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Making sense of the EU wide stress test: a comparison with the SRISK approach

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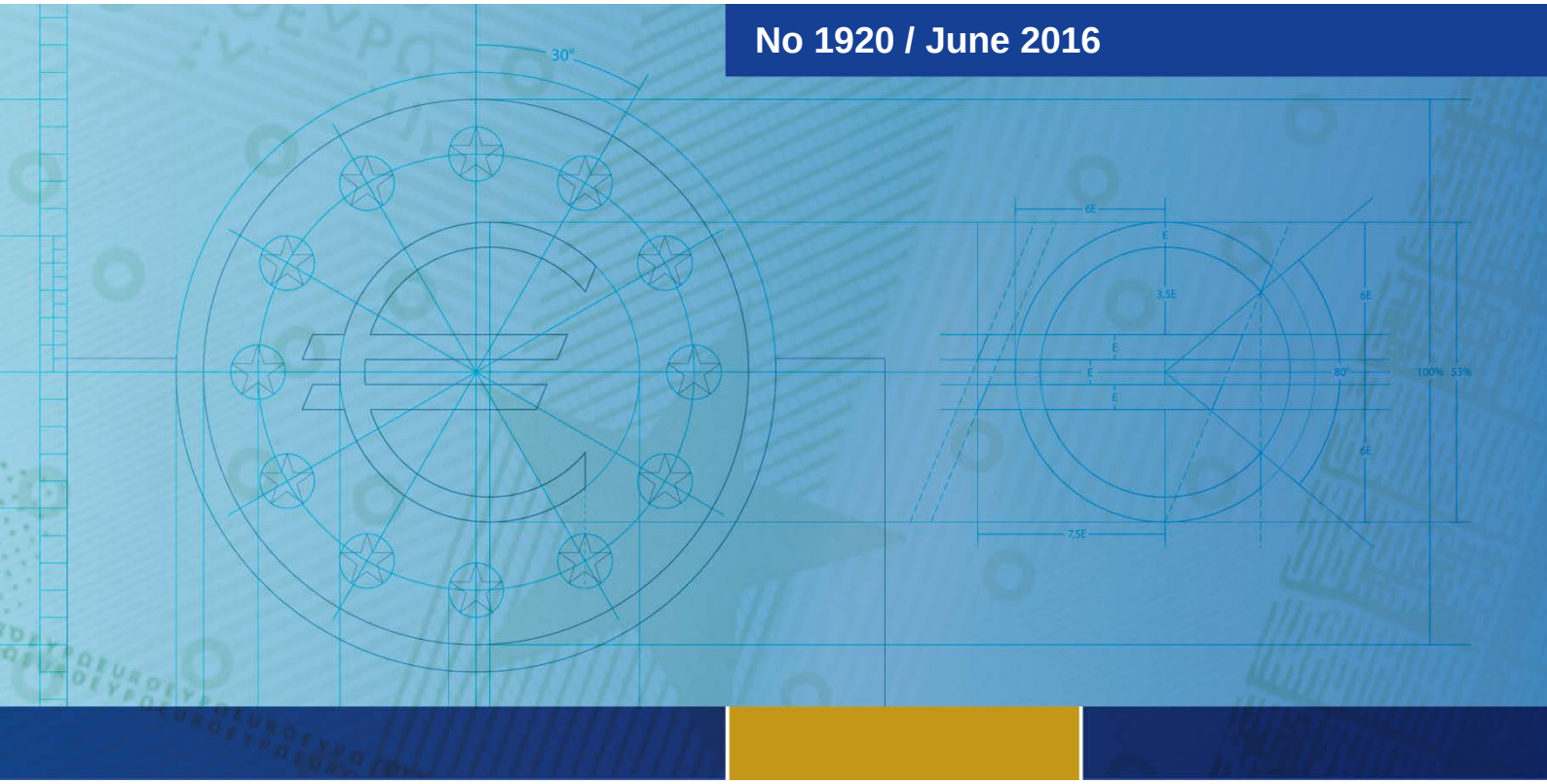

Abstract

We analyse the SRISK measure with respect to its usage as a benchmark for the ECB/EBA 2014 stress test. By regressing the ECB/EBA stress test impact and the SRISK stress impact on a set of factors that are commonly associated with bank credit losses and bank vulnerability, we find that the ECB/EBA stress impact is consistent with findings in the literature on credit losses. In contrast, the SRISK measure bears much less relation to these factors; it is largely driven by the banks' leverage ratio. These differences are deeply rooted in the construction of the respective measures. With its focus on losses to bank equity, the SRISK measure appears poorly matched as a benchmark for the supervisory stress test in Europe, which is centred on losses to banks' total assets.

JEL codes: C21, G01, G21

Keywords: SRISK, stress test evaluation, Asset Quality Review.

Non-technical summary

When the results of the ECB comprehensive assessment were published, the exercise was proclaimed a success by policy makers. At the same time, in a series of policy papers, Acharya and Steffen (2014a,b) used the SRISK measure as a benchmark for the stress test and interpreted the low correlation of the results with their measure as lack of robustness of the ECB stress test. They suggest that the use of risk weighted assets as measure of exposure and discretion of national regulators could have affected the results of the ECB stress test. Furthermore, they question whether the Comprehensive Assessment has properly taken into account systemic risk.

In an earlier study, Acharya, Engle, and Pierret (2014) propose SRISK as a benchmark for supervisory stress tests, comparing it with stress test results conducted in the US (SCAP) and the EU (EBA Stress test of 2011). They argue that SRISK is an easy to use benchmark for stress tests, quoting the high correlation of SRISK and stress test shortfalls in the majority of the past US and EBA stress tests. However, the correlations are calculated for dollar amounts which are naturally affected by size i.e. larger banks tend to have larger shortfalls. The way the stress test impact on bank capital is engineered differs greatly between the ECB/EBA stress test and SRISK. While the former starts by specifying a macro scenario and possible shocks to the financial markets, and then derives key metrics such as probability of default and loss given default for loans via a model, SRISK infers the stress impact from long term covariance of bank stock returns with market returns, specifying the initial shock in terms of a decline in the stock market. It thereby sidesteps modelling the transmission mechanisms of macro-economic developments to bank risk metrics and then to bank losses explicitly and rather models directly bank losses.

While the success of a stress test depends on the function it was designed for, the quality of a macro stress test hinges on the plausibility and severity of the scenario and its translation into stress test impact. Ideally, the stress test impact on bank capital should reflect banks' exposure to a number of risks, most importantly, credit risk due to macro- and micro factors and trading risks related to market exposures.

This motivates an investigation of the stress impacts of both the ECB comprehensive assessment and SRISK to examine how they relate to a set of factors that explain bank fragility. We proceed by regressing the stress impacts of both measures on a set of macro variables, bank balance sheet variables and market based measures to better understand the drivers behind the stress scenarios. We focus our analysis on the impact of the stress scenario employed by the ECB and by Acharya and Steffen (2014a,b,c) instead of the capital shortfall, which is also affected the by choice of threshold for adequate capitalization. We normalise the dollar amount of stress impact by a common notion of firm exposure to make the comparison across banks meaningful.

We regard this exercise as an anatomy lesson of the stress test measures, which should facilitate an assessment of their plausibility and their relationship to economic reality. While the regression results for the ECB stress impact are consistent with the literature on credit losses and economic intuition, the SRISK stress impact is much less related to these factors. We find that the SRISK stress impact is highly positively correlated with market leverage ratio, and also with price to book ratio, with the share

of explained variance in univariate regressions reaching 90% and 50% respectively. In other words, banks with a high ratio of equity to total assets are hit proportionally harder by the stress. To a certain extent this could be explained by riskier asset portfolios, but certainly not linearly to the extent found in the data. Furthermore, there is no reason why banks with a higher price to book ratio should be hit harder by a stress.

The findings suggest a nearly mechanical relationship between SRISK stress impact and market leverage ratio, which can also be explained by decomposing the analytical formula for SRISK stress impact appropriately. If heterogeneity in market leverage ratio is large, this is likely to dominate the heterogeneity in covariance of bank stock returns with the market index, and the market leverage becomes the driving factor behind the SRISK stress impact. This explains, why SRISK and ECB stress test results diverge in particular for banks that are close to bankruptcy and highly capitalised banks, which points towards another problem of the SRISK's usage as a benchmark for stress tests, namely its focus on equity holders. SRISK is set up to model returns to equity holders; therefore the stress impact is bounded by the amount of equity. This is particularly worrying for banks that are initially insufficiently capitalised, where the limit on losses is most likely binding in a stress scenario. We show that this has important practical implications, namely SRISK stress impact is only a tiny fraction of the size of the ECB/EBA stress impact for the least well capitalised banks.

Therefore we conclude that SRISK is unsuitable as benchmark for macro-prudential stress tests. The question which leverage ratio or which threshold to use can be treated independently of the question which stress model to use. While not addressing the first question and not definitely answering the second question, our findings cast doubt on the usefulness of SRISK as a benchmark for supervisory stress tests.

1. Introduction

When the results of the ECB Comprehensive Assessment (CA) were published, the exercise was proclaimed a success by policy makers. At the same time, in a series of policy papers Acharya and Steffen (2014a,b,c) use SRISK as a benchmark of appropriate stress to cast doubt on its robustness. They point at the negative correlation between ECB/EBA stress test shortfalls and SRISK, questioning whether the CA has properly taken into account systemic risk (Steffen 2014) and suggesting that the use of risk weighted assets and discretion of national regulators could have affected the results of the ECB/EBA stress test (Acharya and Steffen 2014b). In an earlier study Acharya, Engle, and Pierret (2014) use SRISK to compare it with stress test results conducted in the US (SCAP) and the EU (EBA Stress test of 2011). They present SRISK as a robust, easy to use benchmark for macro-prudential stress tests, quoting the high correlation of SRISK and stress test shortfalls in the majority of past US and EBA stress tests. We investigate this point in the context of the ECB/EBA stress test results, highlighting the importance of adequate normalisation of the shortfall measures by exposures.

The way stress test impact on bank capital is engineered differs fundamentally between the ECB/EBA stress test and SRISK. While the former starts by specifying a macro scenario and possible shocks to the financial markets, and then derives key metrics such as probability of default and loss given default for loans via a model, SRISK infers the stress impact from long term covariance of bank stock returns with market returns, specifying the initial shock in terms of a decline in the stock market. It thereby sidesteps modelling the transmission mechanisms of macro-economic developments to bank risk metrics and then to bank losses explicitly and rather models directly banks losses.

Proponents of the market based perspective would argue that while not modelling the transmission channels and a sophisticated stress scenario, assuming that a severe downturn at the stock market is a reflection of a severe crisis, the information contained in the thus modelled bank losses implicitly accounts for all the relevant transmission channels. This can be argued to bear fewer sources of mistakes or omissions, as the market processes the entire information set. In particular, complex contagion mechanisms that are notoriously difficult to model, such as illiquidity spirals, fire sale externalities and information contagion, are all implicitly reflected in market prices, to the extent that the market is aware of these channels. Its conceptual problems lie within the assumptions that the model for the long term co-variation between bank returns and market returns remain valid for a long horizon and during significant stress on the banking system, which need not be the case when the market's information set changes.

While the success of the stress test, as discussed in Borio, Drehmann, and Tsatsaronis (2014), depends on the function it was designed for, the quality of a macro stress test hinges on the plausibility and severity of the scenario and its translation into stress test impact (Alfaro and Drehmann 2009). Ideally, the stress test impact should reflect banks' exposure to a number of risks, most importantly credit risk due to macro and micro factors and trading risks related to market exposures. This motivates an investigation of the stress impacts of both the ECB comprehensive

assessment and SRISK to examine how they relate to a set of factors that explain bank fragility. While the previous comparisons of SRISK and ECB/EBA stress test results cited here compare the shortfalls directly, we focus on the impact of the stress scenarios employed by the ECB and by Acharya and Steffen (2014a,b) instead of the capital shortfalls. We normalise the dollar amount of stress impact by a common notion of firm exposure. The thus obtained measures capture the losses associated with the stress scenario as a fraction of exposure, which effectively defines the stress test; the shortfalls follow mechanically after defining the hurdle rate and the particular measure of leverage.

We proceed by regressing the stress impacts of both measures on a set of macro variables, bank balance sheet variables and market based measures to understand the drivers behind the stress scenarios. We regard this exercise as an anatomy lesson of the stress test measures, which should facilitate an assessment of their plausibility and their relationship to economic reality.

In Section 2 we provide some background about the ECB/EBA stress test and SRISK. Section 3 describes the data. Results about the ECB/EBA stress test are in Section 4. Section 5 compares SRISK to ECB/EBA stress test outcomes and Section 6 concludes.

2. The ECB/EBA stress test and the SRISK measure

The ECB/EBA stress test was conducted on 130 Eurozone banks as a part of the comprehensive assessment (CA) in 2014. A distinguishing feature of this stress test, compared to the previous ones, is that it incorporates corrections to asset valuation and classifications that resulted from the asset quality review (AQR), which was also part of the CA. The stress test itself combined a bottom-up stress test with a top-down verification thereby achieving harmonisation across participating banks and verifying the results that were subject to each bank's discretion. The baseline scenario was constructed based on European Commission forecasts for the years 2014 – 2016. The European Systemic Risk Board modified the baseline scenario by the materialisation of the main risks to financial stability to arrive at the adverse scenario.[1] EBA then published the stress test methodology where key stress parameters were derived from the scenarios and restrictions were imposed on the banks' application of the scenario. The thus obtained results were cross-checked with the outcome of a macro stress test to detect misuse of banks' discretion. The main outcome of the stress test is the capital shortfall, defined as the maximum of the capital needs to meet a common equity Tier 1 (CET1) ratio of 8% in the baseline scenario or a CET1 ratio of 5.5% in the adverse scenario, where CET1 is measured according to the respective legislation in each year. The results are published in the Aggregate Report on the Comprehensive Assessment (ECB 2014). Rather than on the shortfall, we focus on the stress impact, i.e. the loss of bank capital in the stress scenario. The shortfall shows which banks are most undercapitalized, while the stress impact is more informative about bank exposure to risks.

