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Assessing Banking Risk in Europe: Replication of and Extension of "Testing macroprudential stress tests: The risk of regulatory risk weights" by Acharya, Engle, and Pierret (2014)

Comparative Macroprudential Stress Testing: Assessing European Banks in 2018

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Abstract

This report analyzes the findings of the article *"Testing Macroprudential Stress Tests: The Risk of Regulatory Risk Weights"* by Acharya, Engle, and Pierret (2014), which concludes that regulatory stress tests often underestimate capital shortfalls compared to V-Lab, especially during times of economic stress, giving an overly optimistic view of banks' stability. To evaluate this claim, the same comparative analysis from the article for the 2011 EBA stress tests and the V-Lab stress test was replicated and extended to 2016 and 2018. The final results indeed corroborate the article's conclusion that risk-based regulatory capital shortfalls are underestimated, with asset-based capital shortfalls yielding more favorable outcomes.

Key Words: V-Lab Stress Test; EBA Stress Test; Risk-weighted-based Capital Requirements; Asset-based Capital Requirements; Capital Shortfalls.

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1. Introduction

The 2008 financial crisis had profound and far-reaching effects on the global economy, particularly within the baking sector. Numerous financial institutions faced severe liquidity shortages and solvency crises, resulting in government bailouts and substantial monetary interventions. In this manner, as stated by Buch and Dages (2018) "the global crisis exposed a pattern of excessive risk-taking and inadequate capital and liquidity buffers within the industry, together with shortcomings in the prudential framework".

In order to prevent the recurrence of the crises and to address the new challenges and uncertainties of the post-crisis economy, a series of initiatives and new regulations were implemented with the aim of improving the resilience of the banking industry and restoring public confidence. Particular emphasis was given to the implementation of macroprudential stress tests in order to evaluate the resilience of financial institutions, ensuring that banks could survive adverse economic conditions.

Nevertheless, criticism has emerged on the accuracy and efficiency of the traditional regulatory stress test. The article *"Testing Macroprudential Stress Tests: The Risk of Regulatory Risk Weights"* by Acharya, Engle, and Pierret (2014), critically evaluated the limitations of traditional stress tests by comparing its results with a market-based alternative, the V-Lab stress test. This comparison exposed notable differences between the capital shortfall estimated by the regulatory stress tests and those derived from real-time market data, thereby undermining the accuracy of regulatory risk-weight based stress tests.

This report aims to assess prevailing doubts regarding the effectiveness of the traditional regulatory stress test. To critically evaluate the conclusions presented in the article *"Testing Macroprudential Stress Tests: The Risk of Regulatory Risk Weights"* by Acharya, Engle, and Pierret (2014), will be conducted a replication of Figure 3 a) – EBA Capital Shortfall vs SRISK,

Figure 3 b) EBA Overall Shortfall vs SRISK, Figure 4 a) EBA “absolute” risk-based Capital Shortfall vs SRISK and Figure 4 b) – EBA leveraged based capital shortfall vs SRISK, as well as Table 3 – Realized volatility regressions, for the year 2011 of the referred article.

Furthermore, by extending the recreation and analysis of the mentioned figures and table to the years 2016 and 2018, this paper aims to contribute to the ongoing discussion about the adequacy of macroprudential stress tests and assess whether the discrepancies between regulatory and marked-based stress tests have persisted or widened in recent years. The ultimate goal is to offer insights into how regulatory frameworks can be enhanced to better capture emerging risk and safeguard financial stability in an increasingly complex and interconnected global economy.

2. SRISK and V-Lab Data

In order to obtain a deeper understanding of the methodology employed by the Volatility Laboratory (V-Lab) in its systemic risk analysis, an analysis of V-Lab and the range of data it offers was conducted. The key concepts from this examination are outlined below according to the information presented on the V-Lab website.

The **Crisis Threshold** represents the market index decline percentage over six months that triggers a systemic crisis, the default threshold is 40%, mirroring the 2007-2009 financial crisis. (Volatility Laboratory n.d.).

Prudential Capital Requirement (k) is the capital ratio an institution needs to withstand a crisis. According to the Volatility Laboratory (n.d.), the default prudential capital requirement is defined as 8% for firms in Africa, Asia, and America and 5.5% for Europe, which will be the focus of this report.

As quoted by the Volatility Laboratory (n.d.), **SRISK** accounts for "the expected capital shortfall of a financial firm in a systemic crisis where the broad market index falls by more than 40% in a six-month period". SRISK is calculated as

$$SRISK = k * Debt - (1 - k) * (1 - LRMES) * MV \quad (1)$$

LRMES represents the expected percentage loss in a firm's equity when the MSCI All-Country World Index falls by the crisis threshold in a six-month period (Volatility Laboratory n.d.). It is computed according to the formula below, where **d** is the six-month crisis threshold for the market index decline and **beta** is the firm's Dynamic Conditional Beta (Volatility Laboratory n.d.).

$$LRMES = 1 - \exp(\log(1 - d) * beta) \quad (2)$$

According to the same source, **Marginal SRISK** is defined as the difference between SRISK at the currently selected market decline and SRISK at a 0% market decline.

Cor is defined by Volatility Laboratory (n.d.) as “the dynamic conditional correlation between the equity return on a stock and the return on the MSCI All-Country World Index”.

Vol is the annualized volatility of the equity of the company, estimated with a GJR-GARCH model and updated daily (Volatility Laboratory n.d.).

Lastly, **Lvg** is the Quasi Leverage of a company, calculated as 1 plus its book value of liabilities divided by its market value of equity (Volatility Laboratory n.d.). In the case of firms with separate accounts, liabilities should be reduced by the proportion of separate accounts to include in the SRISK calculation.

3. Literature and Previous Research

"Testing Macroprudential Stress Tests: The Risk of Regulatory Risk Weights"

The global financial crisis of 2008 underscored the need for robust mechanisms to assess the resilience of financial institutions. One key tool developed in the aftermath was the macroprudential stress test, which became integral to financial regulation. Stress tests are designed to evaluate how well a bank can withstand adverse economic scenarios and ensure that it holds sufficient capital to absorb potential losses. In the context of the paper "*Testing Macroprudential Stress Tests: The Risk of Regulatory Risk Weights"* by Acharya, Engle, and Pierret (2014), plays a crucial role by critiquing traditional regulatory stress tests and proposing an alternative market-based approach.

Regulatory stress tests, as conducted by bodies like the Federal Reserve and the European Central Bank, rely on regulatory risk weights to assess risk. These weights are predefined metrics that assign the level of risk to different assets held by banks, for instance, government bonds may receive a lower risk weight, while loans to small businesses might be classified as riskier. However, multiple studies have criticized the static and rule-based approach. Risk weight is often based on regulatory assumptions rather than real-time data, which can misrepresent actual market conditions. The paper argues that the risk weight failed to capture evolving market risks, such as those seen during the financial crisis, where ostensibly safe assets like mortgage-backed securities turned out to be highly volatile. Similarly, Demirgüç-Kunt and Detragiache (2010) contend that regulatory stress tests provide a snapshot of bank stability based on historical data, which may not reflect certain markets shift or contagion effects. Acharya, Engle, and Pierret (2014) build upon this criticism, demonstrating how regulatory risk weights can underestimate systemic risk, particularly in times of financial distress. The paper compares the capital shortfall predicted by regulatory stress tests to those estimated using a market-based alternative the V-lab stress test developed at NYU. The V-lab

test uses real-time market data making it more responsive to changes in market conditions and systemic risk factors

This test offers a distinct approach to evaluating systemic risk instead of relying on fixed risk weights. It uses statistical models to assess value at risk and expected shortfall, key measures that reflect an institution's risk exposure based on current market data. Value at risk, for instance, meets the maximum potential loss over a specific period with a certain confidence level, while the expected shortfall calculates the expected loss if that threshold is exceeded. These techniques provide a dynamic view of risk, taking into account market volatility asset correlation, and systemic shocks. Multiple studies have emphasized the value of market-based measures and assessing financial stability. Adrian and Brunnermeier (2016) proposed a "CoVar", a model similar to the V-lab that captures the spillover risk from one financial institution to another. They argue that market-based stress tests can more accurately capture interconnectedness and contagion risk factors that regulatory tests often overlook. The V-lab model like the CoVar model adapts to market conditions, offering a more forward-looking perspective on the risk. In this paper, we also find that the V-Lab stress test consistently predicts larger capital shortfalls compared to regulatory tests, particularly during periods of financial instability. This suggests that regulatory tests may give a false sense of security by underestimating the true risk exposure of banks especially those "too big to fail"

The core debate surrounding stress testing frameworks is whether to rely on regulatory or market-based approaches to measure risk. Advocates of regulatory stress tests argued that they are almost standardized and transparent, making it easier for regulators to compare banks across the sector. Regulatory stress tests also ensure consistency, as banks are evaluated under the same hypothetical scenarios. However, their reliance on fixed risk weights can overlook important dynamics of financial markets. Market-based stress tests, like V-Lab, provide more flexibility and can quickly incorporate changes in market volatility and systematic risk. Studies

like Huang, Zhou, and Zhu (2012) have shown that market-based measures, such as credit default swap (CDS) spreads, can offer early warnings of financial stress well before regulatory tests reflect this risk. Acharya, Engle, and Pierret (2014) reinforce this argument by showing that V-lab tests, which incorporate market data, highlight larger capital shortfalls and better reflect real-time risk. However, critics of the market-based approach caution that these models can be highly sensitive to short-term market fluctuations, which may lead to overestimation of this during periods of temporary market stress. This could force banks to hold excessive capital buffers, potentially stifling lending and economic growth oh this "procyclical" nature of market-based stress tests could exacerbate economic downturns by concerning banks' lending capacity during times of market volatility

Since the publication of Acharya, Engle, and Pierret (2014), new risks have emerged in the financial sector, particularly in the fields of climate risk and digital assets, which introduce further complexity into the stress testing debate. Recent studies have highlighted the growing importance of integrating climate-related financial risk into stress-testing frameworks. The Network for Greening the Financial System (NGFS) has called for stress tests that incorporate scenarios related to climate change, such as the transition to a low-carbon economy or physical risk from extreme weather events. The market-based model could be more adaptable to this risk as they integrate environmental data into their stressed scenarios. Secondly, the digital assets and cryptocurrencies. The rise of digital currencies and decentralized finance has introduced new sources of systematic risk. Stress testing frameworks must now account for the volatility and potential contagion effect of digital assets. Some studies argue that the regulatory stress test, as currently structured does not adequately capture the risk posed by cryptocurrency and their interconnectedness with traditional financial institutions. Market-based stress tests could offer a better approach to integrating these new financial products into systematic risk evaluations.

