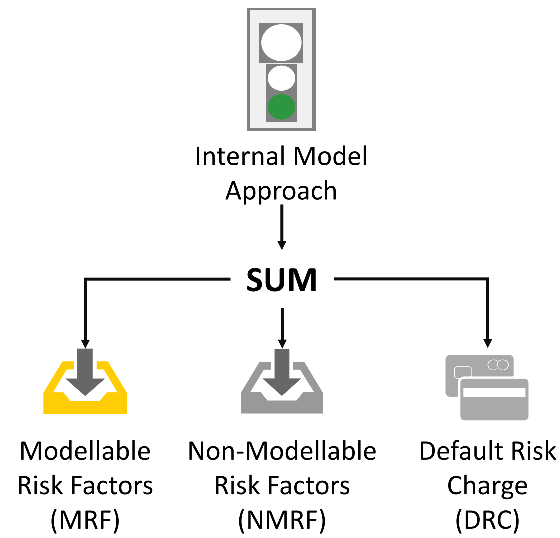

Fig. (2). The FRTB's IMA.

The risk factor eligibility test (RFET) distinguishes between modellable and non-modellable risk factors. Under the revised framework, a risk factor is considered modellable if sufficient real prices that represent the risk factor can be identified (BCBS, 2019a). Risk factors that do not have enough reliable data to bestow 'modellable' status must be modelled under the non-modellable risk factor specifications. The BCBS requires non-modellable risk factors to be modelled separately, using the most severe period of stress over the analytical period and with limited diversification benefits. This inflates the capital charge with the aim of protecting against the risk of unreliable non-modellable data.

For the assembly and constitution of the simple portfolios used in this work, two key assumptions were made, namely:

1. the P&L attribution test has been passed
2. the backtesting[2] test has been passed
3. as a result of (1) and (2) above, the portfolio has been greenlighted – i.e., approved for IMA status – according to BCBS's traffic light approval process (Fig. **1**), and
4. the applicable risk factors in the portfolio have passed the RFET.

These assumptions allowed the capital requirements for certain portfolios of assets, defined in Section 4 to be modelled using the IMA with modellable risk factors.

[2] The backtesting requirements as laid out by the BCBS (2019a).

As this revised market risk framework is considerably more complex and conservative than the previous framework, some bank struggle with the implementation of the new rules. The next section sets out the portfolio construction and methodology used.

3. METHODOLOGY

3.1. Portfolio Construction

Before any risk measures could be calculated or compared, a portfolio of assets was first required on which the calculations would depend. Simple vanilla instruments (including derivatives, but not *exotic* derivate securities) which constitute typical trading books were selected.

General interest rate risk (GIRR) and foreign exchange (FX) risk classes make up large parts of the trading book for many banks. Asset classes such as equities and commodities were also included to ensure a balanced variety of assets in each portfolio.

Since the Basel 2.5 reforms were introduced in 2009, banks were required to calculate their market risk capital requirements under a period of significant market stress (BCBS, 2009). Expert opinions and analysis suggest that the typical stress period used for market risk calculations remains the GFC of 2007 – 2008. The period of most severe market stress used was Jul-08 – Jun-09 (i.e., the most turbulent market conditions between 2007 and 2022). The 'current period' refers to the most recent 12 months of data used for risk measure calculations.[3]

To properly assess the impact of the new liquidity horizons in the market risk framework, two artificial portfolios were constructed containing instruments spanning multiple asset classes. The main difference between these two portfolios was the average liquidity of the assets included, leading to a variety of different applicable liquidity horizons when scaling the ES risk measure. Table **2** shows the breakdown of the two portfolios, including assets, weights, and liquidity horizons. Both portfolios were assigned a total portfolio size of 10,000,000. Portfolio 2 was constructed to include assets with horizons longer than the familiar 10 days. Instead of adding listed equity shares to the portfolio, a generic market index was used to represent equity holdings in both portfolios. The JSE ALSI (Johannesburg Stock Exchange, ALL Share Index) offers a holistic representation of the South African equity market, for example, over both current and stressed market periods. Risk factor categorisation used to assign liquidity horizons to the positions is presented in the appendix. These data were selected to represent a developing economy marketplace and thus to explore the impact of the FRTB implementation in such a milieu.

[3] In this article, the "current period" is defined to be the 2019 calendar year. Removing any of the 2020 market movements from the analysis ensures that adverse market movements caused by the COVID-19 pandemic do not distort the analysis or comparison between risk measures such as VaR and ES. Studying the COVID-19 pandemic as a viable alternative for a 12-month period of market stress is relevant but falls outside the scope of this work.

Table 2. Portfolio Breakdown (More Details Provided in Table A2 and A3 in the Appendix).

Portfolio 1			Portfolio 2		
Asset	**Weight**	**Liquidity horizon (d)**	**Asset**	**Weight**	**Liquidity horizon (d)**
Equity shares: ALSI	10%	10	Equity shares: ALSI	5%	10
Commodity cash position: Brent Crude	18%	20	Commodity future contract: White Maize	12%	60
Commodity cash position: Gold	7%	20	Commodity cash position: Gold	8%	20
FX spot position: USDZAR	30%	10	FX spot position: BWPZAR	15%	20
FX spot position: EURZAR	32%	10	FX spot position: NZDZAR	10%	20
FX European call option: GBPZAR	3%	40	FX European call option: USDZAR	5%	40
			Interest Rate Swap: Fixed/JIBAR	23%	20
			Interest Rate Swap: JIBAR/Fixed	22%	20

3.2. Valuations

Market data were sourced from Refinitiv's financial information tool, Eikon, with the only exception being the white maize futures data, sourced from the Johannesburg Stock Exchange (JSE). Data cleaning ensured:

- a constant day count convention for all constituents and
- aligning market prices on dates throughout the current and stressed 12-month periods.