[1] For details see EBA/SSM stress test: The macroeconomic adverse scenario (ESRB 2014).

SRISK has been proposed as a measure of systemic risk by Acharya, Engle, and Richardson (2012). SRISK of a bank is the expected capital shortfall in a severe stress scenario to a benchmark capital ratio defined in terms of market leverage. For European banks the threshold is 5.5% market leverage ratio[2]. The stress scenario is a shock that would result in a 40% drop in the general stock market index over a period of six months. More precisely, SRISK is defined as:

$$SRISK_{it} = E_t(CS_{i,t+h} \mid R_{mt+1:t+h} < C) \quad (1)$$

where *CS* denotes Capital shortfall and R_m indicates the systemic event as a drop in the market over the term of six months below the threshold *C* where *C* is taken to be *40%*. This is shown by the authors to result in the following expression:

$$SRISK_{it} = k\,Debt_{it} - (1-k)\,Equity_{it}\,(1+LRMES_{it}) \quad (2)$$

where k denotes the capital requirement and *Debt* is the book value of all liabilities except capital. *LRMES* stands for long run marginal expected shortfall and is extrapolated from the mean daily marginal expected shortfall (MES) to a six month horizon via simulations. *LRMES*Equity* can be interpreted as the stress impact in euros. Normalising it by total assets yields the SRISK stress impact:

$$\frac{SRISK_{Stress\ Impact}}{TA_{Book}} = LRMES * \frac{Equity_{Market}}{TA_{Market}} * \frac{TA_{Market}}{TA_{Book}} \quad (3)$$

There are two ways of obtaining this the stress impact from the data provided on the webpage of V-Lab. Acharya, Engle and Richardson (2012) mention an approximation to LRMES: $LRMES = 1 - \exp(-18 \times MES)$, which they employ in cases where simulations have not yet been implemented. Alternatively, using the SRISK measure as a starting point, we can back out the impact of the stress test on market equity as follows:

$$\frac{SRISK_{Stress\ Imapct}}{TA_{Book}} = \left(\frac{Equity_{Market}}{TA_{Market}} - 0.055\right)\left(\frac{TA_{Market}}{TA_{Book}}\right) + \frac{SRISK_{Shortfall}}{TA_{Book}} \quad (4)$$

where $Equity_{Market}$ stands for market value of equity, TA_{Market} for market value of total assets (the sum of market value of equity and book value of liabilities). $SRISK_{Shortfall}$ is the capital shortfall in EUR, which has a positive value when a bank has too little equity and negative when it has a surplus. The first expression is the difference between the initial market leverage ratio and the benchmark leverage ratio, rescaled from market value of total assets to book value of total assets. Then the shortfall after the shock is added. If a bank has an initial market leverage ratio above 5.5% and has a shortfall after the shock, the stress impact is the loss of capital from the initial level to the benchmark capital ratio plus the shortfall. If a bank is below the benchmark market leverage ratio before the shock, the stress impact is equal to the shortfall after the shock reduced for the initial shortfall. Cross-checking results obtained from these methods confirms that any disagreement due the approximation involved or different data used is insignificant, so we go ahead with the values obtained via the second method, described by equation (4).

[2] Market leverage ratio is defined as market value of equity divided by market value of assets, which is approximated as the sum of market value of equity and book value of liabilities.

Table 1: Comparision of ECB/EBA stress impact and SRISK stress impact.

	ECB/EBA stress test impact	SRISK stress impact
Calculation	*[ECB/EBA stress on CET1] * RWA/TA*	$= \left(\frac{Equity_{Market}}{TA_{Market}} - 0.055 \right) \left(\frac{TA_{Market}}{TA_{Book}} \right) + \frac{SRISK_{Shortfall}}{TA_{Book}}$
Economic interpretation of stress	Losses associated with adverse macroeconomic conditions (GDP, Inflation) and adverse conditions on the financial markets (yields, equity, FX) – mainly losses related to credit risk	Losses associated with any event that causes the aggregated stock market to drop by 40% - covers any financial market shock that is severe enough
Transmission mechanism	Weak macro conditions such as (high unemployment, recession, low inflation) increase the probability that borrowers default on their loans, and the losses in that case (reduced collateral values), the adverse conditions to the financial markets lead to mark to market gains or losses on the bank's trading portfolios	Not explicitly modelled.
Static balance sheet assumption	Yes	Yes (in the sense that debt is not reduced – the composition of assets and liabilities could change significantly in terms of risk and liquidity profile)
Perspective	All stakeholders, losses to the assets	Equity holders, losses to market equity
Direct and indirect contagion	Not modelled and therefore not part of the scenario.	Not modelled explicitly, but potentially the modelling of the impact of the stress on the bank's equity includes contagion and spillovers from other parts of the financial markets.

3. Data and descriptive statistics

We obtain data about the ECB/EBA stress test results from the Aggregate Report on The Comprehensive Assessment (ECB 2014) and data on banking and trading book losses from EBA. We use the following stress test outcomes as dependent variables in the regression analysis:

- **Adverse scenario stress impact / TA**: Impact of the adverse scenario of the ECB/EBA stress test on CET1 (ECB communication variable B6), scaled by total assets. Stress impact is originally reported in basis points of risk weighted assets (RWA). We rescale it and express it in percent of total assets. Normalizing the stress impact by some measure of

bank size is necessary to make it comparable across banks. If one could argue that the stress impact on an asset class should be proportional to its risk weighted assets, expressing it relative to RWA would be preferable. We perform regressions with stress impact scaled by RWA as a robustness check.

- **Baseline scenario stress impact / TA**: Impact of the baseline scenario of the ECB/EBA stress test on CET1 (ECB communication variable B4), scaled by total assets. We focus on the adverse scenario stress impact, which has greater variation in outcomes across banks, and analyse the impact of the baseline scenario in robustness checks.
- **Banking book losses / TA**: Three year cumulative losses on financial and non-financial assets in the banking book in the adverse scenario, scaled by total assets. By isolating the losses on the credit portfolio from the trading activities, one would expect to see more clearly the influences of the macro-economic stress scenario that ultimately translates into probability of default and loss given default metrics of loan portfolios.
- **Trading book losses / securities holdings**: Three year cumulative losses in the trading book in the adverse scenario, scaled by total assets.

We compute the **SRISK stress impact / TA** using equation (4) from SRISK values published on the V-Lab website.[3] By transforming the dollar values of SRISK shortfall, as they are originally reported, into stress impact scaled by total assets we make it directly comparable to the ECB/EBA stress impact.

Losses in a stress scenario are likely to depend on the existing **macroeconomic conditions**. For some variables we construct values weighted by exposure of banks to different countries to account for the fact that banks are likely to be affected by macroeconomic conditions not only in the country of their headquarters but also in countries where they have asset exposure – i.e. the effect of macroeconomic conditions in a particular country on a bank is assumed to be proportional to the exposure of the bank to that country relative to the total assets of the bank.[4] In the regression analysis we use the following variables:

- Real GDP growth, 3 year cumulated and weighted by bank exposures (Source: IMF World Economic Outlook).
- Sovereign bond yields, average of monthly observations for 2013 (Source: Bloomberg).
- Unemployment rate, 3 year average (Source: Eurostat, obtained through ECB SDW).
- Expected default frequency (EDF) for nonfinancial firms, country benchmark, average over firms weighted by total assets, average of monthly observations for 2013, weighted by bank exposures (ECB SDW[5], source: KMV – Moody's).

[3] http://vlab.stern.nyu.edu/en/#

[4] For details about weighting macroeconomic variables by bank exposures see Appendix.

[5] ECB Statistical Data Warehouse

We use **quality of banking supervision** measures from Barth, Caprio, and Levine (2012). Variables are constructed as averages over up to four survey waves ranging back until 1999. Higher index levels imply tighter regulation.

- The bank activities restrictions index describes how much activities of banks are restricted to providing core banking services. The index is higher when banks are for example prohibited from engaging in securities underwriting, brokering or dealing, insurance underwriting, real estate investment or if banks are not allowed to own nonfinancial firms.
- The capital regulatory index is higher the more stringent regulatory requirements for holding capital are. It also measures how narrowly capital is defined.
- The supervisory power index measures whether supervisory authorities have the power to prevent and correct problems. For example, the index is higher if authorities can restructure and reorganise troubled banks or declare a deeply troubled bank insolvent.
- The private monitoring index is high when financial statements issued by a bank have to be audited, when a large share of the 10 largest banks is rated by international rating agencies, when there is no explicit deposit insurance scheme and if bank accounting fulfils certain requirements.
- The moral hazard mitigation index measures the extent to which features of the explicit deposit insurance reduce moral hazard, i.e. that the funding modalities of a bank do not discourage a bank from engaging in high risk lending. A high value implies that the deposit insurance system has designed to be effective in mitigating moral hazard, for instance by charging banks for the insurance scheme proportional to their risk, or by insuring less than 100% of the deposits.

Bank balance sheet variables are combined from three sources. If available, we use variables from the dataset accompanying the report about the Comprehensive Assessment (ECB 2014). Additional variables are from SNL and BankScope. For some banks SNL and BankScope are used simultaneously when total assets in both datasets do not differ by more than 10%.

- Bank size, measured as the logarithm of total assets (CA report)
- Tier 1 ratio (Source: CA report)
- Book leverage ratio: book value of equity divided by total assets (Source: CA report)
- RWA to total assets ratio (CA report)
- Gross loans excluding interbank loans (Source: SNL, BankScope)
- Securities holdings (Source: SNL, BankScope)
- ROA (Return on average assets) (Source: SNL, BankScope)
- Impaired loans ratio: impaired loans over gross loans (Source: SNL, BankScope)

Market data is compiled from Bloomberg unless specified otherwise:

- Bank 5 year CDS spreads, average over end-of-month observations in 2013
- Price to book ratio, end of 2013
- Market leverage ratio: market value of equity over the sum of market value of equity and book value of liabilities (source V-Lab)
- Bank stock returns for the period 2011-2013.[6]
- Bank stock 4-factor alpha: average daily abnormal return over the period 2011-2013, computed as the intercept from the Carhart (1997) four factor asset pricing model, which builds on the Fama-French (1993) three factor model and augments it with another factor capturing the momentum effect. We use the return on Eurstoxx50 as a proxy for market return and the German 5-year government bond yield as the risk free rate. The other three factors are taken from Andrea Frazzini's data library[7].

The sample of banks subject to the AQR and the stress test consists of 130 banks, but we remove four banks[8] where we have no observations on the explanatory variables in the most basic setup. The descriptive statistics of the full sample are displayed in Table 2. Most explanatory variables are available for at least 120 banks, which represent 96% or more of total assets of banks that were analysed in the CA. For variables based on market data the coverage is more limited and includes about 40 banks, which account for 50% to 67% of total banking assets. SRISK is available for a sample covering 62% of the assets of banks examined in the ECB/EBA stress test.

To provide some indication of the explanatory power of the variables later used in regressions, Table 2 also reports R squared of univariate regressions where adverse scenario stress impact of the ECB/EBA stress test and SRISK stress impact are dependent variables and explanatory variables are included into those regressions individually. Note that the average impact of the adverse scenario normalized by total assets is 1.9 percentage points, while the SRISK stress impact is 2.5 percentage points and can thus be considered the tougher scenario, in particular because it relates to a shorter time horizon of 6 months compared to 3 years. Since SRISK threshold of sufficient capitalisation is effectively higher – it is set to 5.5% market leverage ratio vs. 5.5% risk-weighted capital ratio in ECB/EBA stress test – this amplifies the difference in resulting shortfalls. For the ECB/EBA stress impact in the adverse scenario, the macroeconomic variables display high univariate explanatory power. Impaired loans ratio, ROA as well as bank CDS spreads and abnormal stock returns are highly informative (R squared from 0.30 to 0.44). For SRISK, market leverage ratio and the price to book ratio stand out with extremely high values of R squared.

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6 For variables based on stock returns, only stocks are considered that that have zero returns on less than 50% of the trading days. Stocks that have zero returns on more days may have been suspended from trading or are highly illiquid and thus not suitable for analysis.

7 Available at https://www.aqr.com/library/data-sets/the-devil-in-hmls-details-factors-daily (Asness and Frazzini 2013)

8 Deutsche Bank (Malta), AB SEB Bankas Latvia, AB DNB Bankas Latvia and Swedbank AB, Latvia, jointly representing 0.01% of sample assets.