In conclusion, the literature highlights a persistent tension between regulatory and market-based approaches to stress testing. While regulatory stress tests offer standardization and transparency, they often fail to capture the real-time dynamics of the systemic risk. Market-based models, like most of the ones used until V-Lab, failed to capture the real-time dynamics of systematic risk. On the other hand, a market-based model like the V-Lab one provides a more adaptable framework, incorporating current market conditions into risk assessment. However, concerns about the procyclical tendency as sensitivity to short-term volatility remain. They also argue that integrating market-based measures into macroprudential stress tests with the financial landscape evolving rapidly, particularly with new risks like climate change in digital assets, this integration will likely be crucial for improving the effectiveness of stress tests. Future research should explore how this emerging risk can be systematically incorporated into both regulatory and market-based stress tests to ensure financial stability and an increasingly complex global economy.

In order to compare this initial study with an updated global economy and financial markets, it was necessary to compare the results presented in 2011 with further years. A year that would preferably incorporate new regulations implemented in the banking system or relevant external events happening. To see if the conclusions from 2011 will still be the same. The selection process involved the review of multiple articles and research studies, with particular emphasis placed on the insights provided by the following key source.

"The Decade of Financial Regulatory Reform: 2009 to 2019"

This paper offers a comprehensive review of financial reforms following the global financial crisis in 2008. After the global financial crisis, several financial reforms were implemented to address systematic risk, particularly within asset management and banking. Amendments and new regulations emerged worldwide, especially in the United States and the European Union,

impacting banks, asset managers, insurers, and other financial entities. The report "*The Decade of Financial Regulatory Reform: 2009 to 2019"* by Novick et al. (2020) emphasizes that reforms aimed to enhance transparency bluster capital requirements and improve liquidity and risk management. First of all, it would look at the US financial regulatory reforms the Dodd-Frank Act (DFA) in the United States was a pivotal point in restructuring financial oversights it mandated stricter regulation on OTC derivatives, establishing the financial stability oversight consent (FSOC) and improve reporting for hedge funds and private equities. The term Dodd-Frank refers to a comprehensive and complicated piece of financial regulation born out of the Great Recession of 2008. The full name of the act is the Dodd-Frank Wall Street Reform and Consumer Protection Act but it is better known and most often referred to as the Dodd-Frank in simple terms. It contains laws that place major regulations on the financial industry. It grew out of the Great Recession with the intention of preventing another collapse of the major financial institutions like Lehman Brothers. Dodd-Frank is also geared toward protecting consumers with rules like keeping borrowers from abusive lending and mortgage practices by banks. The document contains 16 major areas of reform. Some of the most important are the following. Consumer protection to oversee financial products like credit cards, loans, and mortgages, which is one of the main reforms to ensure transparency and prevent abusive practices by financial institutions. They also created, like previously referred, the FSOC to identify risk in financial institutions and market practices. The Volcker rule, restricted prior proprietary trading by banks and limited their investment in hedge funds and private equity to reduce risky activities. They also increased oversight of credit rating agencies, holding them accountable for the accuracy of their ratings. They impose stricter standards for mortgage lending to ensure borrowers can repair loans, aiming to prevent subprime lending abuses. In the end, they also established the Federal Insurance Office FIO to monitor the insurance industry, especially concerning systemic risk and international agreements. The US regulators.

Also implemented reforms to improve the quality and frequency of different data. Focusing on mutual fund reporting, liquidity risk, and stress testing.

Some European Financial regulatory reforms were also analyzed, such as the Alternative Investment Fund Managers Directive (AIFMD). “The Alternative Investment Fund Managers Directive (AIFMD) is a European Union (EU) regulation that applies to alternative investments, many of which were left largely unchecked prior to the 2008-09 global financial crisis. The directive sets standards for marketing around raising private capital, remuneration policies, risk monitoring, and reporting, as well as overall accountability. The primary goal of the AIFMD is to protect investors as well as reduce some of the systemic risks that alternative investment funds can pose to the EU and its economy.” Says A. Hayes (2021) in “Alternative Investment Fund Managers Directive (AIFMD)”

New regulations such as the Markets in Financial Instruments Directive (MiFID II) and European Market Infrastructure Regulation (EMIR) also appeared after the crisis to increase the transparency and accountability of the different markets and to reduce the risk associated with derivative trading. Finally, the paper focuses on the possible future areas of financial regulations. The different examples given are, firstly the LIBOR transition. Which is a benchmark interest rate that is used globally in financial contracts of any type. However, some concerns about manipulation and reliability have risen in the past years. And so, regulators initiated its phase-out. In 2021 the Secured Overnight Financing Rate (SOFR) has emerged as its replacement. This transition includes multiple risks, with contract changing, managing financial reports, etc. A second example included in this paper is the issue of cybersecurity. Financial markets are becoming more and more digital. With it, the protection of financial infrastructure has become one of the top priorities. It is not impossible to see the trading platforms, financial data, etc. being attacked causes large-scale market instability. Financial institutions are investing in advanced security measures such as real-time monitoring, incident

response protocols, and regulatory compliance frameworks like the EU's General Data Protection Regulation (GDPR). With these two being the main preoccupation right now, the paper still talks about the pension fund underfunding and when the promised future payments exceed their assets. Or as the Central Clearing Counterparties and the market fragmentation and equity market resiliency that is happening in the financial world nowadays. To conclude, the paper *"The Decade of Financial Regulatory Reform: 2009 to 2019"* by Novick et al. (2020) shows us that the evolution of financial regulation after the Great Financial Crisis of 2008 has transformed the market in terms of risk and transparency. The regulatory framework remains a work in progress. And regulations are added every year to adapt to the emerging markets and the shifts in the actual ones.

4. Methodology

Figure 3 a): EBA Disclosed Capital Shortfall vs SRISK 2011

In order to recreate Figure 3 a) from Acharya, Engle, and Pierret (2014), the capital shortfall estimate presented in the EBA stress test published in July 2011 (EBA_Shortfall.RWA) was regressed on the capital shortfall estimates SRISK under V-Lab stress scenario, in € millions. The disclosed capital shortfall estimates in the 2011 EBA stress test are given by

$$Disclosed\ Capital\ Shortfall\ =\ \max(0, [k' * RWA_S - Capital_S]) \qquad (3)$$

Where k' is the 5% prudential capital ratio used in the 2011 EBA stress test (Acharya, Engle, and Pierret 2014). RWAs are the risk-weighted assets of each bank at the end of the adverse stress test scenario (Acharya, Engle, and Pierret 2014), on 31/12/2012, given by item 30025 "Capital adequacy – Risk-weighted assets after the effects of mandatory restructuring plans publicly announced and fully committed before 30 April 2011". $Capital_S$ refers to the capital level of each bank also at the end of the adverse stress test scenario (Acharya, Engle, and Pierret 2014), on 31/12/2012, given by item 30035 "Capital adequacy - Core Tier 1 capital after government support, capital raisings and effects of restructuring plans fully committed by 30 April 2011". Python was used for the correct cleaning and treatment of the EBA data to achieve the desired Disclosed Capital Shortfall.

The SRISK capital shortfall estimates were obtained by collecting the SRISK value provided on the V-Lab database for each bank on 31/12/2010 and converting these values to EUR using the relevant historical USD/EUR exchange rate of 0.7518 obtained through Yahoo! Finance (2010).

When cross-referencing the already clean and treated data from EBA and V-Lab it was only possible to identify 26 matching banks out of the 90 banks participating in the 2011 EBA stress test. Since the V-Lab database and SRISK estimations are based on public market-based

information, most of the banks not identified on the V-Lab database were non-public traded banks.

Figure 3 b): EBA Overall Capital Shortfall vs SRISK 2011

To recreate Figure 3 b) from Acharya, Engle, and Pierret (2014), the Overall Shortfall estimates disclosed in the EBA Capital exercise in December 2011 (EBA_Overall_Shortfall) were regressed on the capital shortfall estimates SRISK under V-Lab stress scenario, in € millions.

The overall capital shortfall estimate in the EBA Capital Exercise is given by

$$EBA\ Overall\ Shortfall\ =\ \max(0, [0.09 * RWA - TIC]) + BuffSOV \qquad (4)$$

Where 9% is the target Core Tier 1 capital ratio, RWA_s are the risk-weighted assets of each bank and BuffSOV represents the capital buffer resulting from eurozone sovereign debt exposures (Acharya, Engle, and Pierret 2014).

However, due unavailability of the BuffSOV variable, the overall shortfall was obtained by using item 101300 "Overall Shortfall (+) / Surplus (-) after including sovereign capital buffer and additional impairments on sovereign exposures" on 30/09/2011, from the Capital Composition Data file of the data disclosed regarding the Capital Exercise.

The SRISK capital shortfall estimates were obtained by collecting the SRISK value provided by V-Lab for each bank on 30/09/2011 and converting these values to EUR by using the relevant historical USD/EUR exchange rate of 0.7361 obtained through Yahoo! Finance (2011).

Due to the same restrictions on the availability of SRISK estimates mentioned above, it was only possible to identify 40 banks out of the 90 banks participating in the 2011 EBA stress test.

Figure 4 a): EBA Absolute Risk-based Capital Shortfall vs SRISK 2011

On the recreation of Figure 4 a) from Acharya, Engle, and Pierret (2014), it was regressed the "absolute" risk-based capital shortfall/excess in the EBA stress test disclosed in July 2011

(EBA_Shortfall.RWA (absolute)) on the capital shortfall estimates SRISK under V-Lab stress scenario, in € millions.

The absolute capital shortfall estimates in the 2011 EBA stress test are given by

$$Absolute\ Disclosed\ Capital\ Shortfall\ =\ k' * RWA_S - Capital_S \quad (5)$$

Where k' is the 5% prudential capital ratio used in the 2011 EBA stress test (Acharya, Engle, and Pierret 2014), RWA_s are the risk-weighted assets of each bank at the end of the stress test scenario (Acharya, Engle, and Pierret 2014), 31/12/2012, given by item 30025 "Capital adequacy - Risk-weighted assets after the effects of mandatory restructuring plans publicly announced and fully committed before 30 April 2011"; $Capital_s$ refers to the capital level each bank at the end of the stress test scenario (Acharya, Engle, and Pierret 2014), 31/12/2012, given by item 30035 "Capital adequacy - Core Tier 1 capital after government support, capital raisings and effects of restructuring plans fully committed by 30 April 2011"

The SRISK capital shortfall estimates were obtained by collecting the SRISK value provided by V-Lab for each bank on 31/12/2010 and converting these values to EUR by using the relevant historical USD/EUR exchange rate of 0.7518 obtained through Yahoo! Finance (2010).