All constituents were valued under both current and stressed market conditions. For assets like equity shares, commodities or FX spot positions, stress period valuations involved taking the market price at the start of the current 12-month period and applying the daily price variations from the defined stress period. The resulting price path represented the asset's daily movements if the market were under substantial stress.

European call options were valued using the Black-Scholes option pricing model. Two of the Black-Scholes parameters being stressed during this calculation, namely the underlying asset price and asset volatility. Because the asset volatility is a risk factor in determining the value of the asset, the applicable liquidity horizon for these options increases from 10 days to 40 days according to Table A4 in the appendix.

Interest rate swaps included in the second portfolio were the only assets not valued from first principles. The valuations of these swaps were carried out using third party software. Valuing these swaps under stressed market conditions required the swap curves and discount curves used in the valuation to be stressed (accomplished using the applicable curves from the defined stress period in the valuation, resulting in the swap value being representative of stressed market conditions).

After assets were valued, daily and 10-day profit & loss (P&L) values were generated on which the risk measures would be calculated. The old framework for IMA market risk used the daily P&L values and the square-root-of-time rule to achieve a 10-day risk measure, whereas the revised framework uses 10-day rolling P&L values and a new liquidity scaling method.

3.3. Risk Measure Calculations

Three risk measures were calculated and compared to assess the impact that the revised market risk framework could have on banks: VaR, Stressed VaR and ES. As the BCBS does not prescribe a best-practice method for calculating these risk measures, all calculations were done under both the historical simulation and variance-covariance approaches. This allowed a comparison to be made for these measures and an analysis of the impact on capital requirements.

Table **3** shows the differences between the original framework, Basel 2.5 amendments and the revised framework under the IMA. All three risk measures were calculated for each asset class individually and for the portfolio, under both historical simulation and variance-covariance approaches. VaR and SVaR both require square-root-of-time scaling to a 10-day unwind period under the older frameworks, whereas the newly introduced ES also has a revised scaling method for scaling each asset to its applicable liquidity horizon.

Table 3. Comparison between the existing and revised market risk frameworks under IMA.

	Original Framework	Basel 2.5 Amendments	Revised Framework
Risk measure	VaR	Stressed VaR	ES
Confidence level	99%	99%	97.5%
Data period	Most recent 12-month period	12-month period of stressed market conditions	12-month period of stressed market conditions
Liquidity scaling method	Square-root-of-time scaling	Square-root-of-time scaling	Revised scaling method

ES Under the Revised Market Risk Framework

The ES measure under the revised framework was calculated using a base liquidity horizon of 10 days, as prescribed by the BCBS (BCBS, 2019a). This base horizon was obtained by using rolling 10-day P&L values over a 12-month period in the calculation of ES. This meant that for 250 values over 12 months, a total of 240 P&L values could be generated. From the base horizon, each position in the portfolio was then scaled to its applicable liquidity horizon using (1):

$$ES = \sqrt{\left(ES_T(P)\right)^2 + \sum_{j \geq 2}\left(ES_T(P,j)\sqrt{\frac{LH_j - LH_{j-1}}{T}}\right)^2} \quad (1)$$

(BCBS, 2019a) where

- *ES* is the liquidity-adjusted ES, i.e., the ES adjusted for the various time horizons of different instruments
- T is the length of the base liquidity horizon, $T = 10$ days;
- $ES_T(P)$ is the 10-day ES of portfolio *P*, with positions $P = (p_1, p_2, \dots, p_i)$, with shocks to all the positions in P;
- $ES_T(P,j)$ is the 10-day ES of portfolio *P*, with positions $P = (p_1, p_2, \dots, p_i)$, with shocks to each position in P with risk factors in the subset $Q(p_i, j)$: all other positions excluded;
- $Q(p_i, j)$ is a subset of risk factors for which liquidity horizons, as specified in Table A4 in the appendix, are at least as long as LH_j according to the table below;
- LH_j is the liquidity horizon *j*, with lengths:

j	LH_j
1	10 days
2	20 days
3	40 days
4	60 days
5	120 days

A Worked Example

An example is now employed to better illustrate the workings of the new liquidity horizon scaling formula. Consider a small portfolio of assets comprising three positions:

- a spot position in the USDZAR exchange rate;
- a spot position in the NZDZAR exchange rate; and
- a European call option on the GBPZAR exchange rate.

This portfolio exclusively contains instruments from the FX risk class, but each position would have a different liquidity horizon applied to it. According to Table A4 in the appendix, the first position is specified to have a 10-day horizon. The second position is not listed in the specified currency pairs, and so the position will be classified to have a 20-day liquidity horizon. The third position is a derivative that takes volatility into account when valuing the position, the assigned liquidity horizon will thus be 40 days. As no positions have an assigned liquidity horizon of longer than 40 days, the scaling formula will only include three terms. Applying the scaling formula in (1), yields the following result:

$$ES_{FX} = \sqrt{\left(ES_{10}^{10,20,40}\right)^2 + \left(ES_{10}^{20,40}\right)^2 . \frac{20-10}{10} + (ES_{10}^{40})^2 . \frac{40-10}{10}}$$

$$ES_{FX} = \sqrt{\left(ES_{10}^{10,20,40}\right)^2 + 1 \cdot \left(ES_{10}^{20,40}\right)^2 + 2 \cdot (ES_{10}^{40})^2} (2)$$

The first term in (2) scales all three positions to a 10-day liquidity horizon. After this, only the second and third positions require further scaling. The second term then scales the second and third positions to a further 10 days, bringing the second position up to its defined liquidity horizon. The third term then scales the last position, the derivative, to a further 10 days, but includes a scaling factor of 2. The result leaves all the positions scaled to their required liquidity horizons.

