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Research Paper

The impact of the Fundamental Review of the Trading Book: evaluation on a stylized portfolio

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ABSTRACT

We investigate the impact of the Basel Fundamental Review of the Trading Book (FRTB) on banks' market risk capital requirements under the internal models approach. To do this, we take a stylized portfolio sensitive to the risk factors affected by the FRTB, representative of a typical trading book. Our assessment spans the period 2007–19. We find that the FRTB will entail sizable increases in the regulatory capital intended to absorb market shocks. These increases originate not only from the change in the risk measure and taking longer liquidity horizons (the latter having a greater impact on portfolios more focused on bonds) but also from the strict limitation of portfolio diversification benefits. Our study should be of interest

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to bank supervisors and regulators, risk managers and other decision makers within the banking industry.

Keywords: capital requirement; Basel Committee on Banking Supervision (BCBS); trading book; Fundamental Review of the Trading Book (FRTB); market risk.

1 INTRODUCTION

In response to the global financial crisis (GFC) of 2007–9 the Basel Committee on Banking Supervision (BCBS) proclaimed the Fundamental Review of the Trading Book (FRTB), with the aim of overhauling the capital requirements for market risk arising from trading activities. Capital adequacy is the cornerstone of the micro- and macroprudential regulation of banks (Farkas *et al* 2020), as supervisors seek to establish standards on the minimum capital requirements that banks need to hold to mitigate their risk exposure. The FRTB is the largest change in market risk measurement in the last 25 years.

Banks with substantial trading activity are exposed to portfolio risk, which is currently measured by value-at-risk (VaR). The FRTB has replaced VaR with expected shortfall (ES) and decreased the confidence level from 99% to 97.5% for the internal models approach (IMA) to market risk assessment, which determines the regulatory capital to be held by banks. Policy makers have concurred with higher capital requirements, particularly since the GFC (Chang *et al* 2019; Cohen 2013). The FRTB represents a significant change in the regulatory requirement policies based on regulatory guidelines published since 1998 (Campbell 2006). Under the IMA, calculations must be carried out at the trading desk level instead of the whole portfolio level.[1] Trading desks are defined by the bank but are subject to approval by the national supervisor. To qualify for the IMA, a trading desk must pass the profit-and-loss (P&L) attribution tests and satisfy backtesting requirements on an ongoing basis.[2] The process for trading desk approval within the IMA is described in Figure 1. Banks' eligibility to apply internal models is contingent on 10% of aggregated market risk capital requirements originating from IMA-approved desks (McCullagh *et al* 2023).

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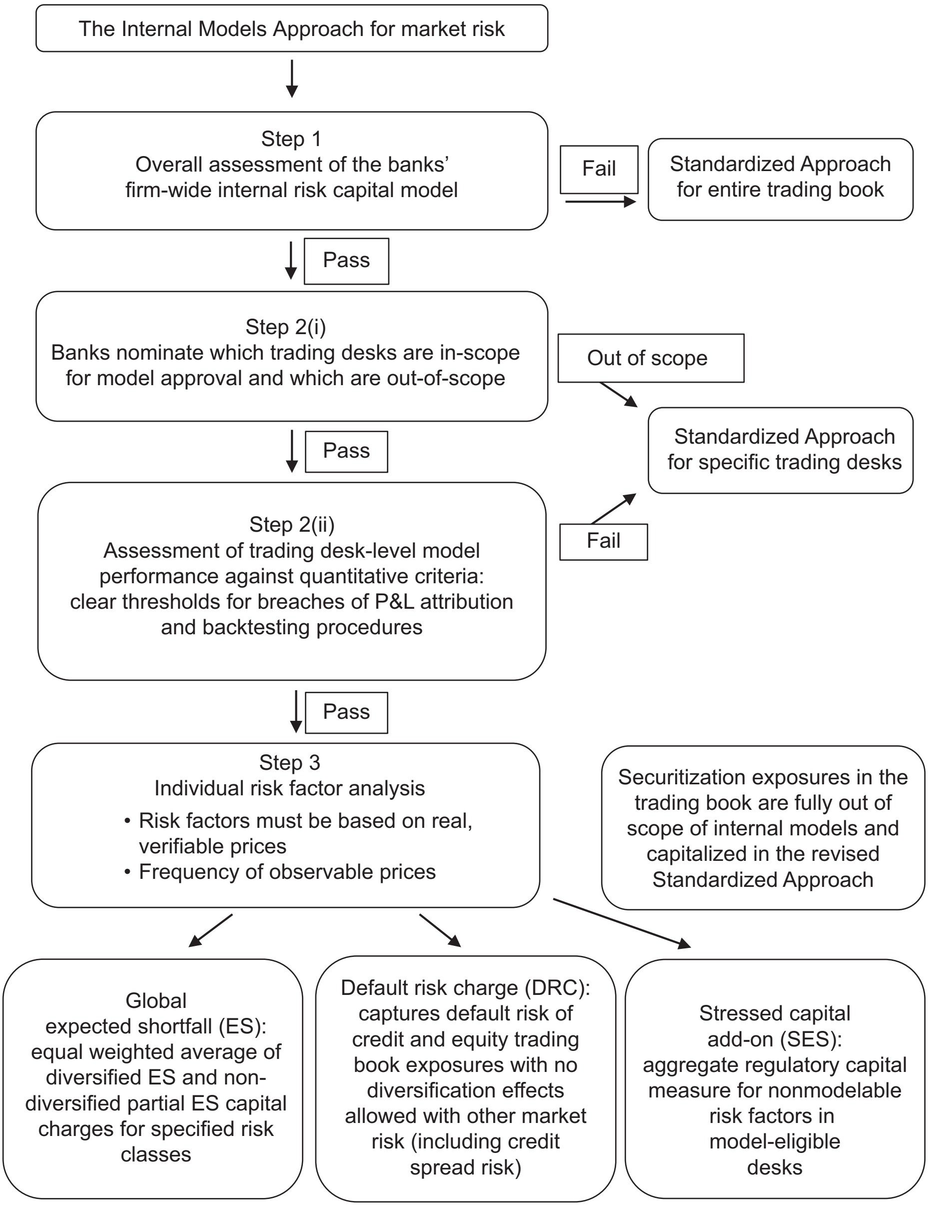
[1] The BCBS describes a trading desk as "a group of traders or trading accounts that implements a well-defined business strategy operating within a clear risk management structure" (Basel Committee on Banking Supervision 2013a, p. 25).