Due to the same restrictions earlier mentioned, it was only possible to cross-reference 26 banks from the 90 banks included in the 2011 EBA stress test.

Figure 4 b): EBA Leverage-based Capital Shortfall vs SRISK 2011

To recreate Figure 4 b) from Acharya, Engle, and Pierret (2014), the "absolute" risk-based capital shortfall/excess in the EBA stress test disclosed in July 2011 (EBA_Shortfall.RWA (absolute)) was regressed on the capital shortfall estimates SRISK under V-Lab stress scenario, in € millions.

The leverage-based capital shortfall estimates in the 2011 EBA stress test are given by

$$Capital\,Shortfall\,(TA) \;=\; k * TA_S - Capital_S \qquad (6)$$

Where k is the 5,5% prudential capital ratio used in the 2011 EBA stress test (Acharya, Engle, and Pierret 2014), TA_s are the total assets of each bank at the end of the stress test scenario, 31/12/2012, given by item 30029 "Capital adequacy - Total assets after the effects of mandatory restructuring plans publicly announced and fully committed and equity raised and fully committed by 30 April 2011 "; $Capital_s$ refers to the capital level each bank at the end of the stress test scenario, 31/12/2012, given by item 30035 "Capital adequacy - Core Tier 1 capital after government support, capital raisings and effects of restructuring plans fully committed by 30 April 2011".

Also as described in the methodology of previous figures The SRISK capital shortfall estimates were obtained by collecting the SRISK value provided by V-Lab for each bank on 31/12/2010 and converting these values to EUR by using the relevant historical USD/EUR exchange rate of 0.7518 obtained through Yahoo! Finance (2010).

Due to the same restrictions earlier mentioned, it was only possible to cross-reference 26 banks from the 90 banks included in the 2011 EBA stress test.

Table 3: Realized Volatility Regressions 2011

Realized volatility regressions

On the recreation of Table 3 from Acharya, Engle, and Pierret (2014), the six-month realized volatility after disclosure of the EBA stress test in July 2011 was regressed on the book-to-market ratios from 2011, the Tier 1 Leverage ratios (EBA T1LVGR), the EBA risk weights and the V-Lab risk weights.

The dependent variable: six-month realized volatility after disclosure of the EBA stress test in July 2011 is given by

$$6-Months\ Realized\ Volatility\ =\ \sqrt{\frac{1}{W}\sum_{t+1}^{t+1+W}\left(r_{it}-\overline{r_{it,W}}\right)^2} \quad (7)$$

Where W=130 days (six months) and $R_{it,W}$ is the six-month forward average stock return of bank i at time t (the stress test disclosure date 15/07/2011) (Acharya, Engle, and Pierret 2014). To approximate this value, Rob Capellini Director at V-Lab and VRI Technology

The Volatility and Risk Institute (VRI) in the NYU Stern School of Business inquired how the estimate of annualized volatility, for which it answered the following: “Each CSV file contains a 'var' column with the daily variance for the firm. To obtain annualized volatility figures, multiply the column values by 252 and take the square root.” Once the annualized volatility was obtained, it was divided by 2 in order to get the 6-month volatility that was our independent variable as shown in equation (7).

$$6-Months\ Volatility\ =\ \frac{\sqrt{var*252}}{\sqrt{2}} \quad (8)$$

The Book-to-market ratios in 2011 were obtained through LSEG Workspace.

The EBA T1LVGR is the ratio of Tier 1 capital to total assets at the end of the stress scenario (Acharya, Engle, and Pierret 2014), given by dividing item 30035 "Capital adequacy - Core Tier 1 capital after government support, capital raisings and effects of restructuring plans fully committed by 30 April 2011” by item 30029 “Capital adequacy - Total assets after the effects of mandatory restructuring plans publicly announced and fully committed and equity raised and fully committed by 30 April 2011 ” for each bank.

The EBA risk weight is the ratio of risk-weighted assets to total assets at the end of the stress scenario (Acharya, Engle, and Pierret 2014), 31/12/2012, given by dividing item 30025 “Capital adequacy - Risk-weighted assets after the effects of mandatory restructuring plans publicly announced and fully committed before 30 April 2011” by item 30029 “Capital

adequacy - Total assets after the effects of mandatory restructuring plans publicly announced and fully committed and equity raised and fully committed by 30 April 2011 " for each bank. The V-Lab risk weight estimates were obtained by collecting the LRMES value provided by V-Lab for each bank on 30/06/2011 and applying them to the formula below.

$$V - Lab\ Risk\ Weight\ = (1 - (1 - k) * LRMES)^{-1} \quad (9)$$

The book-to-market ratio was obtained by resourcing to Refinitiv Eikon. With this tool, it was possible to obtain the common shareholder equity and the market capitalization from 2011. The formula of the book-to-market ratio is the following:

$$Book\ to\ Market\ Ratio\ = \frac{Common\ Shareholder\ Equity}{Marekt\ Capitalization} \quad (10)$$

Due to restrictions on the availability of LMRES estimates, book-to-market ratios from 2011, or six-month realized volatility for some of the 90 banks participating in the 2011 EBA stress test at the required date, the regression has 37 data points, contrarily to the 53 data points presented in the original article.

5. Analysis of 2011 Results

Figure 3 a): EBA Disclosed Capital Shortfall vs SRISK 2011

The results of the 2011 recreation of Figure 3 a) are presented below in Figure 1. It is possible to verify that despite the strong limitation on the data available to conduct the recreation of Figure 3 a), the results closely resemble those of the original figure. Consistent with the original results, the recreated figure report values for the EBA Disclosed Capital Shortfall range between €0 and €720 million, with the majority of observations concentrated at the €0 level. Similarly, the SRISK values in the recreated Figure 3 a) align closely with the ones presented in the original figure, ranging between -€4,000 and €94,000 million.

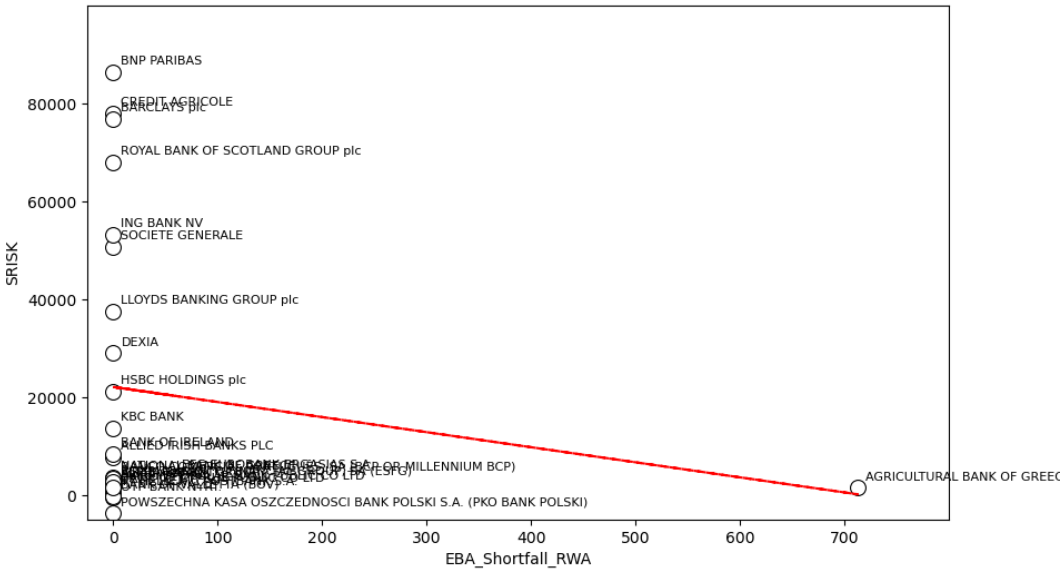

Figure 1: 2011 EBA Disclosed Capital Shortfall vs SRISK

Additionally, the recreated EBA Disclosed Capital Shortfall exhibits an average of approximately €29.64 million, whereas the SRISK value presents an approximate average of €21,189.00 million. These results confirm the conclusion presented in the article "*Testing Macroprudential Stress Tests: The Risk of Regulatory Risk Weights"* by Acharya, Engle, and Pierret (2014), which posits that shortfalls using the V-Lab approach tend to be larger than the ones computed through traditional regulatory stress tests.

The recreated Figure 3 a) presents a correlation coefficient between the two variables of approximately –0.149. However, probably due to the small sample size and the strong uniformization of null results, this metric is not statistically relevant at any conventional significance level.

Although it is not possible to derive confident conclusions from these results, they suggest a disagreement between the EBA stress test results and the SRISK. It should be also noted that the 10 banks that present the highest SRISK values always have a zero EBA Disclosed Capital Shortfall (please verify Annex A)

Figure 3 b): EBA Overall Capital Shortfall vs SRISK 2011

The 2011 recreated Figure 3 b) (figure 2) also closely resembles the corresponding one in the article "*Testing Macroprudential Stress Tests: The Risk of Regulatory Risk Weights"* by Acharya, Engle, and Pierret (2014). Also consistent with the original results, the recreated figure report values for the EBA Overall Capital Shortfall range between €0 million and €15,000, with the majority of observations concentrated between €0 and €4,000. The SRISK values in the recreated Figure 3 b) align closely with the ones presented in the original figure, ranging between -€3,000 and €96,000 million.

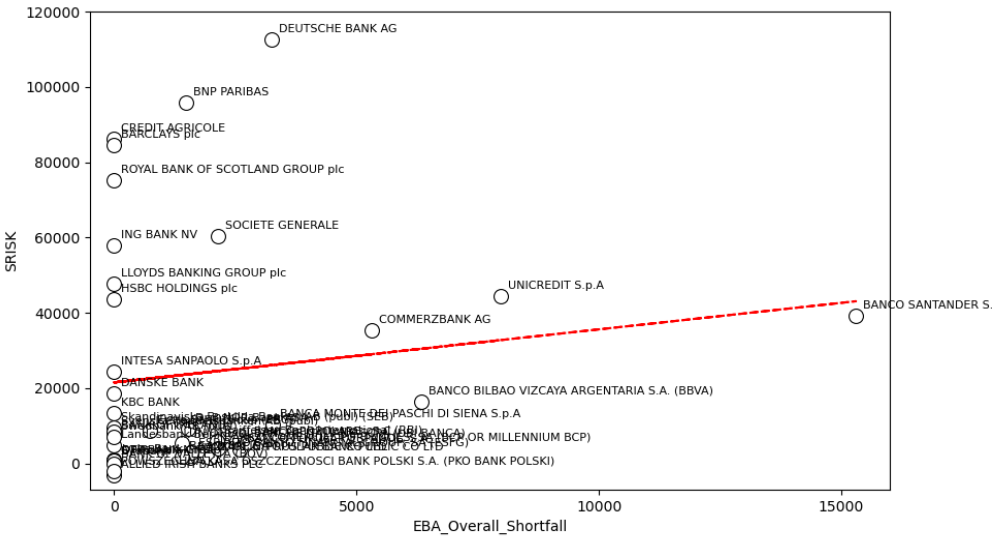

Figure 2: 2011 EBA Overall Shortfall vs SRISK

Furthermore, the recreated EBA Disclosed Overall Shortfall presents an average of approximately €1,619.13 million, whereas the SRISK value presents an approximate average of €23,781.43 million. Although these averages are closer than those observed in the 2011 recreated Figure 3 a), they still exhibit a significant disparity. Once more, this difference reinforces the conclusion presented in the original article, which asserts that shortfalls using the V-Lab approach tend to be larger than the ones computed through traditional regulatory stress tests.