Table 2: Descriptive statistics

Variable	Mean	St. dev.	Min	Median	Max	N	Coverage of bank assets [%]	R2: Adv. scen. stress impact	R2: SRISK stress impact
Dependent variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Adv. scen. stress impact/ TA	1.9206	3.6400	-0.6768	1.2141	39.89	130	100.00		
Base. scen. stress impact/ TA	0.1668	0.5537	-0.6823	0.0375	2.8770	130	100.00		
Banking book losses	1.6771	1.5073	0.0048	1.0457	7.4541	99	87.98		
Trading book losses	0.0090	0.0076	0.0000	0.0071	0.0307	97	87.17		
SRISK stress impact/ TA	2.5258	3.1813	0.0097	1.8580	21.13	43	62.07		
SRISK stress impact/ MCAP	41.33	10.94	10.15	44.35	56.79	43	62.07		
Macroeconomic variables									
GDP growth, 3 year	0.0160	0.0534	-0.1585	0.0263	0.1535	129	99.99	0.1710	0.0006
Govt. bond yield	0.0220	0.0199	0.0063	0.0116	0.0990	111	98.89	0.2592	0.0095
EDF nonfin. sector	0.0114	0.0188	0.0016	0.0064	0.1088	117	99.52	0.0591	0.0001
Unemployment, 3 year average	0.1123	0.0567	0.0481	0.0975	0.2411	121	90.02	0.0011	0.0227
Quality of bank supervision									
Bank activity restr. ind.	5.7264	1.1502	4.5000	5.2500	7.7500	127	99.93	0.0605	0.0291
Capital regulatory ind.	6.5787	1.0428	4.8500	6.7500	8.7500	127	99.93	0.0059	0.0008
Supervisory power ind.	9.9372	1.6327	7.0000	9.5000	13.50	127	99.93	0.0481	0.0041
Private monitoring ind.	7.7992	0.7203	6.5000	7.5000	10.00	127	99.93	0.0155	0.2174
Moral hzd. mitigation ind.	1.7241	0.6427	0.5000	2.0000	2.7500	127	99.93	0.0000	0.0045
Bank balance sheet variables									
Total assets	169	303	0.5670	54.18	1,640	130	100.00	0.0131	0.0063
Tier 1 ratio	0.1367	0.0561	-0.0370	0.1225	0.3728	127	98.57	0.0127	0.0963
Book leverage ratio	0.0648	0.0721	0.0000	0.0522	0.7870	126	99.73	0.0364	0.1103
ROA	-0.0026	0.0190	-0.0788	0.0017	0.0264	126	99.73	0.3005	0.0024
ROE	-0.0818	0.4285	-2.3920	0.0302	0.3189	126	99.73	0.2472	0.0149
Loans/ TA	0.5471	0.2014	0.0201	0.5862	0.8923	124	98.40	0.0150	0.0000
Gross loans/ TA	0.5866	0.2088	0.0215	0.6326	0.9691	122	98.21	0.0439	0.0067
Securities/ TA	0.2587	0.1588	0.0034	0.2449	0.9528	120	97.33	0.0150	0.0000
RWA/ TA	0.4529	0.1995	0.0014	0.4502	1.0991	130	100.00	0.1541	0.0001
Impaired loans ratio	0.1078	0.1069	0.0000	0.0741	0.4081	108	92.15	0.4333	0.0661
Loan loss prov. ratio	0.01	0.0193	-0.0077	0.004	0.0973	121	96.53	0.1886	0.0253
Market based variables									
Bank CDS spread	2.7075	2.5590	0.7068	1.6791	11.73	54	67.78	0.4404	0.0220
Bank stock return 2011-13	19.29	52.38	-92.31	17.15	147	41	48.63	0.2545	0.1691
Bank stock 4-factor alpha	0.0418	0.1609	-0.5481	0.0646	0.4818	41	48.63	0.3057	0.0013
Market lev. ratio	5.4468	5.5243	0.0201	4.0568	35.97	43	62.07	0.0029	0.8923
P/B ratio	0.7870	0.4029	0.0224	0.7255	1.7939	42	48.32	0.0747	0.4875

The table reports descriptive statistics of variables used in regressions and a selection of other variables. Column (8) and (9) report R squared ratio of univariate regressions of ECB/EBA adverse scenario stress impact and the SRISK stress impact, respectively. Total assets are in billions of EUR.

4. Analysis of the ECB/EBA adverse scenario stress impact

The results presented in this section identify several factors that predict bank vulnerability, as measured by the ECB/EBA adverse scenario stress impact on Tier 1 capital. **Table 3** displays the results for the total adverse scenario stress impact. The following two tables (Table 4 and Table 5) provide results separately for banking book losses and trading book losses. Columns (1) to (4) in Table 3 report results for regressions with variables describing macroeconomic conditions, quality of

bank supervision and bank balance sheet variables. Market based measures, which are available only for a subsample of banks, are included in specifications (5) and (6). GDP growth and government bond yields have a significant effect on the stress impact in the adverse scenario. They are not included simultaneously because of their high correlation. Creditworthiness of nonfinancial corporations, measured by the average expected default frequency (EDF) and unemployment rate do not have a significant effect. Restrictions on bank activities and more stringent capital requirements are associated with lower stress impact. Looking at characteristics of individual banks, smaller banks are expected to be hit more. Banks with riskier assets reflected in higher RWA ratio and high existing impaired loans are expected to suffer larger losses in the adverse scenario. Market based measures, CDS spreads and abnormal returns on bank stock are very good predictors of stress impact.

Table 3: Adverse scenario stress impact.

	Adv. scen. stress impact/ TA (1)	Adv. scen. stress impact/ TA (2)	Adv. scen. stress impact/ TA (3)	Adv. scen. stress impact/ TA (4)	Adv. scen. stress impact/ TA (5)	Adv. scen. stress impact/ TA (6)
GDP growth, 3 year	-11.8112***			-7.7331***		-19.5453***
	(-3.47)			(-3.02)		(-5.32)
Govt. bond yield		33.0032***				
		(5.37)				
EDF nonfin. sector			10.7192			
			(0.73)			
Unemployment, 3 year average			4.5003			
			(0.78)			
Bank activity restr. ind.	-0.3765**	-0.4091**	-0.3019	-0.4416***	-0.2726*	-0.3996*
	(-2.31)	(-2.43)	(-1.12)	(-4.03)	(-2.02)	(-2.17)
Capital regulatory ind.	-0.3659*	-0.3987**	-0.4216	-0.5170***	-0.2400*	-0.3202*
	(-2.07)	(-2.55)	(-1.31)	(-3.75)	(-2.08)	(-1.89)
Size	-0.2685***	-0.2371*	-0.2566**	-0.2432***	-0.2744**	-0.2469*
	(-3.21)	(-1.88)	(-2.54)	(-3.25)	(-2.42)	(-2.00)
Book leverage ratio	-4.1229	-7.0662	-9.6953*	-5.0698	-9.8820	-9.1439
	(-0.99)	(-1.59)	(-1.88)	(-1.32)	(-0.83)	(-0.67)
Loans/ TA	-1.1830*	-0.9124	-1.1920	-1.2594*	-1.5578*	-1.7908
	(-2.01)	(-1.28)	(-1.50)	(-1.77)	(-2.07)	(-1.05)
RWA/ TA	2.8346***	2.2486***	2.9307***	1.8523**	2.5746*	-0.0314
	(4.10)	(3.38)	(3.57)	(2.57)	(2.12)	(-0.02)
ROA	-27.2224**	-33.1259***	-39.0208***	-14.6771	-17.6079	-10.3840
	(-2.77)	(-3.90)	(-4.60)	(-1.37)	(-1.40)	(-0.91)
Impaired loans ratio				5.5447***		
				(4.51)		
Bank CDS spread					0.3450***	
					(7.12)	
Bank stock 4-factor alpha						-3.7657*
						(-1.89)
N of observations	121	108	105	105	51	41
Coverage of bank assets [%]	98.33	97.36	88.01	92.08	67.71	48.63
Adjusted R2	0.5082	0.5653	0.4350	0.6005	0.5965	0.5796

The dependent variable is adverse scenario stress impact scaled by total assets. Regressions are estimated using OLS with standard errors clustered at country level. In parentheses are t-statistics. Significance levels of 0.10, 0.05 and 0.01 are denoted by *, **, ***, respectively.

Note that none of the explanatory variables except the market variables carry any forward looking component. This does by no means imply that they have no explanatory power for the stress test results, because they carry substantial information on the starting point of the scenario, and since

most of the macro-variables have strong inertia the starting point already captures a significant amount of the cross-sectional heterogeneity of the macro-variables in a stress scenario, even without having a model for the future dynamics of the economy or the transmission mechanism. This is hardly surprising, as one would expect a significant part of a macro stress to be a common shock that affects all countries. The extent to which this shock is accompanied by country specific amplifiers, and how country specificities including different starting levels then introduce cross-country and cross-bank heterogeneity that cannot be captured via this regression analysis. The following results can therefore be understood as an analysis of how much of the information of the stress scenario is contained by information on the starting point of the scenario, and which of these initial conditions matter the most for the model based outcome of a three year stress scenario.

Table 4: Banking book losses.

	Banking book losses/ TA (1)	Banking book losses/ TA (2)	Banking book losses/ TA (3)	Banking book losses/ TA (4)	Banking book losses/ TA (5)	Banking book losses/ TA (6)
GDP growth, 3 year	-15.2905***			-6.0403*		-16.3241***
	(-4.93)			(-2.04)		(-6.25)
Govt. bond yield		39.0753***				
		(10.65)				
EDF nonfin. sector			66.2478***			
			(5.73)			
Unemployment, 3 year average			5.2772			
			(1.20)			
Bank activity restr. ind.	0.1517	0.1423	0.1733	0.2507**	0.4378	-0.0304
	(0.97)	(0.98)	(0.80)	(2.68)	(1.49)	(-0.11)
Capital regulatory ind.	-0.0683	-0.1449	-0.2328	-0.1666*	-0.2224	-0.1940
	(-0.56)	(-1.43)	(-0.89)	(-2.01)	(-1.10)	(-1.12)
Size	-0.0971	-0.0166	0.0263	0.0022	0.2658	-0.0355
	(-1.03)	(-0.18)	(0.26)	(0.03)	(1.39)	(-0.22)
Book leverage ratio	-12.1830	-10.4768	-14.1095*	-11.5830**	18.7465	-12.1626
	(-1.72)	(-1.75)	(-2.13)	(-2.20)	(0.91)	(-1.00)
Loans/ TA	-0.1503	0.7972	1.2444	1.2948	2.1543	2.2521
	(-0.23)	(1.48)	(1.66)	(1.31)	(1.11)	(0.98)
RWA/ TA	5.8324***	4.6393***	4.8560***	4.5324***	0.8527	2.6168
	(4.57)	(3.89)	(3.42)	(3.81)	(0.30)	(0.86)
ROA	-13.1440*	-7.0051	-1.8614	1.4014	30.9355***	-0.8940
	(-1.81)	(-0.76)	(-0.22)	(0.16)	(3.70)	(-0.06)
Impaired loans ratio				6.7411***		
				(4.25)		
Bank CDS spread					0.3156***	
					(6.41)	
Bank stock 4-factor alpha						-4.5338**
						(-2.92)
N of observations	99	93	87	89	43	39
Coverage of bank assets [%]	87.98	87.37	77.93	83.67	63.50	48.56
Adjusted R2	0.6642	0.6912	0.6936	0.6893	0.7278	0.6353

The dependent variable is banking book losses under the adverse scenario scaled by total assets. Regressions are estimated using OLS with standard errors clustered at country level. In parentheses are t-statistics. Significance levels of 0.10, 0.05 and 0.01 are denoted by *, **, ***, respectively.

Table 4 displays the results for **banking book losses** under the adverse scenario. The explanatory variables and the structure of the table are identical as in Table 3 for the total impact of the adverse scenario. Overall, the results are similar with some noteworthy differences. The positive effect of EDF

of nonfinancial firms is now significant. Bank activity restriction and capital regulatory index become less informative. For restrictions on bank activities this is expected as they mainly apply to activities that are part of the trading book not banking book. In contrast to the total stress impact, bank size does not matter much for banking book losses. Impaired loans ratio, CDS spread and abnormal bank stock returns remain strong predictors. The share of explained variance is higher than in regressions of total stress impact, reaching up to 70%.

Table 5: Trading book losses.

	Trading book losses/ TA (1)	Trading book losses/ TA (2)	Trading book losses/ TA (3)	Trading book losses/ TA (4)	Trading book losses/ TA (5)	Trading book losses/ TA (6)
GDP growth, 3 year	0.3271			0.2679		-0.2981*
	(0.48)			(0.42)		(-2.14)
Govt. bond yield		1.0079				
		(1.10)				
EDF nonfin. sector			2.9785			
			(1.42)			
Unemployment, 3 year average			-0.8655*			
			(-1.88)			
Bank activity restr. ind.	0.0087	-0.0185	0.0084	-0.0054	-0.0184	0.0331**
	(0.31)	(-0.63)	(0.30)	(-0.20)	(-0.48)	(2.52)
Capital regulatory ind.	-0.0262	-0.0394*	-0.0000	-0.0331	-0.0596**	-0.0143
	(-1.53)	(-2.13)	(-0.00)	(-1.64)	(-2.27)	(-1.41)
Size	0.0400***	0.0420***	0.0593***	0.0342**	-0.0065	0.0342*
	(3.00)	(3.32)	(3.16)	(2.88)	(-0.18)	(2.18)
Book leverage ratio	-1.6735***	-1.7731***	-1.8183***	-1.8166***	-0.2680	-1.7420*
	(-3.34)	(-3.31)	(-3.20)	(-3.05)	(-0.15)	(-1.80)
Loans/ TA	-0.4169***	-0.4268***	-0.2380	-0.3771**	-0.5173*	-0.7179**
	(-3.35)	(-3.59)	(-1.38)	(-2.85)	(-2.03)	(-2.71)
RWA/ TA	0.2328	0.2157	0.1548	0.1972	0.0455	0.5210***
	(1.60)	(1.30)	(0.78)	(1.06)	(0.15)	(6.93)
ROA	-0.1191	-0.2208	0.4580	-0.2510	0.9987	2.8520***
	(-0.12)	(-0.18)	(0.30)	(-0.26)	(0.59)	(4.24)
Impaired loans ratio				-0.0104		
				(-0.04)		
Bank CDS spread					-0.0047	
					(-0.43)	
Bank stock 4-factor alpha						0.0039
						(0.02)
N of observations	99	93	87	89	43	39
Coverage of bank assets [%]	87.98	87.37	77.93	83.67	63.50	48.56
Adjusted R2	0.1868	0.1848	0.1829	0.1474	0.0243	0.2244

The dependent variable is trading book losses under the adverse scenario scaled by total assets. Regressions are estimated using OLS with standard errors clustered at country level. In parentheses are t-statistics. Significance levels of 0.10, 0.05 and 0.01 are denoted by *, **, ***, respectively.