Reduced Sets of Risk Factors

The ES must also be calibrated to a period of stressed market conditions. The BCBS allowed banks to follow an indirect approach to this calibration using reduced sets of risk factors. The BCBS specified that these reduced sets should have sufficiently long observation histories and would be subject to supervisory approval (BCBS, 2019b). Another specification was that the reduced sets of risk factors should be able to explain at least 75% of the variance of the full set of applicable risk factors. This meant that the ES calculation using the reduced set of risk factors should at least be 75% the size of the ES under the full risk factor set. The ES under the revised market risk framework is thus:

$$ES = ES_{R,S} \times \frac{ES_{F,C}}{ES_{R,C}} (3)$$

where

- $ES_{R,S}$ is the ES measure with a reduced set of risk factors under stressed market conditions;
- $ES_{R,C}$ is the ES measure with a reduced set of risk factors for the current market conditions; and
- $ES_{F,C}$ is the ES measure with a full set of risk factors for the current market conditions.

The BCBS recognised the computational burden that the new ES-based capital requirement with liquidity horizon scaling would place on banks daily. Although banks would have to calculate the $ES_{R,S}$ and the ratio of $\frac{ES_{F,C}}{ES_{R,C}}$ every day, they conceded that the ES for individual risk classes could be updated on a weekly basis (BCBS, 2018). This reduced the daily number of required ES calculations under the revised framework from 63 to 15. Because of the small size and simplicity of the portfolios used in the example calculations, there was no need to specify a reduced set of risk factors. The full set of applicable risk factors were used.

Aggregate Capital Requirement Calculation

The Internally Modelled Capital Charge (IMCC) is given below as the weighted average of the constrained and unconstrained ES calculations (BCBS, 2019b):

$$IMCC = \rho\big(IMCC(C)\big) + (1-\rho)\left(\sum_{i=1}^{B} IMCC(C_i)\right) (4)$$

where

- $IMCC(C)$ is the ES of all modellable risk factors included in portfolio P, with no constraints on cross-risk class correlations;
- $IMCC(C_i)$ is the ES of each of the broad regulatory risk classes (equity risk, commodity risk, foreign exchange risk, interest rate risk and credit spread risk) individually;
- B is the number of risk classes that the portfolio P is exposed to; and
- ρ is the weight assigned to the unconstrained $IMCC(C)$, currently 0.5.

By averaging the constrained and unconstrained ES calculations in **Error! Reference source not found.**4), the BCBS introduced an upper limit on the diversification or hedging benefits that a bank may allow for in calculating their aggregate capital requirement for market risk. The unconstrained ES allows for any hedging or diversification benefits, whereas the sum of the partial ES calculations for each risk class constrains these benefits. This achieves the BCBS's objective of restraining the recognition of hedging or diversification benefits that could disappear under stressed market conditions, as explained in Section 2. The initial value for ρ is set at 50% but could be subject to change under different local jurisdictions.

4. RESULTS

VaR and ES measures from both the older and revised market risk methodologies are compared and analysed under both the historical simulation and variance-covariance approaches. The market data used as model input were mainly sourced from Refinitiv's Eikon tool, with the only exception being the white maize futures price history that was sourced from the JSE. The valuations, risk measures and resulting capital requirements were all calculated using the R programming language.

4.1. Data Preparation

The data preparation phase comprised gathering, cleaning, and formatting input data. Pearson asset correlation matrices were calculated for both portfolios during data preparation. The correlations between the different assets changed considerably in some cases, proving the BCBS's point that some

Table 4. Combined Pearson Correlation Matrix of Portfolio 2.

	ALSI	Maize Future	Gold	BWPZAR	NZDZAR	USDZAR Option	IRS1	IRS2
ALSI	**1**	-0.32	-0.04	-0.04	-0.01	-0.24	-0.1	0.18
Maize Future	0.53	**1**	0.03	-0.06	0.05	0.08	-0.27	0.02
Gold	0.18	-0.14	**1**	0.61	0	0.24	-0.42	0.76
BWPZAR	-0.61	0.11	-0.37	**1**	0.57	0.84	-0.18	0.47
NZDZAR	0.16	0.57	-0.44	0.47	**1**	0.69	0.06	-0.06
USDZAR Option	-0.74	0.02	-0.44	0.93	0.38	**1**	-0.13	0.22
IR Swap 1	0.66	0.32	0.36	-0.51	0.1	-0.59	**1**	-0.73
IR Swap 2	-0.75	-0.49	-0.27	0.45	-0.28	0.56	-0.96	**1**

Fig. (3). (**a**) ALSI asset valuation and (**b**) USDZAR asset valuation.

diversification benefits can and do swiftly vanish under stressed market conditions (BCBS, 2019a).

Table **4** shows the Pearson correlation matrix for all assets in Portfolio 2. The upper triangle of the matrix reflects the correlations under the defined current period (calendar year 2019), with the lower triangle represents these correlations under the stressed period (12-month period of Jul-08 – Jun 09).

4.2. Portfolio Valuations

All the positions were valued under both the current and stressed market conditions. The 12-month period of stressed market conditions used was Jul-08 – Jun-, a common stress period choice for regulatory purposes as it reflects the most severe consequences of the global financial crisis.

For most instruments, market values were readily available using non-proprietary price databases such as Refinitiv's Eikon, which meant that for the current period, their values were equal to their market value. Value under the stressed period were estimated by applying the daily price variations that occurred under the stressed period to their current market price. For derivatives such as options or interest rate swaps, both current and stressed market values were calculated. Some positions' values such as the equity shares in the ALSI decreased noticeably under stressed market conditions. Fig. (**3a**) shows the ALSI asset valuation under both the current and stressed periods.