The recreated Figure 3 b) exhibits a correlation coefficient between the two variables of approximately 0.132. Although this figure presents a higher sample size and weaker uniformity for EBA Overall Shortfall values, the correlation between the two variables was not strong enough to present statistically significant results at any conventional significance level.

However, it is essential to observe that six of the most vulnerable banks identified by V-Lab present a €0 Overall Shortfall according to EBA (verify Annex B), suggesting a clear misalignment between EBA and V-Lab stress test results.

Figure 4 a): EBA Absolute Risk-based Capital Shortfall vs SRISK 2011

The 2011 recreated Figure 4 a) (figure 3) also closely resembles the corresponding one in the referenced article. Similarly to the original results, the recreated figure reports values for the "absolute" EBA Disclosed Capital Shortfall range between -€37,00 million and €720, with the majority of observations concentrated between -€5,000 and €0. The SRISK values in the recreated figure also align closely with the ones presented in the original figure, ranging between -€4,000 and €94,000 million, similar to the 2011 recreated Figure 3 a).

Additionally, the recreated EBA Absolute Disclosed Capital Shortfall exhibits an average of approximately -€6,330.16 million, whereas the SRISK value presents an approximate average of €21,189.00 million. These results confirm the conclusion presented in the article "*Testing Macroprudential Stress Tests: The Risk of Regulatory Risk Weights"* by Acharya, Engle, and

Pierret (2014), which posits that shortfalls using the V-Lab approach tend to be extremely larger than the ones computed through traditional regulatory stress tests.

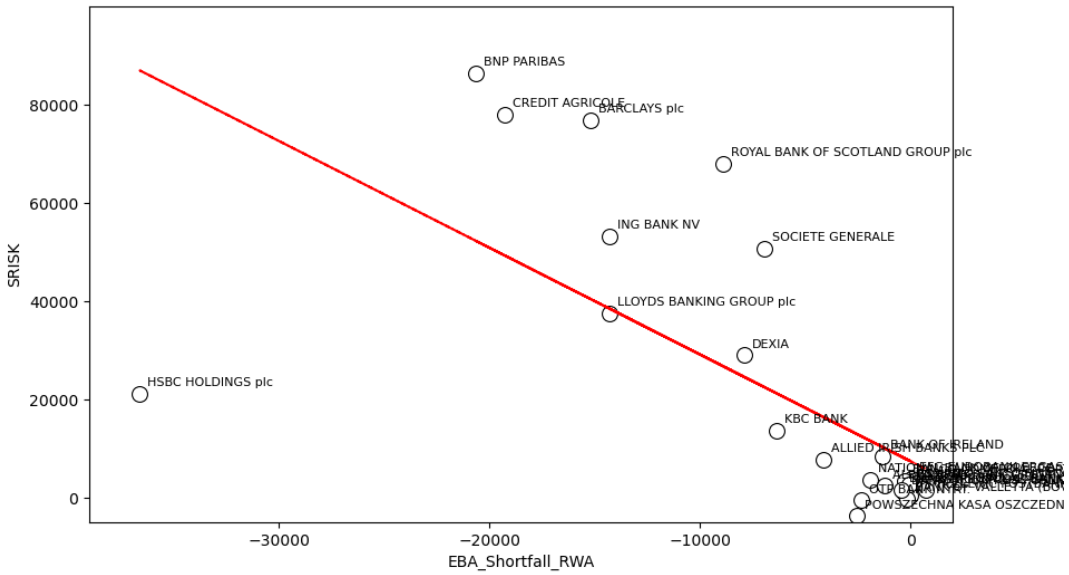

Figure 3: 2011 Absolute EBA Capital Shortfall vs SRISK

The recreated Figure 4 a) reveals a correlation coefficient of approximately –0.672, which is statistically significant at the 1% level. This strong negative correlation robustly emphasizes the divergence between EBA stress tests and V-Lab stress test results, reaffirming the conclusions presented by Acharya, Engle, and Pierret 2014. This misalignment is further reinforced by the observation that the 10 of the safest banks identified by the EBA are categorized as the least safe by the V-Lab (verify Annex C and D).

Figure 4 b): EBA Leverage-based Capital Shortfall vs SRISK 2011

The results of the 2011 recreation of Figure 4 b) are presented below in Figure 4. It is possible to verify that despite the strong limitation on the data available to conduct the recreation of the figure, the results closely resemble those of the original figure. Consistent with the original results, the recreated figure reports values for the EBA Leverage-based Shortfall ranging between -€8,300 million and €73,000 million, with most observations concentrated between

€0 and €8,000 million. Similarly, the SRISK values in the recreated Figure 4 b) align closely with the ones presented in the original figure, ranging between -€4,000 and €94,000 million.

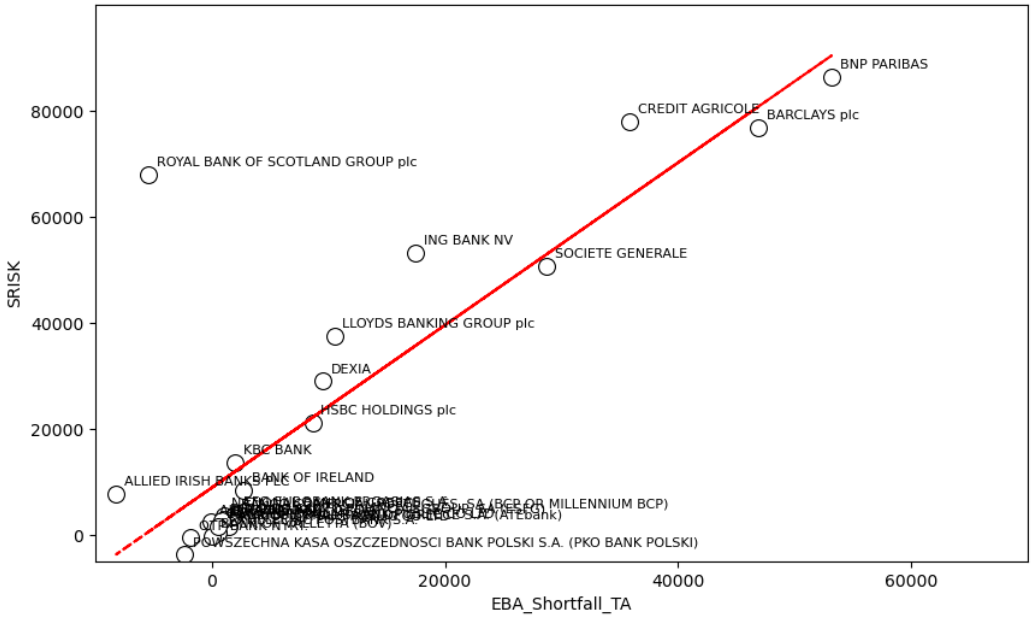

Figure 4: 2011 EBA Leverage-based Shortfall vs SRISK

Additionally, the recreated EBA Leverage-based Shortfall exhibits an average of approximately €8,001.12 million, whereas the SRISK value presents an approximate average of €21,189.00 million. These results confirm the conclusion presented in the article "*Testing Macroprudential Stress Tests: The Risk of Regulatory Risk Weights"* by Acharya, Engle, and Pierret (2014), which posits that shortfalls using the V-Lab approach tend to be larger than the ones computed through traditional regulatory stress tests.

The recreated Figure 4 b) exhibits a positive correlation coefficient of approximately 0.833, which is statistically significant at the 1% level. This result strongly reinforces the conclusions presented by Acharya, Engle, and Pierret 2014 that the correlation between the EBA regulatory Shortfall and SRIKS increases significantly when the EBA shortfall is measured in function of total assets and not risk-weighted assets. Furthermore, it is also possible to verify in Annexes

E and F, that there are eight common banks among the riskiest banks according to the V-Lab and EBA stress tests.

Table 3: Realized Volatility Regressions 2011

	1	2	3	4	5	6
Constant	0,343	-0,0022	0,3872	0,3418	0,0293	-0,0114
Book to Market	0,0481	0,0388	0,0459	0,048	0,0376	0,0309
Vlab Risk Weight		0,1858			0,183	0,1952
EBA T1 lvrg			-0,9503		-0,5707	-1,6097
EBA Risk Weight				0,0022		0,1314
F test	4,28	6,24	2,28	2,08	4,1	3,31
Adj R2	8,81%	23,55%	7,01%	5,96%	21,48%	21,39%

Table 1: 2011 Realized Volatility Regressions

The table represents regression results assessing the relationship between various financial indicators commonly used in banking and financial risk analysis. The constant values range from -0.0114 to 0.0481, providing baseline values for the dependent variable when all explanatory variables are set to 0, indicating a mix of positive and negative intercepts across different models. Among these explanatory variables, the book-to-market ratio shows a positive coefficient in all models, suggesting a consistent positive relationship with the dependent variable even though the magnitude of this effect varies. The V-lab risk weight displays a significant coefficient in certain models, particularly 0.1858, 0.1830, and 0.1952. Highlighting its role in explaining variation in the dependent variable. Conversely, the EBA Tier 1 leverage ratio shows a negative coefficient ranging from -0,5707 to -1,6097 indicating a strong inverse relationship. Implying that higher leverage ratios are associated with lower outcomes in the dependent variable. The EBA risk weight appears in two models with a

relatively small positive coefficient of 0.0022 and 0.1314, suggesting a limited direct effect in this specific context. The overall significance of the regression models is reflected in the F-test values, which range from 2.08 to 6.24 and indicate varying levels of model fit. The highest F-test value of 6.24 points to a more statistically significant model compared to others. The adjusted R^2 values spanning from 5.96% to 23.55%, suggest that while some model provides moderate explanatory power, others leave substitutional space for evolution. In the end, these results show a complex interplay between financial risk indicators and the dependent variable and show the need for further analysis and potential model refinement.