Table 5 presents the results for **trading book losses** under the adverse stress scenario. Relatively low R squared compared to regressions of total stress impact, suggests that expected trading losses do not depend much on existing macroeconomic conditions or past idiosyncratic performance of banks. The most significant effects of bank size, leverage and the ratio of loans to total assets. Banks

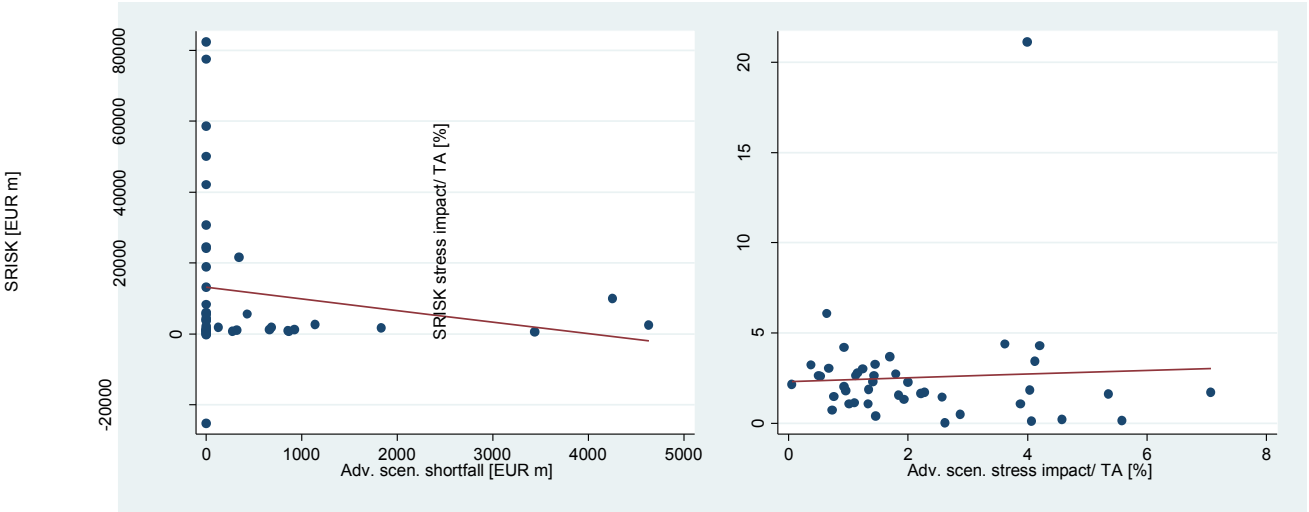
with a larger loan portfolio, almost by definition, have lower trading loses. Impaired loans ratio, bank CDS and abnormal return are not informative at all.[9]

Overall, our results are in line with research linking credit losses to macro-economic dynamics, as for instance Pesaran et al. (2003), Mileris (2012) and Kearns (2004). It is intuitive that the regressions explaining the banking book losses exhibit higher explanatory power than the regressions explaining the trading losses, as net trading positions are far more heterogenous across banks in a country than loan portfolio compositions, and also bear less systematic relation to balance sheet information apart from the size of the trading book, which is strictly negatively related to the loans over total assets ratio.

5. Comparing ECB/EBA stress test outcomes with SRISK

Acharya and Steffen (2014c) find SRISK[10] to be negatively correlated to the shortfall of banks in the adverse scenario of the ECB/EBA stress test but positively correlated with the banking book and trading book losses in the adverse scenario of the same stress test. The stress scenarios of the two measures are different and the benchmark capital requirements differ (5.5% market leverage ratio in SRISK and 5.5% CET 1 ratio in the ECB/EBA stress test). Hence it is not surprising that the two shortfalls are not highly correlated.

Figure 1: Nominal values of SRISK vs. adverse scenario shortfall (left) and SRISK stress impact scaled by total assets vs. adverse scenario stress impact scaled by total assets (right).



[9] In an unreported robustness test, we check whether the reason for poor prediction of trading losses is scaling by total assets. As a better proxy for the size of trading book, we use bank securities holdings. The estimates, however, do not improve in terms of statistical significance.

[10] The dollar value of SRISK shortfall is referred to just as SRISK.

The correlation between SRISK and losses in the stress scenario, however, appears to be positive but this is only due to the fact that Acharya and Steffen (2014c) compute correlations between euro values of both measures. Large banks tend to have large losses and large SRISK. We replicate these results, with the only difference that we compute simple correlations at bank level, instead of rank correlations at country level. In addition to capital shortfall under the adverse scenario, banking book losses, trading book losses and SRISK we include the total stress impact of the adverse scenario and the SRISK stress impact.

Figure 2: SRISK vs. banking book losses and trading book losses, nominal values (left) and stress impact scaled by total assets (right).

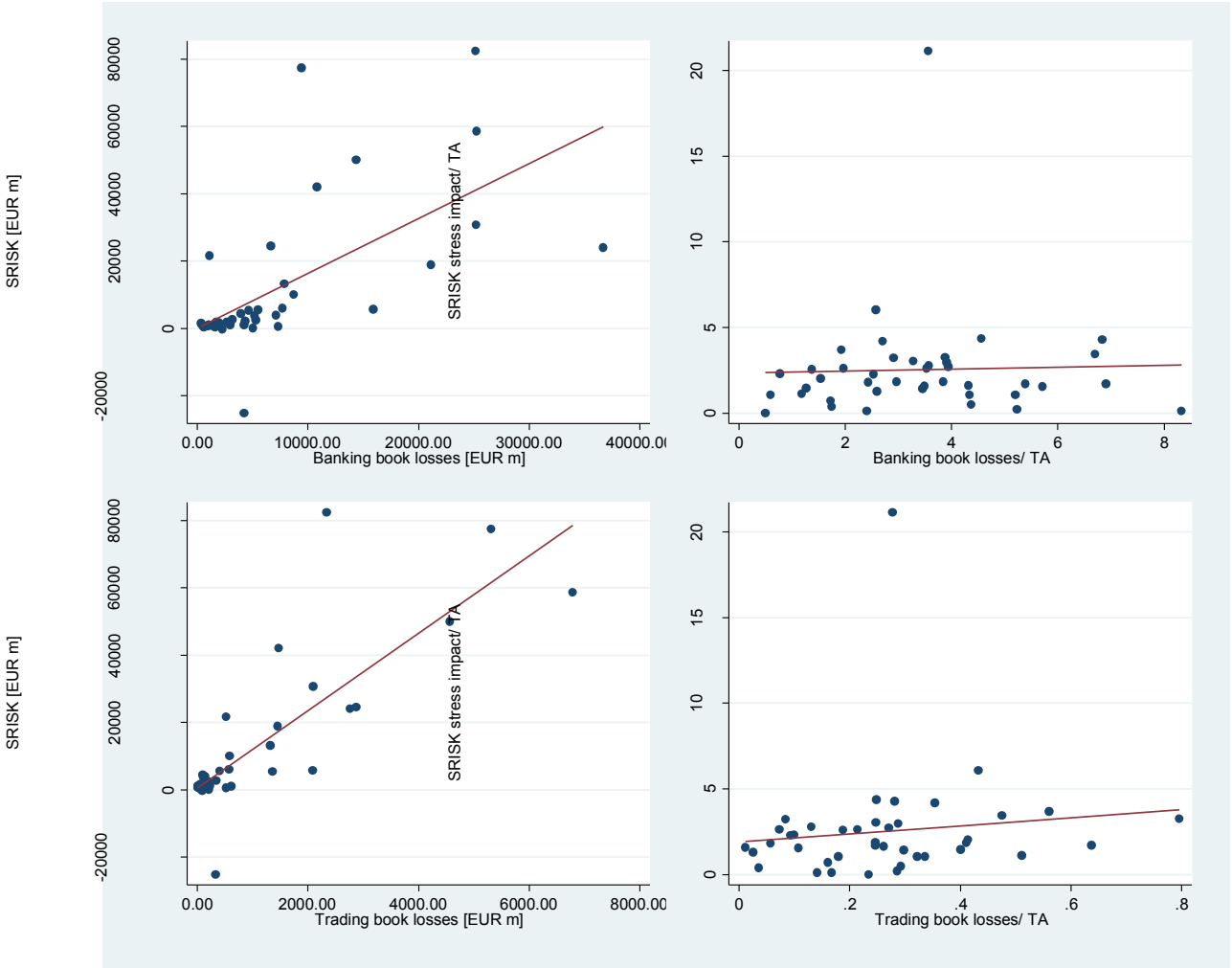


Table 6 reports these results. The values of all measures are nominal amounts in millions of EUR, not scaled by total assets. Thus the correlations are likely due to bank size. In Table 7 we report correlations that do not suffer from this problem. Bank losses under both stress scenarios are scaled by total assets of banks. Instead of to shortfall we compare them to SRISK stress impact. Losses should be compared to losses rather than shortfalls. This comparison shows that the positive

correlation between SRISK and banking and trading book losses disappears once the values are scaled by total assets and SRISK stress impact is used instead of the SRISK shortfall, which is also visible from Figure 2. In contrast, adverse scenario stress impact scaled by total assets exhibits a correlation of 0.60 to banking book losses, which are a large component of the stress impact, and a slightly negative correlation to trading book losses.

Table 6: Correlations between nominal values of stress test losses and SRISK.

	Adv. scen. shortfall [EUR m]	Adv. scen. stress impact [EUR m]	Banking book losses [EUR m]	Trading book losses [EUR m]	SRISK stress impact [EUR m]	SRISK [EUR m]
Adv. scen. shortfall [EUR m]	1.00	0.32	-0.12	-0.20	-0.28	-0.18
Adv. scen. stress impact [EUR m]	0.32	1.00	-0.32	0.05	-0.16	-0.03
Banking book losses [EUR m]	-0.12	-0.32	1.00	0.68	0.79	0.63
Trading book losses [EUR m]	-0.20	0.05	0.68	1.00	0.74	0.82
SRISK stress impact [EUR m]	-0.28	-0.16	0.79	0.74	1.00	0.49
SRISK [EUR m]	-0.18	-0.03	0.63	0.82	0.49	1.00

Table 7: Correlations between stress impact scaled by total assets and SRISK stress impact scaled by total assets.

	Adv. scen. stress impact / TA [%]	Banking book losses / TA [%]	Trading book losses / TA [%]	SRISK stress impact / TA [%]
Adv. scen. stress impact / TA [%]	1.00	0.60	-0.08	0.05
Banking book losses / TA [%]	0.60	1.00	0.07	0.03
Trading book losses / TA [%]	-0.08	0.07	1.00	0.12
SRISK stress impact / TA [%]	0.05	0.03	0.12	1.00

To investigate what factors may explain the SRISK stress impact, we regress it on the same set of explanatory variables as the adverse scenario stress impact in Table 3. The results are reported in **Table 8**. Since SRISK is only available for publicly traded banks, the coverage is limited to about 40 banks corresponding to 50% of total banking assets covered by the CA. The main observation that can be made from Table 8 is that the proportion of explained variance of the SRISK stress impact is very low, with almost no statistically significant coefficients.

The reason that variables that explain the outcomes of the ECB/EBA stress test explain very little variation of the SRISK stress impact is that the model underlying the SRISK measure does not properly account for losses that would wipe out the entire equity of a bank. Rather than modelling the loss of value of assets in case of a shock, as was done in the CA, SRISK models stock returns in case of a shock. In the ECB/EBA stress scenario, the losses under the stress scenario can exceed the capital a bank has prior to the stress. In contrast in the SRISK stress scenario, thinly capitalized banks may experience a large negative stock return, but their equity is not wiped out, however low it may be initially. This bounds the loss of value in the SRISK stress scenario to the initial market value of equity. As a result, the SRISK measure greatly underestimates the loss of value for banks with low initial capital and overestimates the losses for banks with high initial market value of equity. The loss

of value expressed as a proportion of book total assets in the SRISK scenario is consequently best explained by the initial market leverage ratio of a bank – higher capitalized banks have more equity to lose, relative to total assets.

Table 8: SRISK stress impact scaled by total assets.

	SRISK stress impact/ TA (1)	SRISK stress impact/ TA (2)	SRISK stress impact/ TA (3)	SRISK stress impact/ TA (4)	SRISK stress impact/ TA (5)	SRISK stress impact/ TA (6)
GDP growth, 3 year	7.4086			21.3960		13.3523
	(0.54)			(0.97)		(0.75)
Govt. bond yield		7.9244				
		(0.72)				
EDF nonfin. sector			-117.5314			
			(-1.42)			
Unemployment, 3 year average			47.3606			
			(1.70)			
Bank activity restr. ind.	-0.5239	-1.0003	-1.6513**	-0.1994	-0.0866	-1.0753
	(-0.76)	(-1.19)	(-2.69)	(-0.28)	(-0.23)	(-0.89)
Capital regulatory ind.	-0.5831	-0.7504	-2.4928*	-0.5840	-0.1834	-0.9722
	(-1.04)	(-1.18)	(-2.13)	(-1.37)	(-0.81)	(-0.98)
Size	0.3290	0.4676	0.5282	0.4130	0.5763**	0.3350
	(1.01)	(1.05)	(0.99)	(0.91)	(2.46)	(0.73)
Book leverage ratio	89.0338	72.9845	58.6545	85.1226	58.9531**	87.8872
	(1.45)	(1.51)	(1.29)	(1.69)	(2.91)	(1.42)
Loans/ TA	2.6403	2.6896	-2.3614	3.7127	2.4658	4.7119
	(0.78)	(0.68)	(-0.30)	(0.80)	(0.72)	(0.98)
RWA/ TA	-5.6736	-3.2214	-1.0107	-7.1147	-3.7256	-3.2916
	(-1.21)	(-0.85)	(-0.36)	(-0.95)	(-0.76)	(-0.71)
ROA	-3.3458	-10.4252	-9.0891	13.5989	23.4505*	-2.3189
	(-0.16)	(-0.39)	(-0.37)	(1.02)	(1.91)	(-0.13)
Impaired loans ratio				10.8675		
				(0.93)		
Bank CDS spread					0.0421	
					(0.49)	
Bank stock 4-factor alpha						-0.4231
						(-0.11)
N of observations	43	40	39	42	30	36
Coverage of bank assets [%]	62.07	61.88	58.30	61.96	52.14	48.20
Adjusted R2	-0.0203	-0.0362	0.0932	0.0625	0.0973	-0.0266

The dependent variable is the stress impact implied by the SRISK capital shortfall, scaled by book total assets. Regressions are estimated using OLS with standard errors clustered at country level. In parentheses are t-statistics. Significance levels of 0.10, 0.05 and 0.01 are denoted by *, **, ***, respectively.