[2] The P&L attribution was introduced to evaluate the accuracy of the model at the trading desk level, and it compares the daily risk-theoretical P&L with the daily hypothetical P&L through the application of the Spearman correlation and Kolmogorov–Smirnov test metrics. The backtesting compares each desk's one-day VaR (for the most recent 12 months' equally weighted observations) at both the 97.5% and 99% confidence levels. There are also backtesting requirements at the overall risk model level.

FIGURE 1 Process and policy design of the IMA.



Source: data from Basel Committee on Banking Supervision (2019b).

In terms of risk management, over- or underestimation of risk has an impact on banks' profitability and credit availability (Chang *et al* 2019). The consequences of the BCBS proposals, made available in 2016, and the public consultation that followed them have attracted the attention of banks and academics (see, for example, Gopalakrishnan *et al* 2021; Li and Wang 2023). By narrowing the confidence level of the risk metric, we might expect a decrease in capital requirements for market risk. However, for the same confidence level, the ES results in a higher capital charge than the VaR.[3] The European Banking Authority (EBA) also recognized an increase in market risk capital requirements for internal models, driven by the default risk charge (DRC) and the nonmodelable risk factors (NMRFs). However, well-diversified portfolios should be relatively immune to changes in the risk metric (Li and Wang 2023).

So, whether the new regulatory requirements lead to higher capital charges, as in previous regulatory reforms, and whether the impact varies according to the asset class are questions still lacking a clear answer. When faced with stringent capital requirements, banks are expected to follow a portfolio optimization approach (Gopalakrishnan *et al* 2021), which calls for them to gauge the impact of the FRTB on trading portfolios. To address these open questions, we create a stylized portfolio that is representative of the asset classes in banks' trading books and run a sensitivity analysis of the portfolio composition. Our study compares the capital charges resulting from the current IMA with those from IMA in the context of the FRTB.

Our results suggest that, unlike the present use of VaR and stressed VaR metrics, the FRTB causes an increase in regulatory capital under the IMA and an even larger increase for portfolios with a higher weight in bonds, due to both the diversifiable and nondiversifiable components of the ES. These results contribute to the scarce academic empirical literature on the impact of the FRTB on capital requirements (to the best of our knowledge, only Pederzoli and Torricelli (2021) have followed a similar approach). Our study extends the work of Pederzoli and Torricelli (2021) by taking a deep dive into portfolio composition and the contribution of bonds to capital charges under the FRTB. Most of the considerations on the impact of the FRTB have been enacted by the BCBS or analyzed by consultancy firms.

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[3] The VaR answers the simple question "How bad can things get?", while ES answers the question "If things go bad, what is the expected shortfall?" and represents the expected loss of the tail of the distribution of returns beyond the VaR. ES is often called conditional VaR (CVaR). In other words, it is "the conditional expectation of loss given that the loss is beyond the VaR level" (Yamai and Yoshiba 2005, p. 999). This means that ES represents the average of all losses worse than the VaR. The ES is a subadditive measure of risk, while VaR is not subadditive (Chang *et al* 2019). Under normally distributed returns, the VaR at 99% does not differ much from the ES at 97.5% (Hull 2023).

The rest of this paper is organized as follows: Section 2 reviews the underpinnings of the capital requirements for market risk; Section 3 describes our data and the methodologies we employ; Section 4 presents our main findings; Section 5 discusses our results and states our conclusions.

2 MOTIVATION FOR THE FUNDAMENTAL REVIEW OF THE TRADING BOOK

2.1 Background

Banks entered the GFC with high levels of leverage and inadequate liquidity buffers (Filippova 2018) and were unable to absorb losses. Varotto (2012) points out another two shortcomings of precrisis practices, as previously contended by Acharya *et al* (2009):

(i) the combination of overly narrow credit spreads and the mispricing of risk;

(ii) the belief that volatility in capital markets would remain low.

The GFC witnessed sharp fluctuations in asset and credit markets and an unavoidable increase in risk premiums.

Excessive speculation in credit derivatives and complex securitization added market risk to portfolios, outpacing the capacity of banks to manage risks. The write-downs following the GFC depleted capital reserves, leaving many banks on the verge of collapse (Varotto 2012; McCullagh *et al* 2022).