Others such as the USDZAR exchange rate saw the ZAR weaken in relation to the US dollar when applying the stressed market conditions. These different reactions to the stressed conditions meant that some positions yielded bigger profits under the stressed period, while others showed significant losses. Fig. (**3b**) shows the USDZAR asset valuation under both periods.

These opposing reactions would then impact the total P&L of the portfolio over the 12-month period, depending on the weights assigned to them. As we calculate the different risk measures from the P&L data, these differing reactions to the stressed market conditions showed to have a big impact on the final capital requirement calculations.

After valuing all the assets in both portfolios, the P&L data could be calculated for the individual asset classes and the

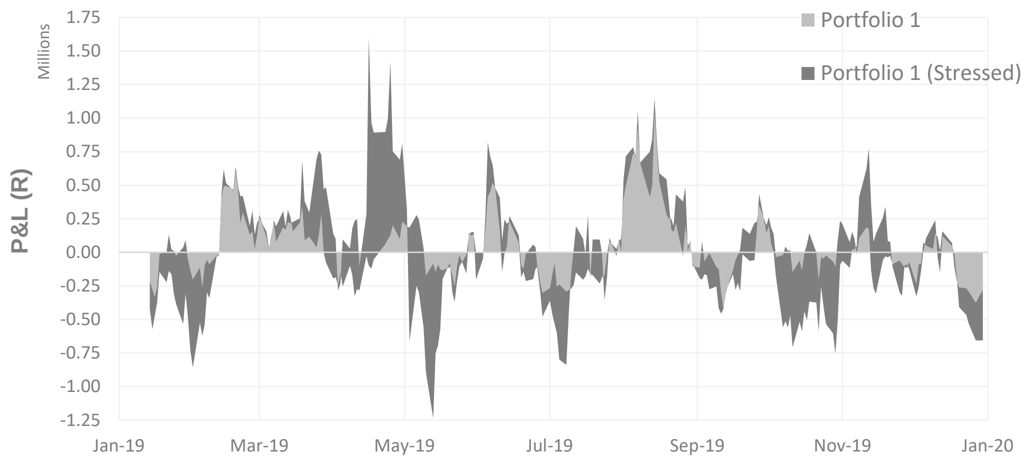

Fig. (4). P&L of Portfolio 1: current vs stressed period.

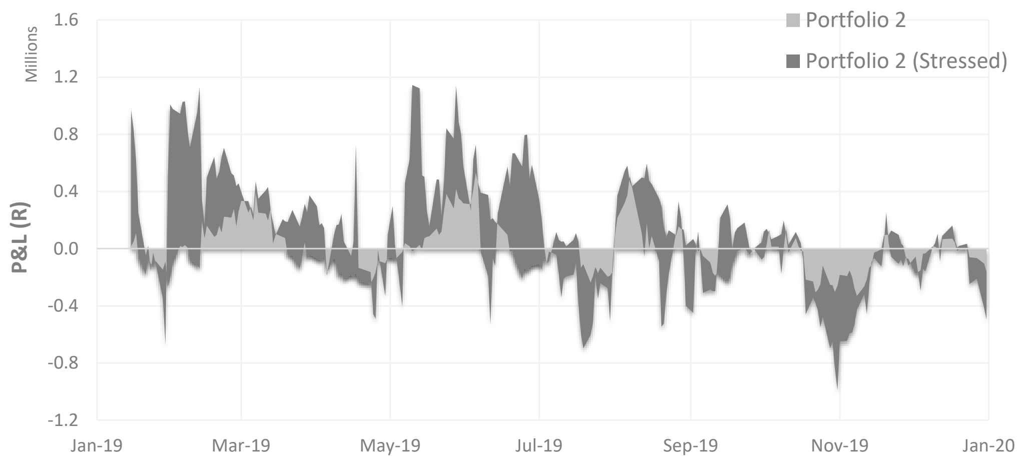

Fig. (5). P&L of Portfolio 2: current vs stressed period.

portfolio. The P&L calculations for Portfolio 1 under both the current and stressed periods are shown in Fig. (**4**).

Fig. (**4**) shows the effect of the stressed market conditions when compared against the current period. The P&Ls of the portfolio become more volatile under the stressed market conditions, as expected. Substantial losses are also more frequent under the stressed period. This strengthens the BCBS's point that banks should hold enough capital to protect themselves during these adverse conditions, and not merely under normal market conditions. Conversely, the second portfolio's P&Ls tell a different story. Fig. (**5**) shows the second portfolio's P&L for both the current and stressed 12-month periods.

For Portfolio 2, the stressed period again showed higher volatility of the P&Ls, but this time most of the volatility came in the form of profits, and not losses. This was mainly due to the interest rate risk and FX risk classes performing well under the stressed period. These classes constitute 75% of the second portfolio.

The BCBS specified in the revised framework that banks should identify and use the 12-month period where its trading portfolio experienced the largest loss (BCBS, 2019b). Banks holding a wide variety of different asset classes could also see their capital requirement impacted by the different reactions to the application of the stressed period for different assets.

4.3. Risk Measures and Capital Requirements

A breakdown of the capital requirement calculations under the revised framework follows below. The ES calculations shown in Tables **5**, **6** and **7** are those made using Portfolio 2, the larger and more diverse portfolio. The results in Tables 8 and 9 compare the risk measures and capital requirements under both the older and revised market risk frameworks. These results are shown for both portfolios, as the impact of the longer liquidity horizons of Portfolio 2 can be compared against the shorter horizons of Portfolio 1. The historical simulation approach or a variant of it is the most widely used risk measure forecasting approach in the commercial banking industry (Escanciano and Pei, 2012). For this reason, the calculations shown in this section were made using the historical simulation approach. The whole process was repeated under the variance-covariance approach with the normal distributional assumption.