The recreation of Table 3 was made difficult by the data retrieving. Comparing our recreation to the table in the paper from Acharya, Engle, and Pierret (2014), we can see that the result is not the same. Still, we were able to find negative values were expected as well as logical results such as the fact that for example, the constant of model 3 was also in the paper from 2014 bigger than the constant in model 5. We, therefore decided to continue with these results and assume that our methodology was good for the rest of the paper.

After understanding how to recreate the different stress tests, and where to find the data. We had to choose a year after 2011 to recreate the same tests, so we could see if the banking risk in Europe had changed with some new regulations. Therefore, we did some research on the different changes in banking regulation.

6. Changes in Banking Regulation

After the 2008 Great Financial Crisis, a significant number of major regulations changed the financial markets. After some research here are the main regulations impacting the financial and banking market. And the years they have been implemented. All the regulations changes

can be found in annex X in a table retrieved from “The Decade of Financial Regulatory Reform: 2009 to 2019”. Doing such will help us choose a year to analyze.

2010-2011: Basel III

The paper "Testing Macroprudential Stress Tests: The Risk of Regulatory Risk Weights" by Acharya, Engle, and Pierret (2014) studies data from 2011, by doing so, it takes into account the Basel III agreements. “Basel III is an international regulatory accord for reforms designed to mitigate risk within the international banking sector by requiring banks to have more capital on hand.” says Peter Gratton in the article “Basel III: What It Is, Capital Requirements, and Implementation”. It increases capital requirements, introducing a minimum Common Equity Tier 1 (CET1) ratio of 7% and a Total Capital Ratio of 10.5%. Basel III also includes a 3% leverage ratio to prevent over-leveraging and liquidity standards like the Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSFR) to ensure short- and long-term stability.

2016: Bail-In and Single Resolution Mechanism (SRM)

This regulation implemented the “bail-in” principle. This means that now, shareholders and creditors are the first to bear losses in the event of bankruptcy. This has changed the risk expectations of banks.

2018: MIFID II

A. Hayes in the article “Alternative Investment Fund Managers Directive (AIFMD)”, Mar 2021 stated that “MiFID II is one of the most important pieces of legislation enacted in finance and investing this century. Rolled out in 2018 by the European Union (EU) to regulate financial markets while increasing protections for investors, it aimed to standardize financial practices across the EU and restore confidence in the industry, especially after the 2008 financial crisis. It focuses on three key areas: service model, product development, and product placement.”. This has been implemented to enhance transparency, investor protection, and market integrity. Introducing stricter rules on trading and investment services.

2021: Basel IV requirements come into force (pre-Basel III adjusted)

Basel IV is following the Basel III agreements and is just an extension of it. The implementation of it still imposed stricter constraints on risk weights for banks. This had a direct impact on the bank's capital ratio and the risks faced.

External Elements

Coming with the choice of years to study, not only the different regulations changes are relevant. We also have to take into account the different external elements that happened over the last decade that could've impacted the financial market over the years. For example, the reference paper *"Testing Macroprudential Stress Tests: The Risk of Regulatory Risk Weights"* by Acharya, Engle, and Pierret (2014), takes into account the European debt crisis that affected the country such as Spain, Italy, Portugal, and most of Greece.

2014: Geopolitical tensions and sanctions against Russia

During that year, the European Union imposed economic sanctions on Russia, restricting the trade and investments made with them. This followed Russia's annexation of the Crimea region. Therefore, for European banks having customers in Russia, this created an increase in the risk of credit and liquidity and a loss of possible opportunities in this region of the world.

2016: Brexit

The Brexit was voted the 23/06/2016. The United Kingdom's leaving the European Union disrupted different markets such as the financial and banking market. This created a lot of uncertainties for banks operating in this region. After that, banks had to reorganize their operations. Some of them relocate their activities previously done in London to another part of Europe. Therefore, they had to meet new regulations and financial challenges.

2020: COVID-19 Pandemic

The COVID pandemic was unprecedented, and with it, a global recession came. Exposing banks to great credit risks, as different businesses or households were not able to meet their debts. Different governments around the world responded with supportive policies. But even with drastic measures, banks remain exposed to potential long-term credit defaults.

Also, over the years the question of sustainable finance and climate risks have been one of the main issues that banks faced. More pressure was put on banks to reassess the risks associated with their non-sustainable assets. They must now take into account the transition risk associated with climate change. With this comes an increase in the difficulty of risk management.

Decision of the Years

We therefore decided to analyze with the same method as 2011 the years 2016 and 2018. We came to this conclusion by looking at what years have seen the most change in banking regulations as well as external elements that could have impacted the banking system and European banks. 2016 was a year seeing new regulations being implemented as well as the Brexit happening both of these created a new environment for European banks. As for 2018 the MIFID II regulations are significant in the banking industry and are worth looking at more in depth their impact on the European banks that we will study in the rest of this paper.

7. Comparative Macroprudential Stress Testing: Assessing European Banks in 2018

2018 Overview and Regulations

In 2018, the European Union continued its trajectory of economic recovery and expansion after the major impacts of the 2008 financial crisis and the following European sovereign debt crisis. According to Eurostat (2024) data, the Real GDP rate for the European Union recorded 2018 a 2.1% increase compared with the previous year. Although this expresses continuous economic growth, it marks a slowdown compared with the higher growth rate presented in previous years. Additionally, the EU's unemployment rate exhibited a continuous decreasing trend since 2013, reaching in 2018 a rate of 7.4% (Eurostat 2009-2020), one of the lowest values in the decade, highlighting significant progress on the labor market recovery and economic stabilization. Furthermore, the same source indicates that the EU presented in 2018 a General Government Gross Debt (% of GDP) of 79.5% (Eurostat 2012-2020), reflecting a substantial reduction from the peak of 86.9% in 2014 at the height of the debt crisis. Finally, it was also reported in 2018 an Inflation rate of 1.8% (Eurostat 2012-2023). By briefly analyzing these indicators it is possible to recognize the EU's efforts on economic recovery and expansion.

Besides the implementation of MIFID II previously explained, that strongly affected investment banks, it is possible to identify in the regulatory changes the commitment of the EU and its institutions to enhance the resilience of the banking sector. Among the most significant reforms from 2011 to 2018 was the progressive introduction of the Basel III Framework, which completed its post-crisis reforms in 2017 as part of an extensive reaction to the 2008 financial crisis (Bank for International Settlements n.d.). Furthermore, the framework mandated stricter

standards for the quality and quantity of regulatory capital; an additional layer of common equity (the capital conservation buffer), that when violated restricts payouts; the definition of a minimum amount of loss-absorbing capital relative to all of a bank's assets and off-balance sheet exposures irrespective of risk weighting; the Liquidity Coverage Ratio, intended to provide sufficient cash to cover funding needs over a 30-day period of stress (Bank for International Settlements n.d.), among other reforms. Of particular importance is the increase on the minimum Commons Equity Tier 1 to 4.5% of RWA, after deductions (Basel Committee on Banking Supervision, 2010).

The 2018 EBA stress test presents significant differences compared to the 2011 stress test which should also be noted. Unlike the 2011 stress test, which evaluated the resilience of banks over a two-year period, the exercise in 2018 covers a period of 3 years (from the end of 2017 to the end of 2020) under a common macroeconomics baseline and adverse scenarios (European Banking Authority 2018). The 2018 adverse scenario accounted for systematic risks threatening the EU banking sector's financial stability, including GDP growth projections of 1.2%, -2.2%, and 0.7% in 2018, 2019, and 2020, respectively (European Banking Authority 2018).

A significant change in the 2018 EBA stress tests was the implementation of the IFRS 9, replacing IAS 39, which, according to the European Banking Authority (2018), "introduced revised provisions for the classification and measurement of financial instruments, impairment, and hedge accounting". The new Expected Credit Losses (ECL) impairment model requires banks to update the amount of ECL recognized at each reporting period taking into consideration all past, present, and forecasted available information, rather than solely recognizing losses when evident (European Banking Authority 2018). According to the "2018 EU-Wide Stress Test Results" also published by the European Banking Authority (2018), the

adoption of IFRS 9 led to a 10 basis points decrease in the Common Equity Tier 1 capital ratio when restating 2017 figures according to IFRS 9.

In the conclusion of the article "*Testing macroprudential stress tests: The risk of regulatory risk weights"*, Acharya, Engle, and Pierret (2014) refer to the following main results. Firstly, the required capitalization according to the V-Lab stress test tends to be larger than in regulatory stress tests, especially in Europe. Additionally, Acharya, Engle, and Pierret (2014) conclude that when capital adequacy is a function of risk-weighted assets in regulatory stress tests, the ranking of financial institutions by capital shortfall deviates considerably from the V-Lab ranking, which is confirmed by the negative correlations presented in Figures 3 a), 3 b) and 4 a) recreated for 2011 (figure 1, 2 and 3). However, Acharya, Engle, and Pierret also state that when regulatory stress tests rely on total assets the correlation with V-Lab results increases significantly, which can also be verified by the significant increase in the correlation of Figure 4 b) of the 2011 recreation (figure 4).

With the purpose of expanding the comparative analysis conducted on the referred article and incorporating an evolutional analysis, the recreation of Figures 3 a), 3 b), 4 a), and 4 b) as well as Table 3 was also conducted for 2018.

2018 Methodology

For the replication of the required tests, it was necessary to extract data from two primary sources, the V-Lab database and the database of EBA EU-wide stress testing results from 2018.

Following the same data collection methodology applied for 2011, the SRISK values for the period of interest were obtained from the V-Lab database. After importing all the available data it was necessary to identify and match the entities included in the EBA 2018 stress test and its respective LEI_Code. Out of the 48 banks present on the EBA 2018 stress test, it was possible to identify 33 corresponding banks on the V-Lab dataset. As V-Lab uses a marked-based risk

model, most of the banks not identified correspond to banks that are not publicly traded. The only exception to this justification is Nordea Bank Group which is publicly traded on the Helsinki and Stockholm stock exchanges but was not included in the V-Lab database.

In the treatment of the data imported from V-Lab it was crucial to convert the SRISK values from USD to EUR using the USD/EUR exchange rate of 0.8374 on 29/12/2017 (Yahoo! Finance 2017).

To obtain the necessary data from the database of 2018EBA EU-wide stress testing results the TRA_OTH.csv file was extracted. Data cleaning and transformation were conducted in Python, consistent with the methodology employed in the 2011 recreation. The data was filtered to include only values corresponding to the end of the stress scenario in December 2020, specifically under the Adverse scenario.