Although credit and market risks are estimated separately, they are in fact intrinsically related and should be measured and managed in an integrated way. The BCBS, despite recognizing the difficulty in assessing interaction between different types of risk, has taken a more integrated approach regarding credit risks contained in trading books (Hartmann 2010). The market risk framework was based on the idea that all risk positions on the trading book were equally liquid (ie, banks could exit or hedge their positions over a 10-day period). As liquidity conditions deteriorated during the GFC, banks were forced to hold risk positions for much longer than expected and incurred large losses from changes in asset values due to fluctuations in liquidity premiums (Basel Committee on Banking Supervision 2013a). Under the current regulatory framework, capital requirements on market risk using the IMA for general market risk are based on the sum of four main indicators (Neisen and Röth 2017):

(i) the traditional VaR at a 99% confidence level and a holding period of 10 days;

(ii) the stressed VaR (SVaR);

(iii) the Incremental Risk Charge (IRC),[4] which implies an additional capital requirement on the default and migration risk of positions in trading book instruments that are sensitive to default risk; and

(iv) a comprehensive risk measure to account for credit correlations in credit exotic trading portfolios.

The deterioration in liquidity across the banking system motivated the BCBS to initiate a comprehensive review of the risk-weighted capital framework, aiming at completing the Basel III reform package and ensuring its implementation. The objective was to "help strengthen the resilience of the global banking system, maintain market confidence in regulatory ratios and provide a level playing field for banks operating internationally" ((European Central Bank 2015, p. 2). This review pertains to the FRTB, which was proposed by the BCBS in May 2012, and was expected to start being implemented, after several revisions, in 2023.[5] The FRTB requires that all positions held for trading be assigned to the trading book and are consequently subject to regulatory requirements.[6]

The FRTB requires that banks' proprietary internal risk models (IMA) run in parallel with a standardized approach (SA) that ascribes standardized risk weights to the exposures. Under the FRTB, the use of the SA is mandatory, and it works as a floor in capital requirements. This output floor aims to facilitate consistent and comparable reporting of market risk across banks and jurisdictions, smoothing the variability of risk-weighted assets (RWAs). Most importantly, the BCBS envisages that the SA will restore confidence in risk models and prevent minimum capital requirements from falling below appropriate levels. The new output floor requires that the RWAs used to determine capital requirements do not fall below 72.5% of market risk calculated using standard methods alone (Basel Committee on Banking Supervision 2017). It is important to note that this floor, combined with the restrictions to portfolio diversification benefits in the FRTB, is expected to discourage some banks from opting for the use of the IMA.

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[4] The FRTB replaces the IRC with the DRC.

[5] As suggested by International Swaps and Derivatives Association and Association for Financial Markets in Europe (2017, p. 8), the entry into force was later extended to January 1, 2025 (see European Commission 2021).

[6] The new standards for minimum capital requirements for market risk set by the FRTB focus on the following aspects: a clearer boundary between the trading book and the banking book; a revised standardized approach and IMA; a limit to the diversification benefit; and incorporation of liquidity considerations, by introducing liquidity risk. According to the BCBS, this review "set out stricter criteria for assigning instruments to the trading book", since "it overhauled the internal models methodology to better address risks observed during the crisis, reinforced the process for supervisors to approve the use of internal models and introduced a new, more risk-sensitive standardised methodology" (Basel Committee on Banking Supervision 2019b, p. 2).

2.2 Choosing expected shortfall over value-at-risk

The BCBS has pointed out some weaknesses in using VaR to define regulatory capital charges (Basel Committee on Banking Supervision 2013a), one of the most important being its failure to capture tail risk. Artzner *et al* (1997) initially proposed using ES to overcome the insufficiencies of VaR and, almost two decades later, the existing literature comparing both market risk measures (namely VaR and ES) has been expanded in terms of estimation error, decomposition into risk factors and optimization (Yamai and Yoshiba 2005); subadditivity and fat-tailed asset returns (Daníelsson *et al* 2013); duplication of computational efforts and related costs for banks adopting IMA (Pearce 2015; Amorello 2016); higher quality data requirements and experienced teams to support the implementation of the FRTB (Orgeldinger 2018).

In summary, the shift from VaR to ES concerns models capturing tail risk adequately, acknowledging that the distribution of losses presents heavy tails. The tail-heaviness of models' P&L distributions has attracted the attention of researchers for a long time. The seminal work by Fama (1965) showed empirically that financial data are not normally distributed. Hull (2023) posited that VaR measured with a 99% confidence level yields a similar result to ES with a 97.5% confidence level under a normal distribution. However, he recognizes that ES can be larger in the presence of heavier tails. In this vein, Kellner and Rösch (2016) pointed out that heavy tails, which are captured by ES rather than VaR, are the main driver of higher capital charges, concurring with studies by Giannopoulos and Tunaru (2005) and Yamai and Yoshiba (2005). Saunders and Cornett (2017) have documented that VaR measures may yield significantly lower results than ES for portfolios exhibiting fat-tailed probability distributions. These assertions motivated us to empirically analyze the impact of the FRTB on a stylized portfolio.

Under the Basel framework (Basel Committee on Banking Supervision 2019a), the regulatory liquidity-adjusted expected shortfall is defined for a 10-day liquidity horizon, scaled by mapping to each risk factor, as follows:

$$\mathrm{ES} = \sqrt{\mathrm{ES}_1^2 + \sum_{j=2}^{5}\left(\mathrm{ES}_j\sqrt{\frac{(\mathrm{LH}_j - \mathrm{LH}_{j-1})}{10}}\right)^2}, \tag{2.1}$$

where ES_1 represents the ES computed from the 10-day changes made to all risk factors to which the portfolio is exposed, ES_j is the ES based on 10-day changes made to the subset of risk factors in category j ($j = 2, \dots, 5$) and above with all other risk factors (up to and including $j-1$) held constant, and LH_j represents the liquidity horizon of length j. Tables 1 and 2 specify the liquidity horizons according to the FRTB and their correspondence for each risk factor, respectively.