Table **5** (using (4)) shows the impact that the scaling to longer liquidity horizons in the portfolio has, compared to a 10-day risk measure as under the older frameworks. The general

Table 5. Liquidity Horizon Scaling Impact.

	Capital Requirement	% of Portfolio
10-day 97.5% ES	295,957	2.96%
Liquidity adjusted 97.5% ES	1,050,868	10.51%

Table 6. Constrained ES.

	Capital Requirement	% of Portfolio
97.5% ES: Equity	80,618	0.81%
97.5% ES: Commodity	411,426	4.11%
97.5% ES: FX	521,301	5.21%
97.5% ES: IR	975,058	9.75%
97.5% ES: Constrained	1,988,403	19.88%

Table 7. Internally Modelled Capital Charge (IMCC).

	Capital Requirement	% of Portfolio
97.5% ES: Unconstrained	1,050,867	10.51%
97.5% ES: Constrained	1,988,403	19.88%
IMCC	1,519,635	15.20%

Table 8. ES vs SVaR for Portfolio 1.

	97.5% Liquidity Adjusted ES	% of Portfolio: ES	99.0% 10-day SVaR	% of portfolio: SVaR
Equity	161,236	1.61%	183,241	1.83%
Commodity	591,097	5.91%	415,022	4.15%
FX	827,899	8.28%	839,544	8.40%
IMCC	1,228,065	12.28%	965,967	9.66%

Table 9. ES vs SVaR for Portfolio 2.

	97.5% Liquidity Adjusted ES	% of Portfolio: ES	99.0% 10-day SVaR	% of portfolio: SVaR
Equity	80,618	0.81%	91,620	0.92%
Commodity	411,426	4.11%	226,604	2.27%
FX	521,301	5.21%	456,653	4.57%
Interest Rate	975,058	9.75%	892,727	8.93%
IMCC	1,519,636	15.20%	917,842	9.18%

expectation after the BCBS's quantitative impact study is for the capital requirements to increase in comparison to the older frameworks (BCBS, 2019a). This result shows the weight of contribution that the newly introduced liquidity horizons could have on this expected increase in capital requirements.

The constrained ES is defined as the simple sum of the individual ES calculations per broad asset class. Summing over the individual asset class ESs restrict the recognition of cross-risk class diversification benefits, while still allowing for diversification or hedging benefits inside each asset class. The relative size of the capital requirement under each asset class is related to the weight assigned to the asset class during the portfolio construction process. Table **6** shows these calculations (using (4)), as performed on Portfolio 2.

The final IMCC under the revised framework is then calculated as the average (ρ = 0.5) of the constrained and unconstrained ESs (Table **7**, using (4)).

A comparison between the capital requirement calculations under the older and revised market risk frameworks was drawn for both portfolios. Tables **8** and **9** show the 97.5% liquidity adjusted ES and 99% SVaR for each asset class individually and the final capital requirement.

Table 10. SRTR vs 10-Day P&L Risk Measures.

	97.5% 10-day ES using 10-day P&Ls	99% 10-day SVaR using SRTR	99% 10-day SVaR using 10-day P&Ls
Equity: Portfolio 1	1.612%	1.832%	1.606%
Equity: Portfolio 2	0.806%	0.916%	0.803%
FX: Portfolio 1	8.279%	8.395%	6.833%

Table 11. IMCC Comparison between Approaches to Risk Measure Calculations (Portfolio 2).

		97.5% liquidity adjusted ES (as % of portfolio)	99% 10-day SVaR (as % of portfolio)	99% 10-day VaR (as % of portfolio)
IMCC under	**Historical simulation**	15.20%	9.18%	5.14%
	Variance-covariance	20.35%	10.97%	3.96%

Under the older framework's SVaR measure, capital requirements decrease from 9.7% to 9.2% from portfolio 1 to 2. The revised framework's ES calculation, however, increases from 12.3% to 15.2%. This increase reiterates the great impact of the longer liquidity horizons of Portfolio 2 on the capital requirement.

The equity risk class is a case where the older framework calculation yielding a higher capital requirement for both portfolios. The same result came in the FX class of Portfolio 1. Table **2**, shows that these cases (in Portfolio 1) had the shortest average liquidity horizons at 10.0 days or 11.4 days for equity and FX classes respectively. This means that minimal to no scaling was applied to these risk classes when calculating the capital requirement under the revised framework. Wang *et al*. (2010) showed that using the SRTR for scaling VaR can result in an overestimation of risk when the data exhibit volatility clustering, serial dependence or heavy-tailed distributions. The difference between the 10-day SVaR using SRTR, 10-day SVaR using 10-day P&Ls, and the liquidity adjusted ES for the equity and FX risk classes are shown in Table 10. This shows that the SRTR overestimated the risk in all three cases, increasing the SVaR measure past the ES at a 97.5% confidence level.

Other cases in Tables **8** and **9** show the liquidity adjusted ES being significantly higher than the older framework's SVaR for classes with horizons longer than 10 days. The biggest increase was seen in the commodity risk class with an average horizon of 20 and 44 days for portfolios 1 and 2 respectively.

4.4. Historical Simulation vs Variance-Covariance Approaches

In calculating these risk measures under both the historical simulation and variance-covariance (VCV) approaches, we were able to analyse the impact that the choice of approach would make on a bank's final IMCC calculation. The VCV approach is a parametric approach, wherein an assumption about the distribution of losses was required. In our case, we assumed the loss distribution for both portfolios to follow the Normal distribution. On the other hand, the historical simulation approach did not make any assumption regarding this loss distribution but rather estimated it using the empirical distribution of past data.