Table 9 demonstrates the **link between the SRISK stress impact and market leverage ratio** very clearly. It compares regressions of ECB stress impact (regressions (1), (2) and (3)) with regressions of the SRISK stress impact (regressions (4), (5) and (6)) on the same set of variables and for an identical sample of banks.[11] In regressions (2) and (5) market leverage ratio is used instead of book leverage ratio, as a control for initial bank capitalization before the stress impact. Using market leverage ratio instead of book leverage ratio does not materially affect estimates of regressions of the ECB stress impact. The estimated effect of market leverage ratio is negative, like the effect of book

[11] Note that the main relationships, the direction of signs and often also significance levels, shown for the adverse scenario stress impact on the full sample also hold for the reduced sample for which SRISK is available.

leverage ratio. Banks with more equity are expected to suffer lower losses. R squared stays at the same level, at about 0.65. In contrast market leverage ratio explains almost the entire variation in the SRISK stress impact. The R squared increases from 0.07 with book leverage ratio to 0.92 with market leverage ratio. In regression (6) market leverage ratio alone explains 89% of the variation in the SRISK stress impact, while it has virtually no explanatory power in case of the adverse scenario stress impact (column (3)). Banks with high initial market capitalization lose much more value in the SRISK stress scenario than those with very low market capitalization.

Table 9: Comparing the ECB adverse scenario stress impact and the SRISK stress impact: the importance of market leverage ratio.

	Adv. scen. stress impact/ TA (1)	Adv. scen. stress impact/ TA (2)	Adv. scen. stress impact/ TA (3)	SRISK stress impact/ TA (4)	SRISK stress impact/ TA (5)	SRISK stress impact/ TA (6)
GDP growth, 3 year	-10.6212**	-4.8839		21.3960	-5.7205	
	(-2.52)	(-1.54)		(0.97)	(-0.94)	
Bank activity restr. ind.	-0.5327***	-0.3927*		-0.1994	-0.3714	
	(-3.07)	(-1.92)		(-0.28)	(-1.21)	
Capital regulatory ind.	-0.5001***	-0.5059***		-0.5840	-0.2337	
	(-4.23)	(-4.75)		(-1.37)	(-1.25)	
Size	-0.2443*	-0.2224		0.4130	0.2982*	
	(-1.95)	(-1.60)		(0.91)	(1.91)	
Loans/ TA	-0.6676	-0.2486		3.7127	-0.1704	
	(-0.51)	(-0.19)		(0.80)	(-0.10)	
RWA/ TA	3.3016**	0.4674		-7.1147	-0.4134	
	(2.41)	(0.25)		(-0.95)	(-0.24)	
Impaired loans ratio	9.5597***	9.8883***		10.8675	-0.6279	
	(7.46)	(6.54)		(0.93)	(-0.44)	
ROA	2.6278	1.9402		13.5989	-17.9481	
	(0.33)	(0.22)		(1.02)	(-1.68)	
Book leverage ratio	-36.1809*			85.1226		
	(-1.88)			(1.69)		
Market lev. ratio		-0.0547**	0.0158		0.5555***	0.5440***
		(-2.40)	(0.37)		(11.85)	(9.45)
N of observations	42	42	43	42	42	43
Coverage of bank assets [%]	61.96	61.96	62.07	61.96	61.96	62.07
Adjusted R2	0.6575	0.6217	-0.0215	0.0625	0.9126	0.8896

The dependent variables are the adverse scenario stress impact of the ECB stress test and the SRISK stress impact. Both are scaled by total assets. Regressions are estimated using OLS with standard errors clustered at country level. In parentheses are t-statistics. Significance levels of 0.10, 0.05 and 0.01 are denoted by *, **, ***, respectively.

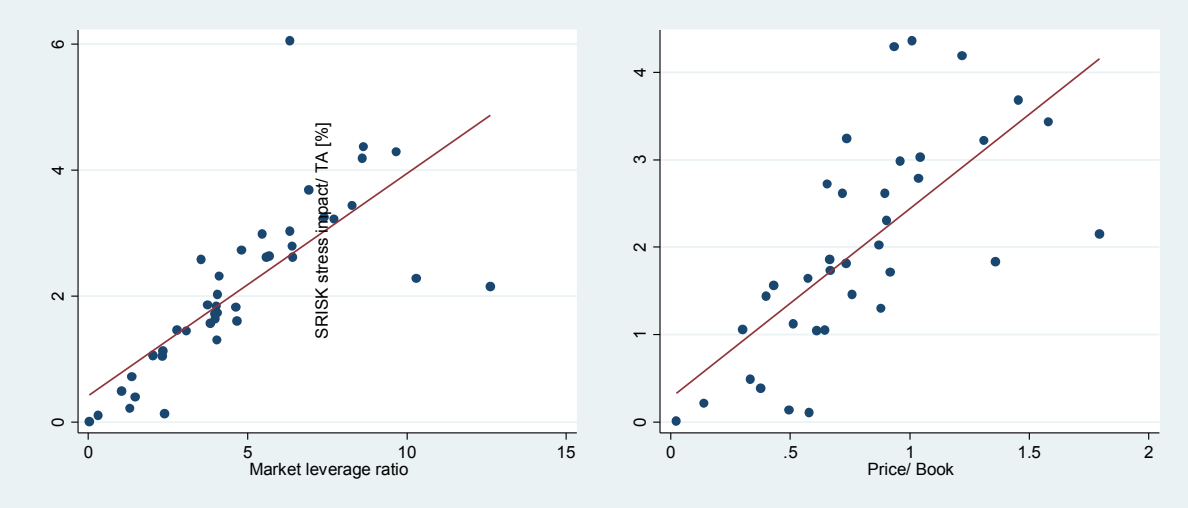
A positive link between market leverage ratio could be consistent with the explanation that banks with higher market equity have riskier portfolios. The relationship is, however, very strong and almost mechanical, suggesting it is due to the design of the SRISK measure. In order to understand this, it is imperative to recall the expression for SRISK stress impact provided earlier:

$$\frac{SRISK_{Stress\ Impact}}{TA_{Book}} = LRMES * \frac{Equity_{Market}}{TA_{Market}} * \frac{TA_{Market}}{TA_{Book}} \quad (5)$$

The first term results from long term covariances with the market, and while better capitalised banks might engage in more risky behaviour than less well capitalised ones, there should and is no strong

relationship between leverage ratio and LRMES. The last term can be roughly approximated by 1, since there is typically no large discrepancy between book and market value of debt. While price to book ratio varies much more, it is effectively dominated by debt in the calculation of this ratio, as equity is a far smaller component of bank balance sheets than debt. The middle term is the market leverage ratio, which can be shown do display a large heterogeneity in our sample, effectively dominating the effect of the variation in LRMES.

Figure 3: SRISK stress impact scaled by total assets vs. market leverage ratio (left) and price to book ratio (right).



The sample for the scatterplot with market leverage ratio does not include Allied Irish Banks, which is an outlier with a market leverage ratio of 36%. The observation of Allied Irish banks lies close to the fitted regression line so it does not affect the correlation. We do not plot it to prevent the other observations being collapsed to a small area of the plot.

Similarly, SRISK stress impact is also highly correlated with price to book ratio, which alone explains 47% of the variation in the SRISK stress scenario. Banks with larger price to book ratio are expected to suffer larger losses in the stress scenario. The correlations of SRISK stress impact with market leverage ratio and price to book ratio are depicted in Figure 3. Table 10 provides the regression results for price to book ratio. Book leverage ratio has a marginally significant negative effect on the stress impact of the ECB/EBA adverse scenario; price to book ratio is insignificant. For SRISK stress impact price to book ratio has a highly significant positive effect.

In order to check, whether SRISK performs better when evaluated in a way it is originally modelled, i.e. in terms of stock returns, we scale SRISK stress impact by initial market capitalization of banks. Loss of value in the SRISK stress scenario divided by market capitalization approximates the stock return over the 6 month period in the SRISK stress scenario. Table 13 in the Appendix reports these results. GDP growth and quality of banking supervision measures now have a significant effects with the expected negative sign.[12] However, the effects of market leverage ratio and price to book ratio are

[12] Note that a larger SRISK stress impact / initial market capitalization should be interpreted as a negative stock return large in absolute value.

still dominant. In addition the negative return on equity in the stress scenario seems to be smaller for banks with higher impaired loans ratio, which is in conflict with economic intuition. This analysis shows that SRISK is inappropriate as a measure of expected bank losses in a stress scenario. Consequently the shortfalls computed based on the SRISK stress scenario do not properly reflect the capital needed for banks to withstand an adverse stress scenario.

Table 10: Comparing the ECB adverse scenario stress impact and the SRISK stress impact: the importance of price to book ratio.

	Adv. scen. stress impact/ TA (1)	Adv. scen. stress impact/ TA (2)	Adv. scen. stress impact/ TA (3)	SRISK stress impact/ TA (4)	SRISK stress impact/ TA (5)	SRISK stress impact/ TA (6)
GDP growth, 3 year	-10.6212**	-16.0250***		21.3960	-8.5172***	
	(-2.52)	(-3.40)		(0.97)	(-4.13)	
Bank activity restr. ind.	-0.5327***	-0.3494		-0.1994	-0.3030**	
	(-3.07)	(-1.78)		(-0.28)	(-2.80)	
Capital regulatory ind.	-0.5001***	-0.2591		-0.5840	-0.1470*	
	(-4.23)	(-1.38)		(-1.37)	(-1.88)	
Size	-0.2443*	-0.2100		0.4130	0.3994***	
	(-1.95)	(-1.55)		(0.91)	(4.83)	
Loans/ TA	-0.6676	-2.9656		3.7127	1.9461	
	(-0.51)	(-1.46)		(0.80)	(1.51)	
RWA/ TA	3.3016**	3.8423**		-7.1147	1.4205	
	(2.41)	(2.88)		(-0.95)	(1.20)	
Impaired loans ratio	9.5597***	8.0456***		10.8675	-3.4866*	
	(7.46)	(3.97)		(0.93)	(-2.10)	
ROA	2.6278	3.9402		13.5989	-0.4996	
	(0.33)	(0.37)		(1.02)	(-0.20)	
Book leverage ratio	-36.1809*	-39.4012*		85.1226	15.5929	
	(-1.88)	(-2.03)		(1.69)	(0.95)	
P/B ratio		-0.1464	-0.6767		2.2048***	2.1594***
		(-0.27)	(-0.76)		(11.15)	(4.37)
N of observations	42	35	36	42	35	36
Coverage of bank assets [%]	61.96	47.73	47.85	61.96	47.73	47.85
Adjusted R2	0.6575	0.6376	-0.0006	0.0625	0.7288	0.4724

The dependent variables are the adverse scenario stress impact of the ECB stress test and the SRISK stress impact. Both are scaled by total assets. Regressions are estimated using OLS with standard errors clustered at country level. In parentheses are t-statistics. Significance levels of 0.10, 0.05 and 0.01 are denoted by *, **, ***, respectively.

To illustrate the extent to which the stress impact of the ECB stress test and the SRISK stress impact differ, Table 11 compares the adverse scenario stress impact and the SRISK stress impact, sorting banks by the ratio of the SRISK stress impact relative to the adverse scenario stress impact. This confirms that for the poorly capitalised banks such as Dexia, Hellenic Bank, Banca Monte Paschi di Sienna, etc., the SRISK stress impact is only a small fraction of the impact under the adverse stress scenario. Likewise, for the highly capitalised banks such as Nordea Bank Finland, the SRISK stress impact is higher than the impact of the ECB stress test by a factor of 10. When looking at the SRISK impact relative to the initial market capitalization of a bank i.e. the return equity investors would suffer in the stress scenario, the SRISK figures range from 10% – 55%, which corresponds to the 40% drop in the general stock market. In contrast the range of losses in the SRISK stress scenario, relative to total assets spans from 0.96% to 21% of total assets of a bank. Given that small losses are

associated with weakly capitalized banks and large ones with banks that have high market capitalization relative to total assets, such dispersion clearly shows that the measure is unsuitable for estimating vulnerability of banks.

Table 11: Comparison of the stress impact of the ECB/EBA adverse scenario with SRISK stress impact, by bank.