TABLE 1 Liquidity horizons according to the FRTB.

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

LH_j is the liquidity horizon, with lengths j. *Source:* data from Basel Committee on Banking Supervision (2019a, p. 90).

TABLE 2 Liquidity horizon n by risk factor.

Risk factor category	n	Risk factor category	n
Interest rate: specified currencies: EUR, USD, GBP, AUD, JPY, SEK, CAD and domestic currency of a bank	10	Equity price (small cap): volatility	60
Interest rate: unspecified currencies	20	Equity: other types	60
Interest rate: volatility	60	FX rate: specified currency pairs	10
Interest rate: other types	60	FX rate: currency pairs	20
Credit spread: sovereign (IG)	20	FX: volatility	40
Credit spread: sovereign (HY)	40	FX: other types	40
Credit spread: corporate (IG)	40	Energy and carbon emissions trading price	20
Credit spread: corporate (HY)	60	Precious metals and nonferrous metals price	20
Credit spread: volatility	120	Other commodities price	60
Credit spread: other types	120	Energy and carbon emissions trading price: volatility	60
Equity price (large cap)	10	Precious metals and nonferrous metals price: volatility	60
Equity price (small cap)	20	Other commodities price: volatility	120
Equity price (large cap): volatility	20	Commodity: other types	120

The liquidity horizon n is determined for each broad category of risk factor as set out in the table. *Source:* data from Basel Committee on Banking Supervision (2019a).

Pederzoli and Torricelli (2021) provide empirical evidence of the magnitude of the impact of the FRTB on capital charges, recalling that, for the IMA, the three main objectives of the FRTB are to capture tail risks more fully; to incorporate liquidity risk by introducing differentiated liquidity horizons; and to constrain the use of correlations between risk factors, thus reducing diversification benefits. They deploy a stylized portfolio sensitive to relevant risk factors that affect trading portfolios: equity, volatility, interest rate, credit spread and exchange rate. While Pederzoli and Torricelli apply the increase in capital requirements of the same order of magnitude as in the IMA, they document the dampening of the diversification effect on the trading book under the new FRTB framework.

3 DATA SAMPLE AND METHODOLOGY

3.1 Data sample

Our stylized portfolio represents the asset classes exposed to the typical risk factors of a trading book, as laid down in the risk-based requirements of the Bank of International Settlements: interest rate, credit spread, equity, foreign exchange (FX) rate and commodity price. Following Pederzoli and Torricelli (2021), we calculate the capital charges under the FRTB of the following exposures:

(a) index positions (sensitive to equity prices);

(b) bond positions (sensitive to credit spread risk, the interest rate and exchange rate);

(c) commodity positions (sensitive to the interest rate, volatility and exchange rate);

(d) an index option (sensitive to equity prices and volatility);[7] and

(e) a foreign currency cash position (sensitive to the exchange rate).

The above portfolio constituents are similar to those used by Pederzoli and Torricelli (2021) and corroborated by McCullagh *et al* (2022), but we also enter commodity positions.[8] The weights of the constituents in the portfolio allow for diversification and representativeness, as contended in extant studies (see, for example, Pederzoli and Torricelli 2021).

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[7] This is an at-the-money European plain-vanilla call option on the Standard & Poor's 500 (S&P 500) index.

[8] For the various types of constituents of trading desks of 78 banks across the world, we refer the reader to, for example, Basel Committee on Banking Supervision (2015).

Table 3 presents the descriptive statistics of the assets in the portfolio. The period of analysis, from January 2007 to December 2019, includes the GFC period, as imposed by the BCBS for the computation of risk measures considering this stress period. Concomitantly, this period is compliant with the minimum horizon of 10 years required by the BCBS for such estimations.

To estimate the relevant risk metrics, we consider the portfolio as of December 31, 2019: the sample yields 3271 observations, and the stress period includes 253 observations. We consider the euro as the base currency, thus assuming the view of a euro-centered bank (Pederzoli and Torricelli (2021) take a similar stance). The positions composing the stylized portfolio are consistent with the majority of risk positions that banks typically hold on their trading books.

3.2 Methodology

We measure the market risk capital requirements under the IMA, both for the current framework (Basel 2.5) and for the FRTB, and then compare the results to gauge the impact of the new regulation.

To compute the market risk capital requirement in Basel 2.5, we consider:

$$\begin{aligned}\mathrm{MRC}_t^{\mathrm{IMA}} &= \max(\mathrm{VaR}_{0.99,t-1}; (m_{\mathrm{c}} + p_{\mathrm{c}}) \times \mathrm{VaR}_{0.99,\mathrm{avg}}) \\ &\quad + \max(\mathrm{SVaR}_{0.99,t-1}; (m_{\mathrm{s}} + p_{\mathrm{s}}) \times \mathrm{SVaR}_{0.99,\mathrm{avg}}) \qquad (3.1)\end{aligned}$$

where $\mathrm{VaR}_{0.99,t-1}$ and $\mathrm{SVaR}_{0.99,t-1}$ denote the previous day's VaR and SVaR computed at a 99% confidence level, and $\mathrm{VaR}_{0.99,\mathrm{avg}}$ and $S\mathrm{VaR}_{0.99,\mathrm{avg}}$ denote the averages of the VaR and SVaR measures over the preceding 60 business days; m_{c} and m_{s} are multiplication factors set by national supervisory authorities, with a minimum value of 3, based on the assessment of the quality of the bank's risk management system; and p_{c} and p_{s} are plus factors, which can range from 0 to 1, depending on the outcome of the VaR backtesting performed by the bank.