The items used for Figures 3 a), 4 a), and 4 b) were items 183507 "Total Risk Exposure Amount", 183106 "Common Equity Tier 1 Capital" and 183111 "Total Leverage Ratio Exposures", corresponding to RWA, $Capital_S$, and TA, respectively. Considering the lack of a clear item of TA as in the 2011 dataset, the Total Leverage Ratio Exposure was considered to be the best proxy possible. According to the European Central Bank (n.d.), this item includes some on-balance-sheet assets and some off-balance-sheet items, irrespective of how risky these are, which provide a more complete picture of the bank's total exposure. However, it is important to note that the inclusion of off-balance-sheet items can overestimate the bank's exposures, leading to an overly conservative representation of its financial position, and incorporate a potential misalignment with accounting metrics.

Figure 3 a): EBA Disclosed Capital Shortfall vs SRISK 2018

To replicate Figure 3 a), after completing the necessary cleaning and transformation of the data, it was used the same formula as in 2011 to calculate the Disclosed Capital Shortfall (3)

(EBA_Shortfall.RWA), applying the 2018 EBA dataset with the corresponding items above mentioned. However, after the application of the formula, all banks presented a Disclosed Shortfall equal to 0.

To ensure consistency with the analysis conducted for 2011, the SRISK values extracted referred to the last working day of 2017, which was 29/12/2017, also using Python for that purpose.

Subsequently, the data from the EBA dataset and V-Lab dataset were cross-referenced using the LEI_Code identifier, merging into a final sample size of 33 data points. Lastly, the visualization of the relation between the Disclosed Capital Shortfall and the SRISK was also conducted through Python. As expected, due to the uniformly zero values obtained for the Disclosed Capital Shortfall it was not possible to plot the linear regression between the two variables and neither assess its correlation.

Figure 3 b): Overall Capital Shortfall vs SRISK 2018

As previously mentioned in this report, for the 2011 recreation of Figure 3 b) it was used item code 101300 “Overall Shortfall (+) / Surplus (-) after including sovereign capital buffer and additional impairments on sovereign exposures”, from the EBA database. However, an equivalent or suitable proxy item for this metric could not be identified in the 2018 database.

As an alternative it was analyzed the possibility of following equation (4) presented in the article “*Testing macroprudential stress tests: The risk of regulatory risk weights”* by Acharya, Engle, and Pierret (2014), but no item was found to properly represent the *BuffSOV* component. Consequently, it will not be possible to conduct a comparative or evolutionary analysis between the EBA overall shortfall and SRISK based on the available data.

Figure 4 a): EBA Absolute Risk-based Capital Shortfall vs SRISK 2018

The recreation of Figure 4 a) followed a similar methodology to Figure 3 a). On the calculation of the "absolute" risk-based capital shortfall/excess (EBA_Shortfall.RWA), the same formula used in the recreation of Figure 4 a) in 2011 (5) was applied to the 2018 EBA dataset using the corresponding items above mentioned.

Again, to ensure consistency with the analysis conducted for 2011, the SRISK values extracted referred to the last working day of 2017, which was 29/12/2017, also using Python for that purpose.

Following the same process of the remaining figures, the data from the EBA dataset and V-Lab dataset were cross-referenced using the LEI_Code identifier, merging also into a final sample size of 33 data points. Lastly, the visualization of the relation between the "absolute" Disclosed Capital Shortfall and the SRISK was also conducted through Python. Differently from the 2018 recreation of Figure 3 a), as the "absolute" Disclosed Capital Shortfall does not present uniform outcomes, it was possible to compute a linear regression and the correlation between the two variables.

Figure 4 b): EBA Leverage-based Capital Shortfall vs SRISK 2018

Lastly, the 2018 recreation of Figure 4 b) followed the same methodology and formula (6) used for the 2011 recreation of Figure 4 b), applying it to the 2018 dataset and using the corresponding items earlier mentioned.

The SRISK values were also extracted to the last working day of 2017, which was 29/12/2017, again, using Python for that purpose.

Subsequently, the data from the EBA dataset and V-Lab dataset were cross-referenced using the LEI_Code identifier, merging also into a final sample size of 33 data points. Python was used for the visualization of the relation between the Capital Shortfall (TA) and the SRISK as

presented in Figure 9. It was possible to compute the linear regression and the correlation between the two variables.

Table 3: Realized Volatility Regressions 2018

Lastly, for the recreation of Table 3 on the realized volatility regressions it was followed the same methodology as previously employed for the recreation of the same table for the 2011 data.

To calculate the 6-month realized volatility the same formula presented by the VRI (8) was followed for the V-Lab data on the desired date (30/12/2018).

Also to ensure coherency with the 2011 results, the Book-to-market ratios were obtained through the same source, Refenitiv EIKON.

The calculation of the V-Lab Risk Weight formula (9) was followed, based on LMRES values present on the V-Lab dataset for each bank on 30/12/2018.

The EBA T1LVGR was defined as the ratio between Tier 1 Capital and TA at the end of the stress scenario (Acharya, Engle, and Pierret 2014). The item used as Tier 1 Capital was 183106 "Common Equity Tier 1 Capital" at the end of the EBA stress test scenario. As mentioned in the previous figures, since no direct TA item was available on the EBA 2018 dataset, item 183111 "Total Leverage Ratio Exposure" was utilized as a proxy on this calculation.

The EBA risk weight was computed by dividing the RWA by the TA, using the respective items "Total Risk Exposure amount" and the "Total Leverage Ratio Exposure" respectively.

Upon cross-referencing the dataset of EBA, V-Lab, and Refenitiv EIKON, it was only possible to recreate the required regressions for 23 data points.

2018 Analysis of Results

Figure 3 a): Disclosed Capital Shortfall vs SRISK 2018

The analysis of the results of the 2011 recreation results of Figure 3 a) was already conditioned by the reduced sample size and the pronounced uniformization of the Disclosed Capital Shortfall values. Although this uniformity was not absolute, as in 2018, it did not allow to present a statistically relevant correlation between the Disclosed Capital Shortfall and the SRISK, and, therefore, confidently derive conclusions from the results. Similarly, the 2018 recreation analysis also does not allow to determine any correlation between the two variables for the reason above explained in the 2018 methodology and possible to see on figure 5. Despite that, it is crucial to investigate the behavior of the Disclosed Capital Shortfall variable and the factors that influence it.

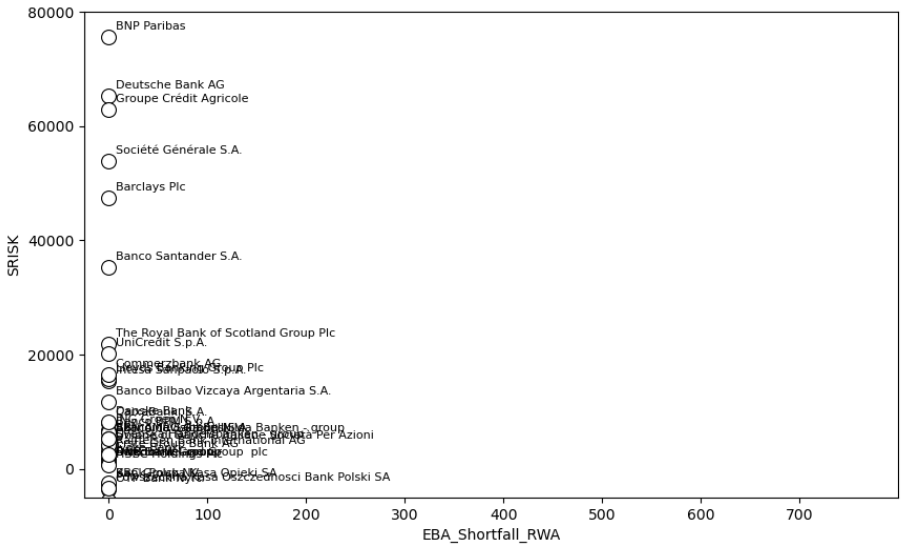

Figure 5: 2018 EBA Disclosed Capital Shortfall vs SRISK

One of the possible explanations for the null values observed may be the fact that the initial levels of Capital$_S$ were already significantly higher than the RWA at the beginning of the stress tests compared with 2011, resulting from the effect of regulatory reforms and capital strengthening initiatives after 2011, like Basel III. To evaluate this possibility, it was useful to

compare the initial levels of $Capital_S$ and RWA during the 2011 and 2018 EBA stress tests. Since no data at the beginning of the stress tests was available for the items used as $Capital_S$ and RWA on the 2011 recreation the comparison was conducted to the earliest dates possible, 31/12/2011 and December 2018. When comparing the increase in the initial average level of $Capital_S$ and RWA it is possible to note that the increase in the initial levels of $Capital_S$ from 2011 to 2018 was significantly higher than the increase in the initial levels of RWA in the same period, approximately 86.49% compared to 35.31% respectively.

The relatively lower increase in the RWA aligned with the decreasing effect of the k factor of 5.5%, resulted in an overall reduction of $k' * RWA_S - Capital_S$. Despite this reduction, the levels of $Capital_S$ and RWA exhibited variations of -4.17% and 5.03%, respectively, from December 2018 to December 2020. However, this inverse relationship that favored a potential increase of $k' * RWA_S$ remained insufficient to deliver a positive Disclosed Capital Shortfall.

It is important to note that this evolutional analysis between 2018 and 2011 is constrained by the differences in the samples. The 2011 sample is significantly larger than the 2018 sample and does not include the same banks. The comparison serves primarily to understand the overall conditions of the banks that EBA found relevant to analyze in each respective year.

Figure 4 a): EBA Absolute Risk-based Capital Shortfall vs SRISK 2018

An analysis of the 2018 recreation of Figure 4 a) reveals that all the Aabsolute risk-based capital shortfall/excess are negative, ranging from -€40,000 to -€970 million, with a considerable concentration between -20,000 and -2,000. These values mean that banks' $Capital_S$ exceeds the capital threshold, even under the adverse scenario. Accordingly, it suggests that none of the banks present in the sample are falling short of the regulatory capital requirements. Compared with the 2011 recreation of the same figure, 2018 presents a considerably lower average for the absolute risk-based capital, approximately -€6,330.16 million in 2011 versus -€11,262.19

million in 2018. This difference may be justified by the larger increase in Capital$_S$ compared to the increase of RWA and the improvement of the economic and financial landscape in Europe, as also mentioned in the analysis of the 2018 recreation of Figure 3 a).