Table **11** compares the IMCC calculation under older and the revised frameworks for Portfolio 2 under both approaches. Note that the ES for the revised framework as well as the SVaR measure from the Basel 2.5 amendments used the stressed market period for the calculation, whereas the standard VaR from the original framework made use of the current period.

McNeil and Frey (2000) proved that the normal assumption often underestimates the tails of loss distributions in financial time series. They found the tails of these distributions to generally be more leptokurtic or heavy-tailed than the normal distribution.

Further analysis showed that applying the market stresses of the period Jul-08 – Jun-09 did significantly increase the volatility of the price movements, but these larger movements came mostly in the form of profits rather than losses. This meant the empirical distribution of the loss tail was not affected to the same degree, under the historical simulation approach, as the profit tail when applying these market stresses. On the other hand, the VCV approach applied the increase in standard deviation to the whole of the distribution when calculating the risk measures, thus increasing the size of the loss tail and subsequently the size of the IMCC. Fig. (**5**) for portfolio 2 showed the difference between the current and stressed 12-month period used in these calculations. The stressed period did have higher price volatility, but large losses were not as frequent as large profits.

The BCBS specifies that banks should identify a common stress period for all modellable risk factors on which their trading book observed the largest loss in a 12-month period (BCBS, 2019b). This ensures that the stress period chosen reflects the period where the empirical tail distribution of losses for the bank's specific trading book would be the most leptokurtic.

5. CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

The revised framework for market risk brings a whole array of changes to the way banks measure and manage risk in their trading book. This work focused on investigating the impact of changes to the IMA under the Minimum Capital Requirement for Market Risk, the new framework proposed by the BCBS and due for implementation from the start of

2023. These changes included the retirement of VaR for a severity measure, ES, and the introduction of various liquidity horizons for assets held in the trading book. A change in the recognition of the risk-reducing effects of hedging and diversification also came with the revised framework, as the BCBS constrains the level of these benefits that banks may allow for when calculating their capital requirements for market risk.

After studying the market risk frameworks, the mathematics that govern them and the typical structure of trading books in South Africa, the impact of these novel changes to the framework were investigated. We calculated and compared various risk measures such as ES, VaR and stressed VaR on both the older and revised market risk framework specifications. Different methods for calculating these risk measures, namely the historical simulation approach and the variance-covariance approach, were also explored.

The reduction in confidence level from 99% down to 97.5% for the new ES calculations helped to ensure a similar risk level was maintained between the older and revised frameworks. The biggest impact on the capital requirements came from the addition of four liquidity horizons longer than the well-known 10 days. Banks holding assets that are less liquid and thus more vulnerable to adverse price movements in stress conditions could see a substantial increase in market risk capital requirement under the revised framework. The reduction in recognition of diversification or hedging benefits also led to an increase in capital requirements as expected. The BCBS does not specify a specific method for calculating these risk measures, thus the choice of method could also impact the capital requirement for banks. The non-parametric historical simulation approach proved the less conservative method for the smaller portfolios in our case.

The revised market risk framework offers a vast array of changes to the way banks protect themselves from adverse market conditions from 2023 onwards. These are just a few of the potential research expansions possible on the topic of FRTB.

Size, Complexity, and Diversity of the Trading Book

The portfolios used to calculate and compare the risk measures comprised less than 10 positions across four of the five possible asset classes. These positions were all held for the duration of the current 12-month period through to maturity. No reduced sets of risk factors were used as the assumed size of the trading book was negligible.

Increasing the size, complexity and diversity of the trading book used in the analysis of the revised framework for market risk could give a more holistic view of the impact that the feature changes could have on a bank’s capital requirements. As banks typically have large trading books consisting of various instruments and derivatives that are traded daily, increasing the size and complexity of the trading book when analysing these frameworks could yield some interesting results. The inclusion of reduced sets of risk factors would not only significantly ease the daily computational burden but could also prove to have an impact on the size of the capital requirements under the revised framework.

Stress Period Classification

The 12-month period of stressed market conditions used was defined as Jul-08 – Jun-09. This is a common stress period choice for regulatory purposes as it reflects the most severe consequences of the global financial crisis. In 2020 however, several articles such as Baker, *et al*. (2020) and Shehzad, *et al*. (2020) have concluded that the COVID-19 pandemic which commenced in Mar-20 caused unprecedented global market volatility. As the BCBS requires banks to identify a common bank-wide stress period under which the market risk capital requirements should be calculated, it would be interesting to assess whether the pandemic of 2020 could surpass the GFC as a common stress period for banks.

IMA

Under the revised market risk framework, the BCBS enhanced the model approval process that determines if a particular trading desk is eligible to use the IMA. These enhancements include the validation tests that a bank’s models must pass to gain this eligibility. The profit and loss attribution is a test to determine if a bank’s internal model can comprehensively measure the risks that drive the daily P&Ls of the particular trading desk (BCBS, 2019a).

The model approval process of Fig. illustrates the revised traffic light approach under the FRTB framework for market risk. The BCBS altered the binary pass/fail approach from previous frameworks to include an 'amber light' category. Trading books that fall under this category may still use the IMA to calculate their capital requirements, with the addition of a capital charge add-on (BCBS, 2019b). Furthermore, the revised IMA recognises the uncertainty of modelling risks for which there are insufficient observable market data. Risk factors that are deemed ‘non-modellable’ are then excluded from the ES calculation, with their capital requirement being calculated by means of a stress test instead (BCBS, 2019a). The introduction of four longer liquidity horizons alongside the familiar 10-day horizon al-lows the ES calculation to incorporate mitigation risk, but default risk required a separate measurement. The new DRC is calculated using a VaR model with a 99.9% confidence level and a 12-month time horizon (BCBS, 2019b).