Regarding the FRTB, the overall capital requirement for the trading desks eligible for the IMA (C_{A}) will be equal to the maximum of the most recent observation and a weighted average of the previous 60 days scaled by a multiplier (m_{c}), as follows:

$$C_{\mathrm{A}} = \max\{\mathrm{IMCC}_{t-1} + \mathrm{SES}_{t-1}; m_{\mathrm{c}} \times \mathrm{IMCC}_{\mathrm{avg}} + \mathrm{SES}_{\mathrm{avg}}\}, \qquad (3.2)$$

where IMCC denotes the capital charge for modelable risk factors of the trading desks approved for the IMA; SES denotes the aggregate regulatory capital measure for the risk factors in model-eligible trading desks that are nonmodelable; the multiplication factor m_{c} is equal to 1.5 but can be set at a higher level by the supervisory authority to address a qualitative and/or backtesting add-on, based on an assessment of the bank's risk management system.

TABLE 3 Descriptive statistics of the assets composing the portfolio. [Table continues on next page.]

Asset	**Obs**	**Mean**	**SD**	**Max**	**Min**	**Kurtosis**	**Skewness**
S&P 500	3 271	1 459.16	622.01	2 919.81	536.42	−1.08	0.49
	253	676.76	69.00	897.34	536.42	1.78	1.19
Nikkei 225	3 271	117.11	36.03	197.62	56.38	−1.17	0.44
	253	70.05	5.45	82.53	56.38	−0.16	−0.12
FTSE 100	3 271	7 631.25	1 234.50	9 939.38	3 870.08	0.03	−0.63
	253	5 029.24	639.24	6 905.97	3 870.08	0.83	0.91
CAC 40	3 271	4 428.44	841.56	6 168.15	2 519.29	−1.04	0.01
	253	3 265.66	387.24	4 539.07	2 519.29	1.31	1.04
DAX 30	3 271	8 782.20	2 581.41	13 559.60	3 666.41	−1.25	0.14
	253	4 829.76	574.47	6 518.47	3 666.41	0.48	0.63
IBEX 35	3 271	10 143.96	1 901.29	15 945.70	5 956.30	1.03	1.04
	253	9 324.82	1 140.60	11 903.89	6 817.39	−0.58	0.25
Nickel	3 271	13 408.91	5 100.98	37 967.28	6 707.90	5.79	2.10
	253	9 683.05	1 991.93	14 417.32	6 799.77	−0.65	0.65

TABLE 3 Continued.

Asset	Obs	Mean	SD	Max	Min	Kurtosis	Skewness
Copper	3 271	5 242.47	845.50	7 531.61	2 022.05	1.70	−0.87
	253	3 362.13	739.04	5 069.295	2 022.05	−0.52	0.40
CALL OPTION	3 020	491.54	165.62	1 165.58	272.67	0.72	1.11
	253	489.77	126.62	816.91	325.93	−0.50	0.71
Bond #1	3 271	1 246.34	127.59	1 460.80	943.50	−0.85	−0.53
	253	1 132.47	55.53	1 260.14	1 044.99	−0.90	0.43
Bond #2	3 271	12 031.32	1 822.05	15 422.30	9 588.68	−1.59	0.30
	253	10 137.86	139.45	10 576.24	9 836.21	0.08	0.53
BOND #3	3 271	4 266.57	429.10	5 038.50	3 251.18	−0.85	−0.50
	253	3 885.94	197.04	4 365.88	3 580.68	−0.69	0.53
JPY cash position	3 271	7 085.08	15.62	9 542.99	5 310.05	−0.14	0.17
	253	6 924.23	482.24	7 533.58	5 707.40	0.04	−0.31

The first row corresponds to the overall period, and the second row to the stress period. “SD” denotes standard deviation. “Obs” denotes the number of observations.

The aggregate capital charge for modelable risk factors (IMCC) is based on the weighted average of the constrained (nondiversifiable) and unconstrained ES, as follows:

$$\text{IMCC} = \rho(\text{IMCC}(C)) + (1-\rho)\bigg(\sum_{i=1}^{B} \text{IMCC}(C_i)\bigg), \tag{3.3}$$

where $\text{IMCC}(C)$ denotes the ES unconstrained capital requirements, $\text{IMCC}(C_i)$ is the ES constrained capital requirements, ρ is set to 0.5 and B represents the broad regulatory risk classes. We compute the capital requirements accordingly. The nondiversifiable component of the market risk capital requirement includes the computation of $\text{ES}_{\text{R,S}}$ (the ES for the reduced set of risk factors based on the stress period), $\text{ES}_{\text{F,C}}$ (the ES for the full set of risk factors based on the current period) and $\text{ES}_{\text{R,C}}$ (ES for the reduced set of risk factors based on the current period). In our stylized portfolio, we assume that the reduced set of risk factors equals the full set, and therefore $\text{ES}_{\text{F,C}}$ and $\text{ES}_{\text{R,C}}$ are the same, and the ratio $\text{ES}_{\text{F,C}}/\text{ES}_{\text{R,C}}$ equals 1. By making this assumption, the remaining overall ES measure ($\text{ES}_{\text{R,S}}$) corresponds to the sum of the breakdown of each risk factor $\text{ES}_{\text{R,S}}$. The second, diversified (unconstrained) component is computed similarly, although it is composed of all risk factors combined.