Bank	Total assets	Market leverage ratio	SRISK stress impact/ TA	Adv. s. stress impact/ TA	SRISK stress impact/ Mcap.	Adv. s. stress impact/ Mcap.	SRISK impact/ Adv. s. impact
Dexia	222,936	0.02	0.01	2.62	27.32	7,402.3	0.00
Österreichische VB	20,904	2.39	0.13	5.59	10.15	423.2	0.02
Hellenic Bank	6,384	0.32	0.11	4.07	14.28	534.8	0.03
Bank of Cyprus	30,342	1.31	0.21	4.58	16.55	359.8	0.05
Banca Monte dei Paschi	198,461	1.03	0.49	2.88	46.89	275.9	0.17
Eurobank Ergasias	77,586	3.96	1.71	7.07	42.81	177.2	0.24
IKB Deutsche Industriebank	27,617	1.46	0.39	1.46	26.22	98.6	0.27
Banca Carige	42,156	2.31	1.05	3.88	39.36	145.9	0.27
Permanent TSB Group	37,601	4.65	1.61	5.35	35.94	119.7	0.30
Banco Comercial Português	82,007	4.02	1.84	4.04	45.37	99.7	0.46
Banca Popolare di Milano	49,353	3.09	1.44	2.57	48.29	86.2	0.56
Banco BPI	42,700	4.05	1.30	1.93	30.33	45.2	0.67
Banca popolare dell'Emilia	61,758	3.99	1.64	2.21	43.22	58.4	0.74
Banca Popolare di Sondrio	32,770	4.06	1.73	2.28	43.26	57.2	0.76
Banco Popolare	126,043	2.03	1.06	1.34	53.79	67.9	0.79
National Bank of Greece	110,930	8.29	3.43	4.13	40.08	48.2	0.83
UBI Banca	124,242	3.82	1.56	1.85	43.10	50.9	0.85
Crédit Agricole Group	1,688,541	1.36	0.71	0.73	43.96	45.3	0.97
Commerzbank	549,654	2.34	1.12	1.11	46.64	46.0	1.01
Alpha Bank	73,697	9.67	4.29	4.20	45.23	44.3	1.02
Deutsche Bank AG	1,611,400	2.04	1.05	1.02	46.36	44.8	1.04
OP-Pohjola Group	100,991	10.29	2.27	2.00	42.58	37.4	1.14
Piraeus Bank	92,010	8.64	4.36	3.62	51.11	42.5	1.20
UniCredit	827,538	3.74	1.86	1.34	49.98	36.1	1.39
Intesa Sanpaolo	624,179	4.80	2.72	1.80	49.37	32.6	1.51
Aareal Bank	42,981	4.12	2.31	1.41	56.79	34.6	1.64
Banco Popular Español	146,709	5.58	2.62	1.43	45.75	25.0	1.83
Banco de Sabadell	163,441	4.63	1.82	0.96	38.24	20.1	1.90
Société Générale	1,214,193	2.78	1.46	0.76	48.87	25.4	1.92
BNP Paribas	1,810,522	4.05	2.02	0.93	46.50	21.4	2.17
KBC Group	238,686	6.92	3.68	1.69	51.01	23.5	2.17
Mediobanca	75,285	7.40	3.24	1.44	44.35	19.8	2.24
Credito Emiliano	31,531	6.42	2.62	1.13	37.83	16.3	2.32
Erste Group Bank	200,118	5.45	2.98	1.24	53.44	22.2	2.41
Bank of Ireland	132,133	6.40	2.78	1.15	40.55	16.8	2.42
Banco Santander	1,115,637	6.33	3.03	0.68	45.38	10.1	4.49
BBVA	582,575	8.61	4.19	0.93	46.91	10.4	4.52
ING Bank	787,644	3.54	2.58	0.54	51.66	10.9	4.74
Caja de Ahorros Barcelona	351,269	5.67	2.63	0.50	46.43	8.9	5.22
Allied Irish Banks	117,734	35.97	21.13	3.99	42.09	7.9	5.30
Bankinter	55,136	7.72	3.22	0.38	38.73	4.6	8.44
Nordea Bank Finland	304,761	6.34	6.05	0.64	45.93	4.9	9.42
HSBC Bank Malta	5,722	12.61	2.15	0.06	14.36	0.4	36.88

Total assets and market capitalization are in million EUR. Market leverage ratio and stress impacts are reported in percent. SRISK impact / Adv. scen. impact is the ratio of the SRISK stress impact over the adverse scenario stress impact. Banks are sorted according to this ratio. At the top of the table are banks that lose very little value in the SRISK stress scenario compared to the value they are expected to lose in the adverse stress scenario of the ECB stress test. At the bottom of the table are banks that suffer large losses under in the SRISK stress scenario relative to their losses in the adverse scenario of the ECB stress test. For a more extensive version of this table that also reports market capitalization, Tier 1 ratio and book leverage ratio of banks see Table 14 in the Appendix.

The stress impact in the adverse scenario of the ECB/EBA stress test shows the opposite pattern. Losses relative to total assets range from 0.06% to 7%. Banks with low initial market value of equity lose a multiple of their equity value (up to 7400%) and well capitalized banks suffer only small losses relative to their market capitalization (less than 10%).

6. Robustness checks

To check the robustness of our results we perform additional regressions and report the results in the Appendix. First, we check whether scaling the stress impact by risk weighted assets instead of by total assets affects the results. Table 15 reports regressions with adverse scenario stress impact scaled by RWA. Explanatory variables are the same as in Table 3 apart from that we use Tier 1 capital ratio instead of book capital ratio and do not include risk weighted to total assets ratio. Because the dependent variable is already scaled by RWA there is no need to include RWA ratio as a control. The signs of estimated coefficients are mostly the same as when scaling by total assets. R squared is noticeably lower. The effect of impaired loans is not significant and higher Tier 1 ratio is associated with higher stress impact, while in the specifications scaled by total assets the effect of book leverage ratio was insignificant or negative.

Throughout the analysis we focused on the adverse scenario stress impact of the ECB/EBA stress test. In Table 16 we report results with the baseline scenario stress impact as the dependent variables. The results are very similar but the significance levels of estimated coefficients and R squared ratios are lower compared to the regressions for the adverse scenario, which is expected given that the variation of the stress impact across banks is lower in the baseline scenario. Furthermore we verify whether the assumption that the error terms only display correlation within the country clusters critically affects the inference. The results show that this is not the case in general, our conclusion about statistical significance remain valid for the vast majority of the coefficients.

7. Conclusions

A number of policy papers by Acharya and Steffen (2014a,b) that raise doubt on robustness of the ECB stress test, using SRISK as a benchmark, motivate a deeper analysis of the way stress is modelled in order to assess which results are credible. Accounting for size reveals that the stress impact on bank capital implied by SRISK is only marginally correlated with the stress impact as modelled for the ECB/EBA stress test, and key components thereof such as credit losses and trading losses.

The fundamental differences in the construction of SRISK stress impact and ECB/EBA stress test impact are reflected in the results of the multivariate regression analysis. On the one hand, the ECB/EBA stress test impact, and in particular the losses in the banking book, can be understood in terms of risk factors associated with credit losses. They also can be explained by market based

measures of bank vulnerability such as CDS spreads, while trading book losses display a more idiosyncratic behaviour, after controlling for the proportion of trading book assets in total assets.

SRISK stress impact, on the other hand, is rather disconnected from both basic risk factors related to credit losses and market implied measures of bank vulnerability.[13] It seems implausible that bank losses in a stress scenario are unrelated to existing default frequencies in the corporate sector, impaired loan ratios etc., even on the six month horizon of the SRISK stress. While the turmoil of 2008 illustrated how banks can be brought into jeopardy not by the original credit losses but also by secondary exacerbating factors such as illiquidity spirals and fire sales, the impact of credit losses on bank risk cannot be negated. While our analysis can neither verify the results obtained by the ECB/EBA stress test nor the SRISK results, it facilitates an intuitive understanding of the main drivers behind the results.

SRISK stress impact is highly positively correlated with market leverage ratio, and also with price to book ratio, with R squared in univariate regressions reaching 90% and 50% respectively. In other words, banks with a high ratio of equity to total assets are proportionally hit harder by the stress. To a certain extent this could be explained by riskier asset portfolios, but certainly not linearly to the extent found in the data. Furthermore, there is no reason why banks with a higher price to book ratio should suffer larger losses.

The findings suggest a rather mechanical relationship between SRISK stress impact and market leverage ratio, which can be explained by decomposing the analytical formula for SRISK stress impact appropriately. If heterogeneity in market leverage ratios is large, this is likely to dominate the heterogeneity in covariance of bank stock returns with the market index, and the market leverage becomes the driving factor behind the SRISK stress impact. This explains why SRISK and ECB stress test results diverge in particular for banks that are close to bankruptcy and banks that are extremely well capitalised.

The SRISK stress scenario is set up to model returns to equity holders; therefore the stress impact is bounded by the amount of equity. This is particularly worrying for banks that are initially insufficiently capitalised, where the limit on losses is most likely binding in a stress scenario. We show that this has severe practical implications, namely the SRISK stress impact is lower than what the ECB stress test finds up to a factor of 270 for the least well capitalised bank.

While not denying the usefulness of market implied measures of bank risk, we argue that the stress impact would have to be calculated relative to the total balance sheet. The difficulty in using a measure based on stock returns is to properly model losses in states where all equity is wiped out. The ECB/EBA stress test, on the other hand, models the entire asset side and thus captures the whole balance sheet; the challenges with this approach lie rather in the modelling of the stress scenario and losses of different asset classes.

[13] While public backstops and gambling on bail-outs participation of debt holders could explain this to a certain extent, it would nevertheless be brave to argue that CDS spreads are therefore not informative.

References

Acharya, V. V, R. Engle, and D. Pierret. 2014. Testing Macroprudential Stress Tests: The Risk of Regulatory Risk Weights. *Journal of Monetary Economics* 65:36–53.

Acharya, V. V, R. Engle, and M. Richardson. 2012. Capital Shortfall: A New Approach to Ranking and Regulating Systemic Risks. *American Economic Review* 102:59–64.

Acharya, V. V, and S. Steffen. 2014a. Benchmarking the European Central Bank's Asset Quality Review and Stress Test: A Tale of Two Leverage Ratios. *VOX CEPR's Policy Portal* .

Acharya, V. V, and S. Steffen. 2014b. Making Sense of the Comprehensive Assesment. *Working paper.* October 27.

Acharya, V. V, and S. Steffen. 2014c. Falling Short of Expectations ? Stress-Testing the European Banking System. *CEPS Policy Brief* 315.

Alfaro, R., and M. Drehmann. 2009. Macro Stress Tests and Crises: What Can We Learn? *BIS Quarterly Review* :29–42.

Angrist, J. D., and J.-S. Pischke. 2009. *Mostly Harmless Econometrics: An Empiricist's Companion*. *Princeton University Press* .

Asness, C., and A. Frazzini. 2013. The Devil in HML's Details. *Journal of Portfolio Management* .

Barth, J. R., G. Caprio, and R. Levine. 2012. The Evolution and Impact of Bank Regulations. *World Bank Policy Research Working Paper 6288* :1–27.

Barth, J. R., G. Caprio, and R. Levine. 2013. Bank Regulation and Supervision in 180 Countries from 1999 to 2011. *Journal of Financial Economic Policy* 5:111–219.

Borio, C., M. Drehmann, and K. Tsatsaronis. 2014. Stress-Testing Macro Stress Testing: Does It Live up to Expectations? *Journal of Financial Stability* 12:3–15.

Cameron, A. C., and D. L. Miller. 2013. A Practitioner's Guide to Cluster-Robust Inference. *Working paper* :1–60.

Carhart, M. M. 1997. On Persistence in Mutual Fund Performance. *Journal of Finance* LII:57–82.

ECB. 2014. Aggregate Report on the Comprehensive Assessment. *European Central Bank* October 20.

ESRB. 2014. EBA/SSM Stress Test: The Macroeconomic Adverse Scenario.:1–17.

Fama, E. F., and K. R. French. 1993. Common Risk Factors in the Returns on Stocks and Bonds. *Journal of Financial Economics* 33:3–56.

Garcia, R. I., J. G. Ibrahim, and H. Zhu. 2010. Variable Selection for Regression Models With Missing Data. *Statistica Sinica* 20:149–65.

Kearns, A. 2004. Loan Losses and the Macroeconomy: A Framework for Stress Testing Credit Institutions' Financial Well-Being. *Financial Stability Report* :111–22.

Mileris, R. 2012. Macroeconomic Determinants of Loan Portfolio Credit Risk in Banks. *Inzinerine Ekonomika-Engineering Economics* 23:496–504.

Pesaran, M. H., T. Schuermann, B.-J. Treutler, and S. M. Weiner. 2003. Macroeconomic Dynamics and Credit Risk. *CESifo Working Paper No. 995* .

Schmidheiny, K. 2012. Clustering in the Linear Model. *Short Guideds to Microeconometrics - Universitaet Basel* :7–11.

Steffen, S. 2014. Robustness, Validity and Significance of the ECB's Asset Quality Review and Stress Test Exercise. *Study requested by the European Parliament's Economic and Monetary Affairs Committee* .

Zou, H. 2006. The Adaptive Lasso and Its Oracle Properties. *Journal of the American Statistical Association* 101:1418–29.

Annex 1: Weighting scheme

We use data on bank exposures to 67 different countries to weight variables describing macroeconomic conditions. These data are from ECB and have a few limitations that need to be addressed. Firstly, total exposures are not always equal to total assets. However, in most cases, more than 90% of assets are covered. Secondly, data on some exposures are missing for 30 banks in the AQR sample. We scale up other exposures of these banks so that they sum up to 100% of total assets. Then we assume that the banks, for which exposure data is missing completely, are only exposed to the country they are headquartered in. Given that the covered banks have an average exposure of 73% to their home country, this is a reasonable approximation. Lastly, macroeconomic data is not available for all countries banks can have exposures to. We deal with this problem as follows: If for example government bond yield data for Luxemburg is missing, for the specific purpose of calculating the weighted government bond yield, the exposure of all banks towards Luxemburg is dropped and the remaining exposures are scaled up to sum to 100%. However, this procedure is only applied if the macroeconomic variable is available for the country the financial institution is headquartered in. If not, the macroeconomic variable is treated as missing for such a bank.

Annex 2: Regression setup

Variable selection is based on economic intuition, considering both the data availability of each variable and potential multi-collinearity. Therefore we show regression setups that achieve a coverage of around 105 banks, and the setups where the market based regressors are used, with a much lower coverage of around 40-50 banks. Multi-collinearity is an issue when too many variables relating to the macro-economic environment are used, because the variation of these variables exists mainly on a country level (even though for some of the variables, due to the weighting scheme linked to banks' exposures, there is some additional bank heterogeneity). Given that we cover banks in 12 countries, this limits the number of macro-variables that potentially do not display multi-collinearity to a maximum of 11; in reality since macro-variables are also correlated, the number of them that can be used simultaneously is much lower.