All changes to the capital requirements for market risk framework were excluded from the scope of our project. Investigating the impact that these changes could have on the capital requirements alongside the factors we measured could provide a better understanding of exactly what would be expected of banks in the future. As the deadline for implementation of the revised framework is fast approaching, this type of expertise and knowledge could prove valuable for banks in South Africa and globally.

Standardised Approach

Trading desks that fail the model approval process, need to revert to the SA for the calculation of their market risk capital requirements. This approach, too, has been overhauled since the Basel 2.5 amendments, in which the SA was left largely unchanged since the initial framework published in 1996 (BCBS, 2019a). The revised SA was designed to be more sensitive to the risks that drive a bank’s trading book. The new sensitivity-based method is used to estimate the loss that a bank would suffer under a defined stress scenario. Banks need to calculate their capital requirements under the SA as a fallback, regardless of whether they are eligible to use the IMA. This begs a question to the data and resource intensity that this approach requires, and whether the additional effort and cost the IMA entails would be worth it for South African banks?

LIST OF ABBREVIATIONS

ALSI	=	All Share
BCBS	=	Basel Committee on Banking Supervision
DRC	=	Default Risk Charge
ES	=	Expected Shortfall
FRTB	=	Fundamental Review of the Trading Book
FX	=	Foreign exchange
GFC	=	Global Financial Crisis
IMA	=	Internal Models Approach
IMCC	=	Internal Models Capital Charge
JSE	=	Johannesburg Stock Exchange
P&L	=	Profit and loss
PLA	=	Profit and Loss Attribution
QIS	=	Quantitative Impact Study
RFET	=	Risk Factor Eligibility Test
SA	=	Standardised approach
SVaR	=	Stressed VaR
VaR	=	Value at risk
VCV	=	Variance Covriance

ETHICS STATEMENT

No animal or human studies involved – all data are non-proprietary and freely available from the internet and other non-proprietary sources

CONFLICTS OF INTEREST

The authors assert no conflicts of interest.

ACKNOWLEDGEMENTS

No funding support for the work presented was provided.

APPENDIX: RISK FACTOR CATEGORISATION

Table A1. Summary of Differences between the Current (2023) Basel Market Risk Framework and the FRTB IMA.

	Current IMA Regime (Basel 2.5)	FRTB IMA
Basic metric	99% lower-tailed VaR	ES at 97.5th percentile
Capital formula	$\max[VaR_{t-1}, m_c VaR_{avg}] +$ $\max[SVaR_{t-1}, m_s SVaR_{avg}]$ where $SVaR$ is stressed VaR	$\max[(IMCC_{t-1} + SES_{t-1}), (m_c IMCC_{avg} + SES_{avg})]$ where $IMCC$ is the internal models capital charge, and SES is the stressed ES
Multipliers	m_c, m_s $=$ min $3 +$ addons for deficient risk management and/or backtest under-performance	m_c (capital multiplier) $= min\ 1.5 +$ addons for deficient risk management and/or backtest under-performance (up to $+0.5$)
Data period	Preceding 12 months unweighted	Preceding 12 months unweighted
Stress data period	A 12-month period of "significant financial stress relevant to bank's portfolio". Approved by supervisor and regularly reviewed	12-month period that produces largest firm-wide ES from a dataset that includes 2007. Reviewed at least monthly or for significant factor/portfolio changes
Risks not in VaR		SES charge for non-modellable risk factors

Portfolio specifications

The full specifications of each position held appear in Table A2 and A3 for Portfolios 1 and 2 respectively. Each of the positions were held from the first trading day of the 2019 calendar year until maturity. The positions were all held until the end of the specified current period.

Table A2. Position specifications in Portfolio 1.

Position	Specifications	Position
Equity shares – ALSI	19.5 shares @ 51,264.06 per share	1,000,000
Cash position – Gold	93.8 ounces @ 19,187.33 per troy ounce	1,800,000
Cash position – Brent Crude	1046 barrels @ 669.70 per barrel	700,000

Call Option – GBPZAR	300,000 position @ a strike of 20 per £ Maturity of 17/01/2020	300,000
Spot position – USDZAR	3,200,000 position @ 14.457 per $	3,200,000
Spot position – EURZAR	3,000,000 position @ 16.399 per €	3,000,000

Table A3. Position specifications in Portfolio 2.

Position	Specifications	Position Size
Equity shares – ALSI	9.75 shares @ 51,264.06 per share	500,000
Cash position – Gold	41.7 ounces @ 19,187.33 per troy ounce	800,000
Future Contract – White Maize	1,200,000 position @ 2,746 per ton	1,200,000
Call Option – USDZAR	500,000 position @ a strike of 16.52 per $, maturity of 12/07/2021	500,000
Spot position – BWPZAR	1,500,000 position @ 1.351 per Botswanan Pula	1,500,000
Spot position – NZDZAR	1,000,000 position @ 9.626 per New Zealand Dollar	1,000,000
Interest Rate Swap – Fixed/JIBAR	2,300,000 position @ 13.78% swapped for JIBAR, with quarterly payments and a maturity of 18/04/2025	2,300,000
Interest Rate Swap – JIBAR/Fixed	2,200,000 position @ JIBAR swapped for 13.10%, with quarterly payments and a maturity of 24/03/2030	2,200,000

Table **A4** shows the risk factor categorisation as specified by the BCBS under the revised framework for market risk.