We use historical simulation (HS) to estimate the P&L distributions of the portfolios. This method avoids assuming a particular statistical distribution for P&L; only the future P&L distribution is assumed to be identical to the past distribution, since the risk factor dependencies are driven by historical data. The plain version of HS assigns the same weight to all observations, ascribing the same importance to both recent and older data, which may not produce accurate risk estimates if there are recent trends in data (Čorkalo 2011). We chose to use the HS due to its intuitiveness, ease of implementation and simplicity. As pointed out by Pérignon and Smith (2009), HS is the approach most widely adopted by banks worldwide. As our samples encompass more than 10 years, we avoid eventual biases posed by short periods of analysis (Pritsker 2006). We use age-weighted historical simulation (AWHS) with a decay factor $\lambda = 0.995$ to ensure accuracy and increase the sensitivity of risk estimates.[9] AWHS assigns a higher weight to recent observations rather than to older ones.

Letting the ratio of consecutive weights be constant at λ and denoting by $w(1)$ the weight assigned to the most recent observation, the weight of the second most recent

[9] The decay factor we use is the same as that used in Hull (2023), but other values could be suitable depending on the backtesting results. Still, our value is in line with the optimal decay factor values estimated by Žikovć and Aktan (2011) for a range of different assets over long time intervals. We also note that, as the influence of lambda is cross-sectional to the assets, slight differences in the lambda value are highly unlikely to change our conclusions.

observation equals $w(2) = \lambda w(1)$. Similarly, the weight of the third most recent observation is defined as $w(3) = \lambda^2 w(1)$, and so on. In this case, λ corresponds to a decay factor between 0 and 1, reflecting the exponential rate of decay in the weight of observations with time (ie, as time passes, the weight given to a specific observation decreases exponentially). The weight assigned to an observation i days old is defined as

$$w(i) = \frac{\lambda^{i-1}(1-\lambda)}{1-\lambda^n}, \quad i = 1, \dots, N. \tag{3.4}$$

Another relevant element in the estimation of SVaR and ES relates to the 12-month period of stress, which was selected by considering the worst portfolio losses observed during the period of analysis (from September 2, 2008 to September 1, 2009).

For both the overall sample period and the stress period, the market risk capital requirements are computed according to the current (Basel 2.5) approach for market risk and the FRTB requirements. Specifically, regarding the latter, we consider the following assumptions to simplify the analysis:

(a) the DRC was not considered, since this element is related to a default risk component,[10] beyond the scope of this study (which focuses only on the market risk component);

(b) the capital add-on for NMRFs was not considered (ie, was assumed to be zero), since there are only modelable risk factors composing the portfolio; and

(c) the full set of risk factors was assumed to be equal to the reduced set (ie, the adjustment ratio is equal to 1).[11]

The VaR computation for stock portfolios differs from that for bond portfolios, mostly because, in the former case, the future volatility of the stock price return is estimated based on past observations of the stock price return, while bond price behavior changes over time. In particular, the price of a bond will fluctuate due to changes in the yield curve. For this reason, we compute the value of each bond based on the historical term structure of interest rates. Table 4 presents relevant data on the bonds in the portfolio. For the option position, we use the Black–Scholes pricing model.

[10] See Laurent *et al* (2016) for additional details on the default risk component of the FRTB.

[11] The reduced set of risk factors is used in the calibration of the 12-month stress period and must be subject to approval by the competent authority. According to Basel Committee on Banking Supervision (2019a), this set must be able to explain at least 75% of the variation of the full ES model. The ES will be then expressed as a function of the ES using the reduced set of risk factors for the stress period, scaled up by a ratio (the so-called adjustment ratio) composed of both the ES using the full set of risk factors and the ES using the reduced set of risk factors for the current (ie, whole) period.

TABLE 4 Bonds' characteristics.

	Bond #1	Bond #2	Bond #3
Bond type	Government (US)	Government (Spain)	Corporate (Apple Inc.)
Currency	USD	EUR	USD
Settlement date	Nov 15, 2010	Sep 9, 2008	Apr 30, 2013
Maturity date	Nov 15, 2020	Jan 31, 2024	May 3, 2023
Redemption	Bullet at par	Bullet at par	Bullet at par
Coupon frequency	Semiannual	Annual	Semiannual
Coupon rate (%)	2.625	4.80	2.40
Face value	100	1000	1000
High yield (HY)/ investment grade (IG)	IG	IG	IG

For the calculation of VaR, SVaR and ES under the HS method, we compute the portfolio's P&L for each day within the observation horizon. After ranking the P&L according to the number of scenarios (3271 scenarios for the overall period and 253 scenarios for the stress period), we compute VaR and SVaR at a 99% confidence level using AWHS. To calculate the ES, each asset was mapped to one of the risk factor categories recommended by Basel Committee on Banking Supervision (2019a), resulting in a total of five risk categories (equity price; precious metals price; credit spread; FX rate; and interest rate) for liquidity horizons of 10, 20 and 40 days. This mapping is outlined in Figure 1.

4 EMPIRICAL RESULTS

4.1 Baseline

The baseline scenario departs from the portfolio depicted in Table 5, which shows that the FRTB risk factor mappings for the equity and credit asset classes each make up about 42% of the total portfolio value, while commodities and precious metals have a 9% weight and FX a 7% weight.

First, the VaR and SVaR measures are computed at the 99% confidence level, leading to a total capital charge of €2 581 800, equivalent to 2.3% of the overall portfolio value. Then, the ES is computed at the 97.5% confidence level and based on the weighted average of the constrained and unconstrained components (ie, the IMCC), amounting to €4 591 010, representing 4% of the overall portfolio value. Compared with the sum of the VaR and SVaR, the ES represents an increase of about €2 009 210 (ie, 78%). These results can be observed in Table 6.