Using variable selection techniques such as least angle regressions or LASSO (Zou 2006) starting from the entire set of regressors is not adding much value, because of missing data for some regressors.[14] It is easier to control for this variation in sample size manually than inducing an algorithm to choose a setup where as many banks as possible remain in the sample. Also, applying an algorithm to groups of regressors with similar coverage undermines the whole idea of having a variable selection algorithm. For transparency we report in Table 12 the results of the selected setup when applying least angle regression as variable selection method on the basic set of variables, excluding any variable with coverage of less than 60 banks before applying the algorithm. It chooses a similar number of regressors, with a coverage of 88 banks (see below), as we do. Also, it selects only two macro variables simultaneously and additional two variables with pure cross-country variability (the bank activity restr. ind. and the capital regulatory ind.).

The cross-sectional regression analysis is performed via OLS but we rely on cluster robust standard errors. Note that this does not affect the parameter estimates. The choice of clusters takes into account the guidance from the literature (Cameron and Miller 2013; Schmidheiny 2012; Angrist and Pischke 2009). Given that our macro-variables refer to baseline forecasts or past values and therefore do not reflect a stress scenario, the errors in the regressions are likely to be correlated across banks in the same country/region. Likewise it could be that we neglect bank characteristics that could be related to (i) size or (ii) the business model, which would lead to errors being correlated across banks of similar size or a similar business model. Hence, ideally all these components should be reflected by the clusters, but given that we do not have sufficient observations to allow clustering along those three dimensions, we conduct a robustness analysis clustering by each of those three concepts separately.

[14] Recent developments in variable selection algorithms include ways to overcome the problem of missing data, as discussed in Garcia, Ibrahim, and Zhu (2010). The adaptive LASSO (Zou 2006) would be one way to deal with the missing data, and we intend to complement our setups by the preferred adaptive LASSO solution once this algorithm is implemented in STATA.

The preferred setup is with clustering according to countries (12 countries, results shown in the main text). This follows practice of other papers, in the context of regressions involving individual bank data this is done for instance in Barth, Caprio, and Levine (2013).

Clustering according to the business model classification (9 categories[15]) also has strong economic appeal, while clustering by size suffers from the defect that bank size does not cluster well, but is rather a continuum of values that is artificially broken up into clusters. Furthermore size is to a certain extent reflected in the business model classification, when it meaningfully supports clustering. For the robustness check we create clusters according to the following limits on the bank's total asset: Cluster 1: Size > EUR 800 bn, Cluster 2: EUR 40 bn – EUR 800 bn and Cluster 3: Size < EUR 40 bn. Due to the low number of clusters the variance of these standard errors is likely much larger than in the other specifications, but this clustering separates the G-SIBs and the very small banks from the other banks and therefore has some economic motivation.

Since the number of clusters in each of our methods is rather small, calculating the cluster-robust standard errors increases the variance of the error estimates at the same time as reducing the bias. A priori, it is unknown which of these factors is more relevant in reality. We also cross-check the standard errors with Huber-White heteroscedasticity robust standard errors, which do not correct for intra-cluster correlation of the residuals. Table 17, Table 18 and Table 19 in Annex 5 report estimates comparable to Table 3 with standard errors clustered by business model classification, by size and Huber-White robust standard, respectively.

The main conclusion from this robustness analysis is that significance levels based on standard errors clustered by business model or bank size do not deviate strongly from those clustered by country; they actually result in tighter error bands for some parameters and wider error bands for other parameters without strongly impacting significance of the parameters values. The results based on Huber-White standard errors are also very similar. The main variables we interpret remain statistically significant as reported in Annex 5.

[15] Heinrich Kick (2015), mimeo

Table 12: Results of the least angle variable selection procedure.

	Adv. scen. stress impact/ TA
	(1)
Govt. bond yield	0.0844*
	(2.17)
Unemployment, 3 year average	-0.0307**
	(-2.59)
Loan loss provisions ratio	-0.0007
	(-0.24)
Bank activity restr. ind.	-0.1206**
	(-2.23)
Capital regulatory ind.	-0.1199***
	(-2.67)
Gross loans/ TA	0.4993
	(1.43)
Tier 1 ratio	1.9320
	(1.61)
Impaired loans ratio	2.3138***
	(4.41)
N of observations	88
R2	0.3644

The dependent variable is the stress impact implied by the SRISK capital shortfall, scaled by book total assets. Regressions are estimated using least angle variable selection procedure. In parentheses are t-statistics. Significance levels of 0.10, 0.05 and 0.01 are denoted by *, **, ***, respectively.

Annex 3: SRISK additional regressions

Table 13: SRISK stress impact scaled by market value of equity before the shock.

	SRISK stress impact/ MCAP (1)	SRISK stress impact/ MCAP (2)	SRISK stress impact/ MCAP (3)	SRISK stress impact/ MCAP (4)	SRISK stress impact/ TA (5)	SRISK stress impact/ TA (6)
GDP growth, 3 year	-42.8496**	-78.1105***		-33.0390	-5.7205	-8.5172***
	(-2.43)	(-3.34)		(-1.32)	(-0.94)	(-4.13)
Bank activity restr. ind.	-1.3872	-3.1741**	-1.9251	-3.4632*	-0.3714	-0.3030**
	(-1.13)	(-2.25)	(-1.12)	(-2.17)	(-1.21)	(-2.80)
Capital regulatory ind.	-2.8867**	-3.1219***	-2.6890*	-4.3391**	-0.2337	-0.1470*
	(-2.63)	(-3.42)	(-2.05)	(-2.93)	(-1.25)	(-1.88)
Size	6.0891***	5.3015***	4.1250**	5.8119***	0.2982*	0.3994***
	(5.44)	(4.31)	(2.82)	(6.15)	(1.91)	(4.83)
Book leverage ratio	17.9638	69.1133	84.0374	-0.8979		15.5929
	(0.12)	(0.47)	(0.51)	(-0.01)		(0.95)
Market lev. ratio					0.5555***	
					(11.85)	
P/B ratio						2.2048***
						(11.15)
Loans/ TA	34.0357**	28.8195***	22.0457	33.0739**	-0.1704	1.9461
	(2.71)	(3.06)	(1.55)	(2.46)	(-0.10)	(1.51)
RWA/ TA	-10.2438	-5.3135	1.9484	-2.1497	-0.4134	1.4205
	(-0.46)	(-0.33)	(0.09)	(-0.09)	(-0.24)	(1.20)
ROA	36.6061	-35.7157	-37.9950	41.2167	-17.9481	-0.4996
	(0.88)	(-0.96)	(-0.74)	(1.25)	(-1.68)	(-0.20)
Impaired loans ratio		-38.4420**			-0.6279	-3.4866*
		(-2.44)			(-0.44)	(-2.10)
Bank CDS spread			-0.2393			
			(-0.49)			
Bank stock 4-factor alpha				1.9452		
				(0.11)		
N of observations	43	42	30	36	42	35
Coverage of bank assets [%]	62.07	61.96	52.14	48.20	61.96	47.73
Adjusted R2	0.5134	0.5517	0.0591	0.4653	0.9126	0.7288

The dependent variable is the stress impact implied by the SRISK capital shortfall scaled by the market value of equity before the shock. This way SRISK stress impact can be interpreted as the negative return on bank stock as a result of the shock in the stress scenario. Regressions are estimated using OLS with standard errors clustered at country level. In parentheses are t-statistics. Significance levels of 0.10, 0.05 and 0.01 are denoted by *, **, ***, respectively.

Annex 4: Comparison of the ECB stress test impact and the SRISK stress impact

Table 14: Comparison of the adverse stress impact (of the ECB stress test) with SRISK stress impact, by bank.

Bank	Total assets	Market cap.	Tier 1 ratio	Market lev. ratio	Book lev. ratio	SRISK stress impact/ TA	Adv. s. stress impact/ TA	SRISK stress impact/ Mcap.	Adv. s. stress impact/ Mcap.	SRISK impact/ Adv. s. impact
Dexia	222,936	79	0.21	0.02	1.78	0.01	2.62	27.32	7,402.3	0.00
Österreichische VB	20,904	536	0.14	2.39	5.84	0.13	5.59	10.15	423.2	0.02
Hellenic Bank	6,384	48	0.13	0.32	6.25	0.11	4.07	14.28	534.8	0.03
Bank of Cyprus	30,342	378	0.10	1.31	9.00	0.21	4.58	16.55	359.8	0.05
Banca Monte dei Paschi	198,461	2,078	0.11	1.03	3.11	0.49	2.88	46.89	275.9	0.17
Eurobank Ergasias	77,586	3,061	0.11	3.96	5.83	1.71	7.07	42.81	177.2	0.24
IKB Deutsche Industriebank	27,617	366	0.10	1.46	4.07	0.39	1.46	26.22	98.6	0.27
Banca Carige	42,156	984	0.06	2.31	3.90	1.05	3.88	39.36	145.9	0.27
Permanent TSB Group	37,601	1,664	0.13	4.65	6.34	1.61	5.35	35.94	119.7	0.30
Banco Comercial Português	82,007	3,320	0.13	4.02	3.99	1.84	4.04	45.37	99.7	0.46
Banca Popolare di Milano	49,353	1,474	0.08	3.09	7.39	1.44	2.57	48.29	86.2	0.56
Banco BPI	42,700	1,711	0.16	4.05	5.40	1.30	1.93	30.33	45.2	0.67
Banca popolare dell'Emilia	61,758	2,341	0.09	3.99	7.63	1.64	2.21	43.22	58.4	0.74
Banca Popolare di Sondrio	32,770	1,309	0.08	4.06	6.14	1.73	2.28	43.26	57.2	0.76
Banco Popolare	126,043	2,493	0.11	2.03	6.76	1.06	1.34	53.79	67.9	0.79
National Bank of Greece	110,930	9,340	0.11	8.29	7.10	3.43	4.13	40.08	48.2	0.83
UBI Banca	124,242	4,513	0.13	3.82	9.00	1.56	1.85	43.10	50.9	0.85
Crédit Agricole Group	1,688,541	23,565	0.13	1.36	4.84	0.71	0.73	43.96	45.3	0.97
Commerzbank	549,654	13,518	0.13	2.34	4.90	1.12	1.11	46.64	46.0	1.01
Alpha Bank	73,697	6,978	0.16	9.67	11.35	4.29	4.20	45.23	44.3	1.02
Deutsche Bank AG	1,611,400	35,845	0.17	2.04	3.41	1.05	1.02	46.36	44.8	1.04
OP-Pohjola Group	100,991	4,749	0.17	10.29	7.65	2.27	2.00	42.58	37.4	1.14
Piraeus Bank	92,010	7,853	0.14	8.64	9.28	4.36	3.62	51.11	42.5	1.20
UniCredit	827,538	31,600	0.11	3.74	6.05	1.86	1.34	49.98	36.1	1.39
Intesa Sanpaolo	624,179	29,581	0.12	4.80	7.22	2.72	1.80	49.37	32.6	1.51
Aareal Bank	42,981	1,747	0.19	4.12	5.70	2.31	1.41	56.79	34.6	1.64
Banco Popular Español	146,709	8,415	0.12	5.58	7.92	2.62	1.43	45.75	25.0	1.83
Banco de Sabadell	163,441	7,671	0.12	4.63	6.37	1.82	0.96	38.24	20.1	1.90
Société Générale	1,214,193	34,130	0.13	2.78	4.44	1.46	0.76	48.87	25.4	1.92
BNP Paribas	1,810,522	71,364	0.13	4.05	5.02	2.02	0.93	46.50	21.4	2.17
KBC Group	238,686	17,411	0.16	6.92	6.08	3.68	1.69	51.01	23.5	2.17
Mediobanca	75,285	5,553	0.12	7.40	9.85	3.24	1.44	44.35	19.8	2.24
Credito Emiliano	31,531	1,960	0.10	6.42	6.84	2.62	1.13	37.83	16.3	2.32
Erste Group Bank	200,118	11,039	0.12	5.45	7.39	2.98	1.24	53.44	22.2	2.41
Bank of Ireland	132,133	8,257	0.12	6.40	5.97	2.78	1.15	40.55	16.8	2.42
Banco Santander	1,115,637	74,613	0.13	6.33	7.16	3.03	0.68	45.38	10.1	4.49
BBVA	582,575	52,419	0.12	8.61	7.70	4.19	0.93	46.91	10.4	4.52
ING Bank	787,644	39,256	0.14	3.54	4.29	2.58	0.54	51.66	10.9	4.74
Caja de Ahorros Barcelona	351,269	19,008	0.13	5.67	7.75	2.63	0.50	46.43	8.9	5.22
Allied Irish Banks	117,734	59,111	0.14	35.97	8.91	21.13	3.99	42.09	7.9	5.30
Bankinter	55,136	4,522	0.13	7.72	6.17	3.22	0.38	38.73	4.6	8.44
Nordea Bank Finland	304,761	40,172	0.16	6.34	3.12	6.05	0.64	45.93	4.9	9.42
HSBC Bank Malta	5,722	768	0.09	12.61	7.39	2.15	0.06	14.36	0.4	36.88

Total assets and market capitalization are in million EUR. Tier 1 ratio, leverage ratios and stress impacts are reported in percent. SRISK impact / Adv. scen. impact is the ratio of the SRISK stress impact over the adverse scenario stress impact. Banks are sorted according to this ratio. At the top of the table are banks that lose very little value in the SRISK stress scenario compared to the value they are expected to lose in the adverse stress scenario of the ECB stress test. At the bottom of the table are banks that suffer large losses under in the SRISK stress scenario relative to their losses in the adverse scenario of the ECB stress test.

Annex 5: Robustness checks

Table 15: Adverse scenario stress impact, scaled by risk weighted assets.