Table A4: Risk factor Categorisation.

j	Days	Risk Factor Categories
1	10	Interest Rate: EUR, USD, EUR, GBP, AUD, JPY, SEK, CAD and bank’s reporting currency Equity: Price (large cap) FX: Any pair of EUR, USD, GBP, AUD, JPY, SEK, CAD and bank’s reporting currency
2	20	Interest Rate: Currencies other than those specified above Credit Spread: Sovereign (Investment Grade) Equity: Price (Small Cap), volatility (large cap) FX: Currency pairs other than those specified above Commodities: Energy and carbon emissions, precious metals and base metals prices
3	40	Credit Spread: Sovereign (High Yield), corporate (Investment Grade) FX: Volatility and other risk factors (e.g., correlations)
4	60	Interest Rate: Volatility and other risk factors Credit Spread: Corporate (High Yield) Equity: Volatility (small cap), other risk factors (e.g., correlations) Commodity: Other commodities, volatility of energy and emissions, precious and base metals
5	120	Credit Spread: Volatility and other risk factors Commodities: Volatility of other commodities mentioned above

REFERENCES

Artzner, P., Delbaen, F., Eber, J. and Heath, D. 1999. Coherent measure of risk. *Mathematical Finance*, 9(3): 203–228.

Baker, S., Bloom, N., Davis, S., Kost, K., Sammon, M. and Viratyosin, T. 2020. The unprecedented stock market reaction to COVID-19. *The Review of Asset Pricing Studies*, 10(4): 742 – 758.

BCBS, 1988. International convergence of capital measurement and capital standards. Available from https://www.bis.org/publ/bcbs04a.pdf. [Accessed Aug-21].

BCBS, 1996. Amendment to the capital accord to incorporate market risks. Available at https://www.bis.org/publ/bcbs24.pdf. [Accessed Aug-21].

BCBS, 2005. International convergence of capital measurement and capital standards: a revised framework. Available at https://www.bis.org/publ/bcbs118.pdf. [Accessed Aug-21].

BCBS, 2009. Revisions to the Basel II market risk framework. Available at https://www.bis.org/publ/bcbs158.pdf. [Accessed Aug-21].

BCBS, 2011. Revisions to the Basel II market risk framework. Available at https://www.bis.org/publ/bcbs193.pdf. [Accessed Aug-21].

BCBS, 2015. Fundamental review of the trading book – interim impact analysis. Available at https://www.bis.org/bcbs/publ/d346.pdf. [Accessed Aug-21].

BCBS, 2016. Minimum Capital Requirements for Market Risk. Available at https://www.bis.org/publ/d352.pdf. [Accessed Aug-21].

BCBS, 2018. Frequently asked questions on market risk capital requirements. Available at https://www.bis.org/publ/d437.pdf. [Accessed Aug-21].

BCBS, 2019a. Minimum capital requirements for market risk. Available at https://www.bis.org/publ/d457.pdf. [Accessed Aug-22].

BCBS, 2019b. Explanatory note on the minimum capital requirements for market risk. Available at https://www.bis.org/publ/d457_note.pdf. [Accessed Sep-22].

CGFS, 2018. Structural changes in banking after the crisis. Available at https://www.bis.org/publ/cgfs60.pdf. [Accessed Dec-22].

Cran, 2020. Performance Analytics: Econometric tools for performance and risk analysis. Available from https://cran.r-project.org/web/packages/PerformanceAnalytics/index.html. [Accessed Dec 2020].

Diebold, F., Hickman, A., Inoue, A. and Schuermann, T. 1997. Converting 1-day volatility to h-day volatility: scaling by $\sqrt{h}$ is worse than you think. Discussion Paper Series, Wharton. 97(34).

Escanciano, J. C. and Pei, P. 2012. Pitfalls in backtesting Historical Simulation VaR models. *Journal of Banking and Finance*. 36(8): 2233 – 2244.

FARAG, H. 2018. A review of the fundamentals of the Fundamental Review of the Trading Book II: asymmetries, anomalies, and simple remedies. *Journal of Risk*, 20(6).

International Monetary Fund, 2008. Market and funding illiquidity: When private risk becomes public. *Global Financial Stability Report*, April.

Jorion, P. 2001. Financial Manager Handbook. New York: John Wiley and Sons, Inc.

JP Morgan, 1996. Riskmetrics technical document. Available at https://www.msci.com/documents/10199/5915b101-4206-4ba0-aee2-3449d5c7e95a. [Accessed Aug-21].

Mccullagh, O., Cummins, M., and Killian, S. 2022. The fundamental review of the trading book: implications for portfolio and risk management in the banking sector. *Journal of Money, Credit and Banking*, forthcoming. https://doi.org/10.1111/jmcb.13022

Mcneil, A. J. and Frey, R. 2000. Estimation of tail-related risk measures for heteroscedastic financial time series: an extreme value approach. *Journal of Empirical Finance*. 7(4): 271 – 300.

Pederzoli, C. and Torricelli, C. 2021. An assessment of the Fundamental Review of the Trading Book: the capital requirement impact on a stylised financial portfolio. *International Journal of Banking, Accounting and Finance*, 12(4), 389-403.

Shehzad, K., Xiaoxing, L. and Kazouz, H. 2020. COVID-19's disasters are more perilous than Global Financial Crisis: A rumour or fact? *Finance research letters*. 36(101669).

Visser, D. and van Vuuren, G. 2016. Trading book risk metrics: A South African perspective. *The South African Journal of Economics and Management Sciences*. 19(1): 118 – 138.

Wang, J-N., Yeh, J-H. and cheng, N. 2011. How accurate is the square-root-of-time rule at scaling tail risk: A global study. *Journal of Banking and Finance*. 35(5): 1158-1169

Received: June 15, 2023 Revised: June 18, 2023 Accepted: June 20, 2023