TABLE 5 Portfolio composition: baseline scenario.

Portfolio	Position	Weight (%)
S&P 500	10 000.00	9.09
NIKKEI 225	8 000.00	7.27
FTSE 100	8 000.00	7.27
CAC 40	4 250.00	3.86
DAX 30	4 000.00	3.64
IBEX 35	4 000.00	3.64
Call option	8 000.00	7.27
Nickel	5 050.00	4.59
Copper	5 050.00	4.59
Bond #1	5 212.18	4.74
Bond #2	22 489.42	20.44
Bond #3	18 560.26	16.87
JPY cash position	7 390.98	6.72
Total	110 002.85	100.00

Portfolio as of December 31, 2019. Position is given in thousands of euros.

TABLE 6 VaR, SVaR and ES for the baseline scenario.

<table>
<tr><th>Metric</th><th colspan="2">Value</th><th colspan="2">Percentage of portfolio value</th></tr>
<tr><td>VaR</td><td>745.98</td><td rowspan="2">2581.80</td><td>0.68</td><td rowspan="2">2.35</td></tr>
<tr><td>SVaR</td><td>1835.80</td><td>1.67</td></tr>
<tr><td>ES (IMCC)</td><td colspan="2">4591.01</td><td colspan="2">4.17</td></tr>
</table>

Value is given in thousands of euros.

To highlight the impact of the FRTB in terms of the limits imposed on the diversification benefit, we break down the ES measure into its diversifiable and nondiversifiable elements. As expected, the nondiversifiable ES is higher than the diversifiable ES, yielding an increase of €2 837 520 (ie, €6 009 770 − €3 172 250) as compared with the latter (about 89%), as shown in Table 7.

Table 7 presents the contribution of the five risk factors considered for the computation of the constrained ES. The equity risk factor ranks the highest contribution, followed by the FX and interest rate components. Remarkably, not only is

TABLE 7 ES breakdown for the baseline scenario.

Metric		Value		Percentage of portfolio value	
IMCC (C_i)	Equity	2085.08	6009.77	1.90	5.46
	Metals	775.13		0.70	
	Credit spread	599.62		0.55	
	FX	1509.84		1.37	
	Interest rate	1040.11		0.95	
IMCC (C)		3172.25		2.88	

Value is given in thousands of euros.

TABLE 8 Market risk capital requirement: current regulation versus FRTB under the baseline scenario.

Regulation	Market risk capital requirement	Percentage of portfolio value
Current	7908.92	7.19
FRTB	6911.12	6.28

Market risk capital requirement is given in thousands of euros.

the diversifiable ES measure greater than the sum of the VaR and SVaR measures (€3 172 250 versus €2 581 800: a 23% increase), but also its nondiversifiable component represents almost 5.5% of the overall portfolio value, highlighting one of the main impacts of the FRTB in terms of limiting the diversification benefits of a portfolio with differentiated assets.

However, when considering the three measures (VaR, SVaR and ES) over the preceding 60 business days and the respective multiplication factors, the market risk capital requirement appears to be higher under Basel 2.5, amounting to €7 908 920 (versus €6 911 120 under the FRTB). The results are presented in Table 8. The difference between the two figures (€7 908 920 − €6 911 120), partly explained by the distinct multiplicative factors, will most likely be more than depleted when the DRC and the capital charge for unapproved trading desks (computed using the Standardized Approach[12]) are combined to obtain the final market risk capital requirement under the FRTB.

[12] The capital charge stipulated under the standardized approach (SA) is the sum of three components: the sensitivities based method, the DR and the residual risk add-on.

TABLE 9 Sensitivity analysis: 20% increase in equity exposure.

(a) VaR, SVaR and ES

Metric	Value		Percentage of portfolio value	
VaR	1664.34	4884.39	1.00	2.94
SVaR	3220.05		1.94	
ES	8106.64		4.89	

(b) ES breakdown

Metric		Value		Percentage of portfolio value	
IMCC (C_i)	Equity	4832.41	10624.68	2.92	6.41
	Metals	775.13		0.47	
	Credit spread	599.62		0.36	
	FX	2328.73		1.40	
	Interest rate	2088.79		1.26	
IMCC (C)		5588.59		3.37	

Value is given in thousands of euros.

4.2 Sensitivity analysis

4.2.1 Effect of an increase in the weight of equity positions

To gauge the impact of the FRTB for different compositions of the investment portfolio, we allow the weight of equity positions to increase by 20%, holding everything else constant. We now compute the VaR, SVaR and ES measures (Table 9(a)) and the breakdown of the ES (Table 9(b)).

Table 9 presents an ES that is 66% higher than the sum of the VaR and SVaR measures but an order of magnitude less than that observed in the baseline scenario (78%). Moreover, analyzing the breakdown of the ES, we observe a significant increase in the weight in the portfolio due to the contribution of the risk factors affected by the 20% change, with the equity risk factor more than doubling. The diversifiable ES is also higher than the sum of VaR and SVaR (a 14% increase). Unsurprisingly, the weights of the VaR and SVaR as a percentage of the portfolio value are higher than for the baseline scenario (a 0.68% rise in VaR to 1.00%; a

TABLE 10 Market risk capital requirement: current regulation versus FRTB with a 20% increase in equity.

Regulation	Market risk capital requirement	Percentage of portfolio value
Current	14 564.84	8.79
FRTB	12 140.12	7.32

Market risk capital requirement is given in thousands of euros.

1.67% rise in SVaR to 1.94%), which is impacted by this 20% increase in equity positions.