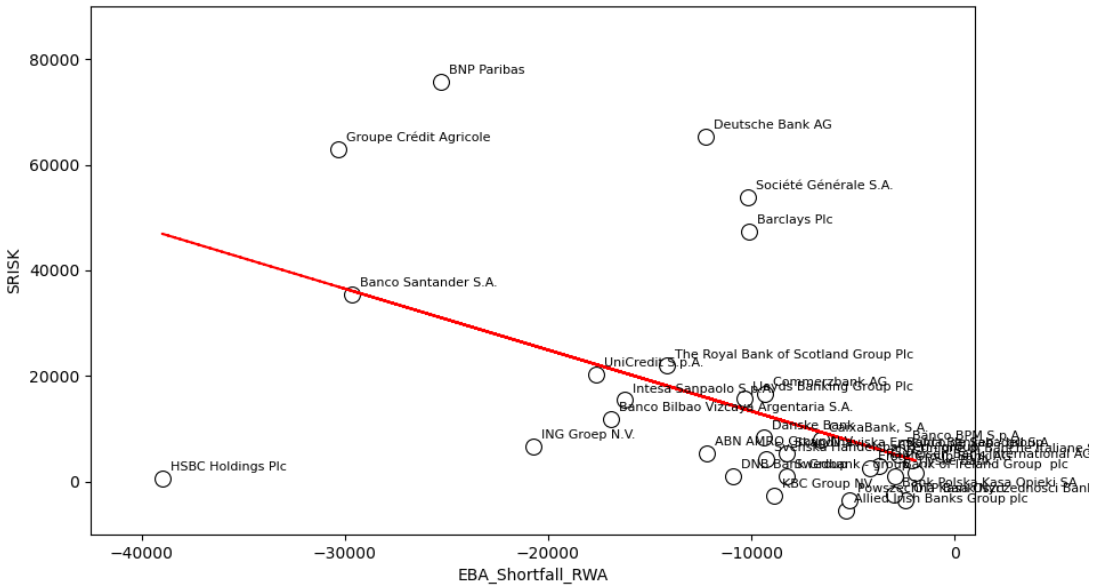

Figure 6: 2018 EBA Absolute Capital Shortfall vs SRISK

SRISK values range from -€5,500 to 80€,000 million, presenting also a lower average of €14,830.20 million in comparison with the 2011 average of €21,189.00 million. This difference is likely attributed to improved capital adequacy among banks and enhanced economic stability relative to 2011.

However, it is important to acknowledge that this evolutional analysis between 2018 and 2011 is constrained by the differences in the samples presented. The 2011 sample is significantly larger than the 2018 sample and does not include the exact same banks. The comparison serves primarily to understand the overall conditions of the banks that EBA found relevant to analyze in each respective year.

Similar to the 2011 recreation of Figure 4 a) and the original Figure 4 a) of the article "*Testing macroprudential stress tests: The risk of regulatory risk weights"* by Acharya, Engle, and

Pierret (2014), the 2018 “absolute” risk-based capital shortfall and SRISK variables reveal a negative correlation of approximately -0.481 at a 99% confidence level. Although this value is notably lower than those computed in the original article and on the 2011 recreation, -0.790 and -0.672 respectively, it still emphasizes the discrepancies in outcomes between EBA stress tests and V-Lab stress tests. This divergence is further reinforced by the observation that six of the safest banks identified by the EBA are categorized among the least safe by the V-Lab (verify Annex H and I).

Figure 4 b): EBA Leverage-based Capital Shortfall 2018

Figure 4 b) employs an alternative approach for the measurement of capital requirements, considering a distinct definition of capital adequacy in stress tests based on the Tier 1 leverage ratio (Acharya, Engle, and Pierret 2014).

By analyzing Figure 7 it is possible to state that the leverage-based shortfall in 2018 ranges from -€9,000 to €40,000 million, with a higher concentration on values between €0 and €20,000 million. Contrary to the remaining figures based on risk-weighted assets that present mostly null or negative values for the regulatory shortfalls, in Figure 4 b), only 8 out of 33 banks present negative values. Suggesting that under this approach most banks are falling short

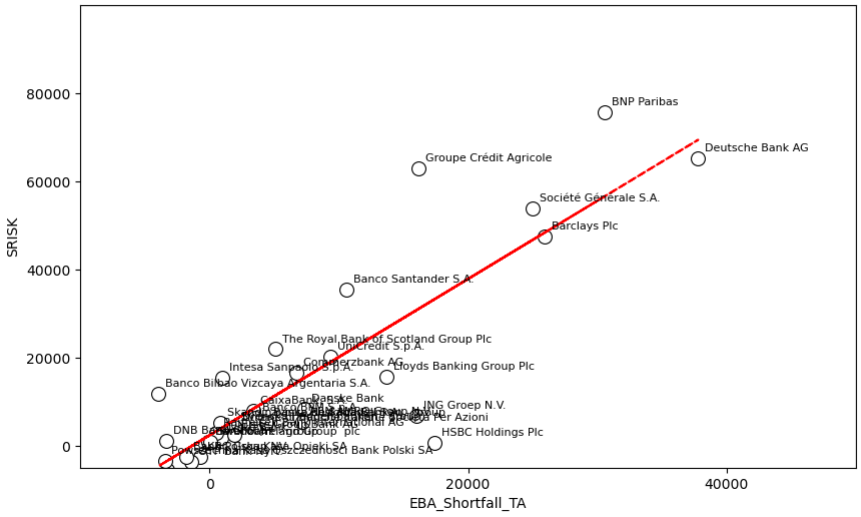

Figure 7: 2018 EBA Leverage-based Shortfall vs SRISK

of the regulatory capital requirements under the adverse scenario. The average leverage-based shortfall in the 2018 recreation is similar to the average leverage-based shortfall in the 2011 recreation, approximately €7,013.19 and €8,001.12 million respectively.

Moreover, as also referred to in the same analysis, it is essential to consider the differences in the sample sizes and content when conducting a comparative analysis between 2011 and 2018.

The SRISK variable exhibits exactly the same behavior as described in the 2018 analysis of Figure 4 a).

In terms of the relationship between the leverage-based shortfall and the SRISK, as in the recreation of 2011, the variables computed a significant positive correlation of approximately 0.853. Additionally, and as expected, 8 out of the 10 less safest banks considered in the V-Lab stress tests are present on the 10 less safest banks according to this EBA stress test approach (please verify Annex J and K). These results emphasize the conclusions presented by Acharya, Engle, and Pierret (2014) in the article "*Testing macroprudential stress tests: The risk of regulatory risk weights"* that the correlation between SRISK and the EBA regulatory shortfalls increases drastically when the last is computed as a function of total assets. Suggesting that the incorporation of leverage-based measures of risk would enhance the effectiveness of regulatory stress tests.

Table 3: Realized Volatility Regressions 2018

The 2018 recreation of Table 3 is presented below in Table 2, displaying the results of regressing different risk factors on the 6-month realized volatility, as defined earlier. The first row of the table presents the values expected for the dependent variable when the remaining Book-to-market and risk factors are set to 0. The positive values are consistent with the expectation that markets typically exhibit some level of baseline volatility, even without the influence of the specific risk factors analyzed.

	1	2	3	4	5	6
Constant	0,1791	0,1566	0,1001	0,1336	0,0831	0,0778
Book to Market	0,0126	0,0112	0,0226	0,0149	0,0216	0,0222
Vlab Risk Weight		0,0157			0,0119	0,0138
EBA T1 lvrg			1,0837		1,081	1,1943
EBA Risk Weight				0,1185		-0,0146
F test	2,92	1,44	6,58	5,48	4,21	2,99
Adj R2	8,02%	3,83%	33,66%	28,95%	30,41%	26,62%

Table 2: 2018 Realized Volatility Regression

As detailed in the 2011 recreation of Table 3, column 2 indicates that the V-Lab Risk Weight contributes positively to the variation of the 6-month realized volatility. However, this model is not statistically relevant.

In column 3, where the regression on the 6-month realized volatility includes the EBA T1LVGR, it is possible to notice the positive effect of this risk factor in the variance of the dependent variable presented by the parameter of 1.0837, which is statistically relevant at the 1% level. This regression presents the higher Adj. R^2 of 33.66% and is statistically relevant at a 1% level, meaning that the regression can explain 33.66% of the behavior of the 6-month realized volatility. These results do not align with the expectations presented in 2011 and with the logical reasoning that banks with higher T1LVGR would be more stable under stress scenarios.

Column 4 shows that the EBA risk weight parameter is also positive and relevant at a 5% significance level. The overall model is also statistically relevant at a 5% level and is able to explain 28.95% of the behavior of the 6-month realized volatility variable.

In column 5 when the regression is conducted in the V-Lab Risk weight and the EBA T1LVGR, the EBA T1LVGR risk factors present a positive parameter and statically relevant at 1% level, contrary to the results presented in 2011 where the EBA T1LVGR exhibits a negative parameter. This regression is able to explain 30.41% of the variation of the 6-month realized volatility and is statistically relevant at a 5% level.

Finally, in column 6, when the EBA Risk Weight is added to the regression, the Adj. R^2 decreases to 26.62%, which contradicts the expectation and results presented in the article *"Testing Macroprudential Stress Tests: The Risk of Regulatory Risk Weights"* by Acharya, Engle, and Pierret (2014). This divergence suggests that in 2018 the EBA Risk Weight variable fails to meaningfully contribute to explaining the variation of the dependent variable. It should be also noted that in this regression the parameter of the EBA Risk Weight turned from positive in column 4 to negative in column 6 and lost its statistical relevance.

8. Limitations

During the recreation of the methodology used for the 2011 analysis in the paper *"Testing Macroprudential Stress Tests: The Risk of Regulatory Risk Weights"* by Acharya, Engle, and Pierret (2014). We found some limitations when applying this methodology to the different years studied in our paper.

First of all, we encountered the same limitations the authors of the article from 2014 did. Namely, the risk-based requirements limitations "It highlights that capital requirements based solely on risk assessments may not adequately protect against changing risk levels over time, particularly for assets like sovereign bonds or mortgages". This suggests that the capital requirements approach may not fully account for evolving financial risks." Acharya, Engle, and Pierret (2014). As well as the fact that we also compare different stress test methodologies with publicly available data. Therefore, the data for some banks were not available. It might also be not as precise as non-public data. This is considered a data limitation. This was visible also in the collection of the Book-to-market ratio of each bank.

But we also encountered new limitations. Limitations that were not present in the 2014 paper. Firstly, the fact that some data needed and used in the stress test methodology of 2011 were not the same or not available in the year we chose to study. For example, the data provided by EBA changed slightly over the years. Which made retrieving data harder than before. Specifically, some data like the total assets of the bank were not available and we had to conduct the analysis with some proxies of the data needed. Therefore, it may not transcript fully the actual values of the desirable variables. Secondly, for specific examples, like the recreation of Table 3, we can also look into the fact that linear regression cannot capture every correlation possible between variables. Finally, with a more critical eye, we can say that the

methodology applied to data in 2011 can be outdated now because of the new financial world we live in today. Therefore, the methodology might not capture what we are expecting as did for the 2011 analysis.