	Adv. scen. stress impact/ RWA (1)	Adv. scen. stress impact/ RWA (2)	Adv. scen. stress impact/ RWA (3)	Adv. scen. stress impact/ RWA (4)	Adv. scen. stress impact/ RWA (5)	Adv. scen. stress impact/ RWA (6)
GDP growth, 3 year	-26.1952***			-25.7178***		-29.4082***
	(-6.17)			(-4.41)		(-9.05)
Govt. bond yield		43.4131*				
		(2.06)				
EDF nonfin. sector			5.3480			
			(0.18)			
Unemployment, 3 year average			1.4072			
			(0.11)			
Bank activity restr. ind.	-0.7141**	-0.5538	-0.1295	-0.9237***	-0.2484	-0.4888
	(-2.47)	(-1.32)	(-0.22)	(-3.93)	(-0.74)	(-1.27)
Capital regulatory ind.	-0.6719*	-0.6303	-0.4162	-0.8638**	-0.3135	-0.5147
	(-1.80)	(-1.61)	(-0.57)	(-2.53)	(-0.81)	(-1.75)
Size	-0.3000*	-0.1680	-0.2081	-0.3809**	-0.0870	-0.1935
	(-2.04)	(-0.76)	(-1.05)	(-2.64)	(-0.38)	(-1.51)
Tier 1 ratio	15.8534***	14.2280**	9.4705	15.8357***	49.5654	33.8787*
	(3.21)	(2.40)	(1.51)	(3.25)	(1.65)	(1.81)
Loans/ TA	-2.3759**	-2.2293**	-2.2695	-4.3548***	-3.3727**	-5.6061
	(-2.67)	(-2.42)	(-1.50)	(-3.06)	(-2.49)	(-1.54)
ROA	-46.6491***	-52.9554***	-58.4939***	-38.1292**	-18.8829	-22.0751
	(-3.64)	(-3.27)	(-4.16)	(-2.19)	(-1.14)	(-0.84)
Impaired loans ratio				3.1261		
				(0.82)		
Bank CDS spread					0.5955***	
					(6.06)	
Bank stock 4-factor alpha						-2.0893
						(-0.33)
N of observations	120	107	105	105	51	41
Coverage of bank assets [%]	97.99	97.03	88.01	92.08	67.71	48.63
Adjusted R2	0.2824	0.2533	0.1385	0.3481	0.3522	0.3545

The dependent variable is adverse scenario stress impact. In this robustness check it is expressed in percent of risk weighted assets as it is originally reported. Regressions are estimated using OLS with standard errors clustered at country level. In parentheses are t-statistics. Significance levels of 0.10, 0.05 and 0.01 are denoted by *, **, ***, respectively.

Table 16: Baseline scenario stress impact.

	Base. scen. stress impact/ TA (1)	Base. scen. stress impact/ TA (2)	Base. scen. stress impact/ TA (3)	Base. scen. stress impact/ TA (4)	Base. scen. stress impact/ TA (5)	Base. scen. stress impact/ TA (6)
GDP growth, 3 year	-2.5900			-1.8128		-6.9832**
	(-1.41)			(-1.15)		(-2.40)
Govt. bond yield		10.4831***				
		(3.78)				
EDF nonfin. sector			3.0748			
			(0.80)			
Unemployment, 3 year average			2.0049			
			(0.91)			
Bank activity restr. ind.	-0.1658**	-0.1901**	-0.1817	-0.1929***	-0.0936	-0.0960
	(-2.22)	(-2.51)	(-1.72)	(-3.28)	(-1.45)	(-0.97)
Capital regulatory ind.	-0.1705**	-0.1787***	-0.2101*	-0.2104***	-0.0465	-0.1301*
	(-2.67)	(-3.31)	(-1.83)	(-3.49)	(-0.94)	(-1.80)
Size	-0.0558	-0.0576	-0.0813*	-0.0486	-0.1554**	-0.0523
	(-1.51)	(-1.73)	(-1.96)	(-1.21)	(-2.27)	(-0.64)
Book leverage ratio	-0.1277	0.0680	-2.4672	-0.0902	-7.6652	-6.2965
	(-0.06)	(0.03)	(-0.88)	(-0.04)	(-0.82)	(-0.58)
Loans/ TA	-0.3569	-0.1739	-0.4646	-0.3532	-0.9365*	-0.0772
	(-1.51)	(-0.64)	(-1.33)	(-1.02)	(-2.03)	(-0.10)
RWA/ TA	0.1361	-0.0446	0.2594	-0.1194	0.5621	-1.7763
	(0.41)	(-0.13)	(0.67)	(-0.45)	(1.08)	(-1.13)
ROA	-7.9635	-12.4109***	-15.1920***	-5.4233	-9.9827	-1.0433
	(-1.49)	(-5.76)	(-6.59)	(-0.92)	(-1.64)	(-0.15)
Impaired loans ratio				1.1687		
				(1.23)		
Bank CDS spread					0.1182***	
					(4.50)	
Bank stock 4-factor alpha						-1.2024
						(-1.06)
N of observations	121	108	105	105	51	41
Coverage of bank assets [%]	98.33	97.36	88.01	92.08	67.71	48.63
Adjusted R2	0.1300	0.2875	0.2119	0.1615	0.2971	0.1837

The dependent variable is baseline scenario stress impact scaled by total assets. Regressions are estimated using OLS with standard errors clustered at country level. In parentheses are t-statistics. Significance levels of 0.10, 0.05 and 0.01 are denoted by *, **, ***, respectively.

Table 17: Adverse scenario stress impact, estimates with clustering of standard errors by business model classification.

	Adv. scen. stress impact/ TA (1)	Adv. scen. stress impact/ TA (2)	Adv. scen. stress impact/ TA (3)	Adv. scen. stress impact/ TA (4)	Adv. scen. stress impact/ TA (5)	Adv. scen. stress impact/ TA (6)
GDP growth, 3 year	-11.8112***			-7.7331***		-19.5453***
	(-3.86)			(-5.55)		(-14.18)
Govt. bond yield		33.0032***				
		(5.51)				
EDF nonfin. sector			10.7192			
			(0.86)			
Unemployment, 3 year average			4.5003			
			(1.06)			
Bank activity restr. ind.	-0.3765**	-0.4091**	-0.3019	-0.4416***	-0.2726*	-0.3996**
	(-2.75)	(-2.36)	(-1.23)	(-5.69)	(-2.21)	(-2.46)
Capital regulatory ind.	-0.3659*	-0.3987*	-0.4216	-0.5170**	-0.2400*	-0.3202
	(-1.84)	(-2.21)	(-1.21)	(-2.81)	(-1.93)	(-1.22)
Size	-0.2685***	-0.2371***	-0.2566***	-0.2432***	-0.2744*	-0.2469**
	(-6.16)	(-4.70)	(-4.61)	(-5.94)	(-2.23)	(-2.33)
Book leverage ratio	-4.1229	-7.0662**	-9.6953***	-5.0698*	-9.8820	-9.1439
	(-1.15)	(-2.69)	(-3.50)	(-1.93)	(-1.56)	(-0.74)
Loans/ TA	-1.1830*	-0.9124	-1.1920	-1.2594*	-1.5578	-1.7908
	(-2.23)	(-1.23)	(-1.19)	(-2.16)	(-1.67)	(-1.45)
RWA/ TA	2.8346***	2.2486***	2.9307**	1.8523***	2.5746***	-0.0314
	(6.45)	(3.48)	(2.94)	(6.21)	(3.53)	(-0.03)
ROA	-27.2224**	-33.1259***	-39.0208***	-14.6771	-17.6079	-10.3840
	(-2.90)	(-3.26)	(-3.62)	(-1.21)	(-1.30)	(-0.74)
Impaired loans ratio				5.5447***		
				(3.82)		
Bank CDS spread					0.3450***	
					(6.74)	
Bank stock 4-factor alpha						-3.7657
						(-1.69)
N of observations	121	108	105	105	51	41
Coverage of bank assets [%]	98.33	97.36	88.01	92.08	67.71	48.63
Adjusted R2	0.5082	0.5653	0.4350	0.6005	0.5965	0.5796

The dependent variable is baseline scenario stress impact scaled by total assets. Regressions are estimated using OLS with standard errors clustered by business model classification, instead of by country. For explanation see Annex 2. In parentheses are t-statistics. Significance levels of 0.10, 0.05 and 0.01 are denoted by *, **, ***, respectively.

Table 18: Adverse scenario stress impact, estimates with clustering of standard errors by size.

	Adv. scen. stress impact/ TA (1)	Adv. scen. stress impact/ TA (2)	Adv. scen. stress impact/ TA (3)	Adv. scen. stress impact/ TA (4)	Adv. scen. stress impact/ TA (5)	Adv. scen. stress impact/ TA (6)
GDP growth, 3 year	-11.8112**			-7.7331***		-19.5453***
	(-5.60)			(-16.92)		(-12.10)
Govt. bond yield		33.0032***				
		(10.67)				
EDF nonfin. sector			10.7192			
			(0.71)			
Unemployment, 3 year average			4.5003*			
			(3.09)			
Bank activity restr. ind.	-0.3765*	-0.4091	-0.3019	-0.4416***	-0.2726	-0.3996***
	(-3.29)	(-2.78)	(-1.61)	(-62.34)	(-2.47)	(-20.12)
Capital regulatory ind.	-0.3659	-0.3987	-0.4216	-0.5170**	-0.2400**	-0.3202**
	(-1.99)	(-2.43)	(-1.61)	(-6.58)	(-5.36)	(-4.65)
Size	-0.2685***	-0.2371**	-0.2566**	-0.2432***	-0.2744*	-0.2469
	(-15.34)	(-7.64)	(-4.34)	(-12.09)	(-3.27)	(-1.73)
Book leverage ratio	-4.1229*	-7.0662*	-9.6953**	-5.0698	-9.8820*	-9.1439
	(-2.93)	(-3.74)	(-6.58)	(-2.33)	(-4.09)	(-0.71)
Loans/ TA	-1.1830**	-0.9124*	-1.1920**	-1.2594***	-1.5578	-1.7908
	(-7.21)	(-3.19)	(-7.10)	(-17.15)	(-1.56)	(-0.83)
RWA/ TA	2.8346**	2.2486*	2.9307**	1.8523***	2.5746**	-0.0314
	(6.33)	(2.99)	(4.32)	(18.44)	(6.60)	(-0.03)
ROA	-27.2224*	-33.1259	-39.0208*	-14.6771*	-17.6079	-10.3840*
	(-4.25)	(-2.85)	(-3.24)	(-3.49)	(-1.41)	(-3.33)
Impaired loans ratio				5.5447***		
				(28.96)		
Bank CDS spread					0.3450**	
					(7.46)	
Bank stock 4-factor alpha						-3.7657
						(-2.60)
N of observations	121	108	105	105	51	41
Coverage of bank assets [%]	98.33	97.36	88.01	92.08	67.71	48.63
Adjusted R2	0.5082	0.5653	0.4350	0.6005	0.5965	0.5796

The dependent variable is baseline scenario stress impact scaled by total assets. Regressions are estimated using OLS with standard errors clustered by size, instead of by country. For explanation see Annex 2. In parentheses are t-statistics. Significance levels of 0.10, 0.05 and 0.01 are denoted by *, **, ***, respectively.

Table 19: Adverse scenario stress impact, estimates with Huber-White standard errors.

	Adv. scen. stress impact/ TA (1)	Adv. scen. stress impact/ TA (2)	Adv. scen. stress impact/ TA (3)	Adv. scen. stress impact/ TA (4)	Adv. scen. stress impact/ TA (5)	Adv. scen. stress impact/ TA (6)
GDP growth, 3 year	-11.8112***			-7.7331***		-19.5453***
	(-3.60)			(-2.64)		(-3.56)
Govt. bond yield		33.0032***				
		(3.79)				
EDF nonfin. sector			10.7192			
			(1.19)			
Unemployment, 3 year average			4.5003			
			(1.11)			
Bank activity restr. ind.	-0.3765***	-0.4091***	-0.3019	-0.4416***	-0.2726*	-0.3996*
	(-2.97)	(-2.86)	(-1.47)	(-3.92)	(-1.70)	(-2.02)
Capital regulatory ind.	-0.3659***	-0.3987***	-0.4216*	-0.5170***	-0.2400**	-0.3202*
	(-3.12)	(-3.53)	(-1.76)	(-4.32)	(-2.03)	(-1.78)
Size	-0.2685***	-0.2371***	-0.2566***	-0.2432***	-0.2744**	-0.2469**
	(-3.86)	(-2.80)	(-3.04)	(-3.57)	(-2.60)	(-2.05)
Book leverage ratio	-4.1229	-7.0662*	-9.6953**	-5.0698	-9.8820	-9.1439
	(-1.16)	(-1.73)	(-2.28)	(-1.37)	(-1.11)	(-0.67)
Loans/ TA	-1.1830**	-0.9124	-1.1920	-1.2594*	-1.5578	-1.7908
	(-2.08)	(-1.35)	(-1.50)	(-1.69)	(-1.63)	(-1.06)
RWA/ TA	2.8346***	2.2486***	2.9307***	1.8523**	2.5746**	-0.0314
	(3.99)	(2.93)	(2.87)	(2.35)	(2.21)	(-0.02)
ROA	-27.2224***	-33.1259***	-39.0208***	-14.6771*	-17.6079	-10.3840
	(-3.43)	(-4.66)	(-4.75)	(-1.78)	(-1.54)	(-1.10)
Impaired loans ratio				5.5447***		
				(3.78)		
Bank CDS spread					0.3450***	
					(3.49)	
Bank stock 4-factor alpha						-3.7657**
						(-2.11)
N of observations	121	108	105	105	51	41
Coverage of bank assets [%]	98.33	97.36	88.01	92.08	67.71	48.63
Adjusted R2	0.5082	0.5653	0.4350	0.6005	0.5965	0.5796

The dependent variable is baseline scenario stress impact scaled by total assets. Regressions are estimated using OLS with Huber-White heteroscedasticity robust standard errors. For explanation see Annex 2. In parentheses are t-statistics. Significance levels of 0.10, 0.05 and 0.01 are denoted by *, **, ***, respectively.

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