Table 10 presents the market risk capital requirement for both Basel 2.5 and the FRTB. Under both regulations, the capital requirement is almost double that in the baseline scenario. The capital required by the current regulation exceeds that required by the FRTB, but only when considering the market risk component. The DRC and the capital charge for unapproved trading desks still need to be added.

4.2.2 Effect of an increase in the weight of bond positions

We now increase the weight of the bond positions by 20%, holding everything else constant. Similarly to the procedure adopted above for an equity increase, under the FRTB these positions are mapped into the credit spread, FX and interest rate risk factors according to the risk factor mapping in Table 2.

Starting with the stand-alone VaR, SVaR and ES measures, Table 11(a) shows that the ES (€6 227 500) is more than double the sum of the VaR (€896 020) and SVaR (€2 197 200), a far higher value than the 78% observed in the baseline scenario. Table 11(b) presents the breakdown of the overall ES measure. In particular, the credit spread risk factor increases almost threefold. The diversifiable ES is again higher than the sum of VaR and SVaR (a 38% increase).

Finally, Table 12 shows the market risk capital requirement for both Basel 2.5 and the FRTB. Here, we observe a slight increase in the market risk capital requirement stemming from the FRTB approach, exceeding the value under the current regulation, a different result from the previous scenarios. Again, considering DRC and the capital charge for unapproved trading desks should be added to the result, there will be a further increase in the FRTB capital requirement.

5 DISCUSSION OF THE RESULTS AND CONCLUDING REMARKS

Our study assessed the likely impact on banks' capital requirements for market risk under the IMA resulting from the introduction of the FRTB. To do so, we computed

TABLE 11 Sensitivity analysis: 20% increase in bonds.

(a) VaR, SVaR and ES

Metric	Value		Percentage of portfolio value	
VaR	896.02	3093.22	0.53	1.85
SVaR	2197.20		1.31	
ES	6227.50		3.72	

(b) ES breakdown

Metric		Value		Percentage of portfolio value	
IMCC (C_i)	Equity	2085.08	8171.17	1.24	4.88
	Metals	775.13		0.46	
	Credit spread	1661.59		0.99	
	FX	1922.44		1.15	
	Interest rate	1726.93		1.03	
IMCC (C)		4283.84		2.56	

Value is given in thousands of euros.

TABLE 12 Market risk capital requirement: current regulation versus FRTB under the scenario with a 20% increase in bonds.

Regulation	Market risk capital requirement	Percentage of portfolio value
Current	9402.08	5.61
FRTB	9459.51	5.65

Market risk capital requirement is given in thousands of euros.

the capital requirement for both the current (Basel 2.5) and proposed frameworks, focusing on the market risk component, based on a stylized portfolio of assets most likely impacted by FRTB. The study provides a significant empirical analysis of a time of regulatory transition, when banks need to take important decisions regarding their risk management methodology.

The combination of the FRTB and the IMA has created three main challenges: the definition of the ES as the new risk measure to capture tail risk (replacing VaR and SVaR); the limitation of the portfolio diversification benefit, with the inception of the nondiversifiable and diversifiable ES measures; and the introduction of five liquidity horizons, to distinguish the different levels of liquidity risk between the asset classes of the trading book.

Our empirical results show that in the scenarios analyzed for a representative trading portfolio, the overall ES measure (obtained from the weighted average of the diversifiable and nondiversifiable ES) is greater than the sum of the VaR and SVaR measures. The overall ES represents an increase of 78%, 66% and 101% compared with the sum of the VaR and stressed VaR in the baseline scenario, the scenario with a 20% increase in equity positions and the scenario with a 20% increase bond positions, respectively. This increase emerges not only from the nondiversifiable ES (as expected, since the diversification benefits between risk factors are neglected) but also from the diversifiable ES, since the latter also exceeds the sum of VaR and SVaR in the three scenarios (an increase of 23%, 14%, and 38%, respectively). As expected, this shows that the portfolio diversification benefits accounted for in the current framework are less well recognized under the FRTB.

When assessing the market risk capital requirement by considering the computation of VaR, SVaR and ES over the preceding 60 business days and each regulation's multiplication factor (ie, 3 for the current regulation and 1.5 for the FRTB), the capital requirement appears to be higher under the current regulation both for the baseline scenario and for the scenario with a 20% increase in equity positions. When we consider the third scenario (20% increase in bond positions), the capital requirement appears to be lower. These results may suggest that an investment structure that focuses more on bond positions than equity positions could lead to a higher market risk capital requirement. The intuition is that a longer liquidity horizon has a greater effect on bonds (in particular on bond #3 in Table 4). Righi and Ceretta (2015) document larger ES estimates for bonds than equity assets, arguing that bonds are directly subject to policy shocks, which might constitute an additional effect.

Finally, our results show the impact of the FRTB on a representative portfolio, as trading portfolios differ by an order of magnitude from bank to bank (Pederzoli and Torricelli 2021). However, the DRC and NMRFs must still be added to our results to obtain results for the FRTB 2025 requirements. The EBA has made available preliminary results on the impact of the FRTB under the IMA, identifying DRC and NMRFs as relevant drivers of the increase in capital requirements (European Banking Authority 2019).

Our study is part of a wider debate on the role of bank regulatory reforms in preventing financial crises. Regulations are becoming ever more stringent. Will the FRTB approach to computing capital charges avoid the huge losses of the not-sodistant past, such as in the 2007–9 GFC that motivated the BCBS to aim to enact FRTB in the near future? Only time will tell.

DECLARATION OF INTEREST

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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