9. Conclusion & Recommendations

The purpose of this report was to critically evaluate the conclusions presented in the article *"Testing Macroprudential Stress Tests: The Risk of Regulatory Risk Weights"* by Acharya, Engle, and Pierret (2014) and further its application to future years. The main point under analysis was the precision of the traditional regulatory stress tests used to evaluate the resilience of European Banks under adverse economic conditions, more specifically its reliance on risk-based measures of capital adequacy.

Although the limitations above mentioned have not allowed for an exact replication of the analysis conducted on the referred article, the conclusions presented in our analysis for 2011 closely resemble the ones presented in the article. Firstly, the required capitalization under the V-Lab approach indeed presented always higher values compared with the EBA regulatory approach, as it is possible to verify in the figures presented and the average shortfalls computed. Secondly, it is possible to see when considering the total assets as the baseline for the regulatory capital requirements, this measure indeed presented a better correlation with the market-based approach, the V-Lab, and similar ranks.

When conducting the same analysis for the further years the following conclusions can be made. Both in 2016 and 2018 the EBA Disclosed Capital Shortfall only presented 0 zero values for all the banks in the sample, indicating that no bank will fall short on the EBA capital requirements under adverse scenarios. Although the resilience of banks has indeed improved over the years, it is not reasonable to state that no bank would exhibit a shortfall under an adverse scenario, which indicates that EBA regulatory shortfalls are underestimated.

Furthermore, the comparison of the EBA Absolute Capital Shortfall with SRISK highlighted the divergences in the results presented by the two stress test methods. This difference was only surpassed when the EBA capital shortfall was computed as a function of total assets. With this adjustment is possible to verify a positive correlation between the two variables for 2016 and 2018, even though the results between the two tests are still unequal.

The biggest limitation in the analysis of 2016 and 2018 was observed in the recreation of Table 3. Due to the limitations already referred to reach statistically relevant results, it was not possible to state secure conclusions on the relevance of the different risk factors. Besides that, it was also not possible to identify a pattern between the 3 years that confirmed the conclusions presented in the article *"Testing Macroprudential Stress Tests: The Risk of Regulatory Risk Weights"* by Acharya, Engle, and Pierret (2014) regarding the relationship between the regulatory risk weights and the 6-months realized volatility.

Overall, all the results from 2016 and 2018 indicate the same conclusion as 2011 and therefore, confirm the fact that "stress tests would be more effective if capital requirements were measured differently from the current static risk-weighted approach" *"Testing Macroprudential Stress Tests: The Risk of Regulatory Risk Weights"* by Acharya, Engle, and Pierret (2014). We can conclude by saying that, even with multiple changes in the financial and banking system over the years. With new regulations coming up over the last decade, we have not verified a drastic change in regulatory stress test results as seen after the global crisis in 2008. And that the regulatory stress tests conducted by financial organizations are still not taking into account the "risk that will change".

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11. Annexes

Annex A: Top 10 highest SRISK and corresponding EBA Shortfall in 2011 Figure 3 a)

Bank Name	SRISK	EBA_Shortfall_RWA
BNP PARIBAS	86,428.998	0.00
CREDIT AGRICOLE	77,916.705	0.00
BARCLAYS plc	76,839.364	0.00
ROYAL BANK OF SCOTLAND GROUP plc	68,062.534	0.00
ING BANK NV	53,162.198	0.00
SOCIETE GENERALE	50,781.814	0.00
LLOYDS BANKING GROUP plc	37,473.025	0.00
DEXIA	28,988.879	0.00
HSBC HOLDINGS plc	21,042.349	0.00
KBC BANK	13,715.006	0.00

Annex B: Top 10 highest SRISK and corresponding EBA Shortfall in 2011 Figure 3 b)

Bank Name	SRISK	EBA_Overall_Shortfall
DEUTSCHE BANK AG	112,576.25	3,238.59
BNP PARIBAS	95,887.32	1,476.32
CREDIT AGRICOLE	86,201.62	0.00
BARCLAYS plc	84,619.16	0.00
ROYAL BANK OF SCOTLAND GROUP plc	75,092.54	0.00
SOCIETE GENERALE	60,436.38	2,130.75
ING BANK NV	57,906.49	0.00
LLOYDS BANKING GROUP plc	47,759.36	0.00
UNICREDIT S.p.A	44,381.82	7,974.04
HSBC HOLDINGS plc	43,499.88	0.00

Annex C: Bottom 10 lowest EBA Shortfalls in 2011 Figure 4 a)

Bank Name	EBA_Shortfall_RWA
HSBC HOLDINGS plc	-36,594.566
BNP PARIBAS	-20,636.614
CREDIT AGRICOLE	-19,281.563
BARCLAYS plc	-15,170.073
LLOYDS BANKING GROUP plc	-14,296.968
ING BANK NV	-14,296.355
ROYAL BANK OF SCOTLAND GROUP plc	-8,914.800
DEXIA	-7,882.038
SOCIETE GENERALE	-6,944.726
KBC BANK	-6,368.865

Annex D: Top 10 highest SRISK in 2011 Figure 4 a)

Bank Name	SRISK
BNP PARIBAS	86,428.998
CREDIT AGRICOLE	77,916.705
BARCLAYS plc	76,839.364
ROYAL BANK OF SCOTLAND GROUP plc	68,062.534
ING BANK NV	53,162.198
SOCIETE GENERALE	50,781.814
LLOYDS BANKING GROUP plc	37,473.025
DEXIA	28,988.879
HSBC HOLDINGS plc	21,042.349
KBC BANK	13,715.006

Annex E: Top 10 highest EBA Shortfalls in 2011 Figure 4 b)

Bank Name	EBA_Shortfall_TA
BNP PARIBAS	53,176.521
BARCLAYS plc	46,875.001
CREDIT AGRICOLE	35,786.506
SOCIETE GENERALE	28,678.422
ING BANK NV	17,458.567
LLOYDS BANKING GROUP plc	10,492.759
DEXIA	9,508.985
HSBC HOLDINGS plc	8,633.162
BANK OF IRELAND	2,675.660
EFG EUROBANK ERGASIAS S.A.	2,011.938

Annex F: Top 10 highest SRISK in 2011 Figure 4 b)

Bank Name	SRISK
BNP PARIBAS	86,428.998
CREDIT AGRICOLE	77,916.705
BARCLAYS plc	76,839.364
ROYAL BANK OF SCOTLAND GROUP plc	68,062.534
ING BANK NV	53,162.198
SOCIETE GENERALE	50,781.814
LLOYDS BANKING GROUP plc	37,473.025
DEXIA	28,988.879
HSBC HOLDINGS plc	21,042.349
KBC BANK	13,715.006

Annex G: Different changes in Financial Regulations over the last 14 years. Their dates and names.

Exhibit 1: Key Post-GFC Financial Regulatory Reforms

US	
Feb 2010	SEC Liquidity Reform of Money Market Funds (MMFs)
Jul 2010	Dodd-Frank Act – created FSOC,* OTC derivatives reform, private fund reform, etc.
Oct 2011	SEC and CFTC Reporting Requirements for Private Funds
Oct 2012	OCC Reforms for Short Term Investment Funds (STIFs)
Jul 2014	SEC Structural Reform of MMFs
Aug 2016	SEC Investment Adviser Data Enhancements
Oct 2016	SEC Rule on Liquidity Risk Management Programs and Swing Pricing
Oct 2016	SEC Investment Company Reporting Modernization Rules
Sep 2019	SEC Exchange-Traded Funds Rule

EU	
Jul 2011	Alternative Investment Fund Managers Directive (AIFMD)
Jul 2011	UCITS IV requirements on governance and risk management, eligible assets, investor information
Nov 2012	Short Selling Regulation
Dec 2012	ESMA Guidelines on ETFs and other UCITS issues
Mar 2013	European Market Infrastructure Regulation (EMIR) central clearing requirements
Aug 2014	UCITS V requirements for depositories and remuneration
Jul 2017	EU Money Market Fund Reform
Jan 2018	MiFID II pre- and post-trade reporting and transparency requirements
Jan 2019	Simple, Transparent, and Standardized (STS) securitization requirements
Jul 2019	ESMA guidelines on liquidity stress testing for MMFs
Sep 2019	ESMA guidelines on liquidity stress testing for AIFs and UCITS

Annex H: Bottom 10 lowest EBA Shortfalls in 2018 Figure 4 a)

Bank Name	EBA_Shortfall_RWA
HSBC Holdings Plc	-38,979.920
Groupe Crédit Agricole	-30,303.155
Banco Santander S.A.	-29,663.566
BNP Paribas	-25,266.049
ING Groep N.V.	-20,695.262
UniCredit S.p.A.	-17,642.607
Banco Bilbao Vizcaya Argentaria S.A.	-16,919.217
Intesa Sanpaolo S.p.A.	-16,211.414
The Royal Bank of Scotland Group Plc	-14,139.240
Deutsche Bank AG	-12,265.796

Annex I: Top 10 highest SRISK in 2018 Figure 4 a)

Bank Name	SRISK
BNP Paribas	75,652.699
Deutsche Bank AG	65,240.239
Groupe Crédit Agricole	62,866.951
Société Générale S.A.	53,846.269
Barclays Plc	47,437.880
Banco Santander S.A.	35,358.776
The Royal Bank of Scotland Group Plc	21,938.350
UniCredit S.p.A.	20,276.908
Commerzbank AG	16,591.083
Lloyds Banking Group Plc	15,715.295

Annex J: Top 10 highest EBA Shortfalls in 2018 Figure 4 b)

Bank Name	EBA_Shortfall_TA
Deutsche Bank AG	37,801.579
BNP Paribas	30,581.915
Barclays Plc	25,925.527
Société Générale S.A.	24,988.186
HSBC Holdings Plc	17,375.037
Groupe Crédit Agricole	16,194.791
ING Groep N.V.	16,010.779
Lloyds Banking Group Plc	13,721.045
Banco Santander S.A.	10,591.960
UniCredit S.p.A.	9,357.147

Annex K: Top 10 highest SRISK in 2018 Figure 4 b)

Bank Name	SRISK
BNP Paribas	75,652.699
Deutsche Bank AG	65,240.239
Groupe Crédit Agricole	62,866.951
Société Générale S.A.	53,846.269
Barclays Plc	47,437.880
Banco Santander S.A.	35,358.777
The Royal Bank of Scotland Group Plc	21,938.350
UniCredit S.p.A.	20,276.908
Commerzbank AG	16,591.083
Lloyds Banking Group Plc	15,715.295